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CHAPTER 2

Cancer Prevalence and Etiology in Wild and Captive Animals

Thomas Madsen*,**, Audrey Arnal†,‡, Marion Vittecoq†,‡,§, Florence Bernex‡,¶,††,‡‡, Jerôme Abadie§§, Sophie Labrut§§, Déborah Garcia†,‡, Dominique Faugère†,‡, Karin Lemberger***, Christa Beckmann**, Benjamin Roche†,‡,†††, Frédéric Thomas†,‡, Beata Ujvari**

*School of Biological Sciences, University of Wollongong, Wollongong, NSW, Australia
**Centre for Integrative Ecology, School of Life and Environmental Sciences, Deakin University, Geelong, VIC, Australia
†MIVEGEC (Infectious Diseases and Vectors: Ecology, Genetics, Evolution and Control), UMR IRD/CNRS/UM 5290, Montpellier, France
‡CREEC (Centre for Ecological and Evolutionary Research on Cancer), Montpellier, France
§Research Center of the Tour du Valat, Arles, France
¶Montpellier University, Montpellier, France
††RHEM, IRCM, Institute of Cancer Research Montpellier, INSERM, Montpellier, France
‡‡ICM Regional Cancer Institute of Montpellier, Montpellier, France
§§LUNAM University, Oniris, AMAROC, Nantes, France
***Vet Diagnostics, Lyon, France
†††UMMISCO (International Center for Mathematical and Computational Modeling of Complex Systems), UMI IRD/UPMC UMMISCO, Bondy, France

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 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 (Papas et al., 1976). In brown bullhead (Ameiurus nebulus), 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, bicolar 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 bicolar 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

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

(Continued)
| Latin name                        | Common name                  | Neoplasia (including benign and malignant abnormal cell growths)                                                                 | References                  |
|----------------------------------|------------------------------|-------------------------------------------------------------------------------------------------------------------------------|------------------------------|
| *Paralithodes platypus*          | Blue king crab               | Anaplastic cells on the surface of the antennal gland, probable tegmental gland adenocarcinoma                                | Morado et al. (2014)        |
| *Insecta*                        |                              |                                                                                                                               |                              |
| *Drosophila melanogaster*        | Fruit fly                    | Gut and testis tumors                                                                                                        | Salomon and Jackson (2008)  |
| **VERTEBRATE**                   |                              |                                                                                                                               |                              |
| **Fish**                         |                              |                                                                                                                               |                              |
| *Agonus cataphractus*            | Armed bullhead               | Dermal fibromas, fibrosarcomas                                                                                                 | Groff (2004)                 |
| *Amia calva*                     | Bowfin                       | Granuloplastic leukemia                                                                                                       | Groff (2004)                 |
| *Anguilla japonica*              | Japanese eel                 | Nephroblastoma                                                                                                                | Groff (2004)                 |
| *Astronotus ocellatus*           | Oscar                        | Adenocarcinomas                                                                                                               | Groff (2004)                 |
| *Barbus barbus plebejus*         | Italian barbel               | Osteoblastic osteosarcoma                                                                                                      | Groff (2004)                 |
| *Carassius auratus*              | Goldfish                     | Fibrosarcoma, pigment cell neoplasm, neurofibromas, schwannomas, focal or multifocal cutaneous erythrophoromas               | Groff (2004)                 |
| *Carassius auratus × Cyprinus carpio* | Goldfish hybrid             | Gonadal neoplasms                                                                                                             | Groff (2004)                 |
| *Carcharhinus brachyurus*        | Bronze whaler shark          | Proliferative, possibly neoplastic, lesions                                                                                | Robbins et al. (2014)       |
| *Carcharhinus leucas*            | Bull shark                   | Cutaneous neoplasms                                                                                                           | Robbins et al. (2014)       |
| *Carcharias taurus rafinesque*   | Gray nurse shark             | Odontogenic, oral, and gingival neoplasms                                                                                     | Robbins et al. (2014)       |
| *Carcharodon carcharias*         | Great white shark            | Proliferative, possibly neoplastic, lesions                                                                                 | Robbins et al. (2014)       |
| *Catostomus commersoni*          | White sucker                 | Cutaneous papillomas                                                                                                          | Groff (2004)                 |
| *Chaetodon multicinctus and C. miliaris* | Butterflyfish hybrids     | Pigment cell neoplasms                                                                                                        | Groff (2004)                 |
| *Chologaster agassizi*           | Spring cavefish              | Spontaneous retinoblastomas                                                                                                    | Groff (2004)                 |
| *Corydoras spp.*                 | Cory catfish                 | Pigment cell neoplasms                                                                                                        | Groff (2004)                 |
| *Cyprinus carpio*                | Common carp                  | Gonadal neoplasms, erythrophoramas                                                                                              | Groff (2004)                 |
| *Danio rerio*                    | Zebrafish                    | Malignant neoplasms of the intestine                                                                                           | Groff (2004)                 |
| *Esox lucius*                    | Northern pike                | Lymphomas, undifferentiated sarcoma of the integument                                                                         | Groff (2004)                 |
| *Esox masquinongy*               | Muskellunge                  | Lymphoma                                                                                                                      | Groff (2004)                 |
| *Fundulus heteroclitus*          | Mummichog                    | Hepatoblastoma                                                                                                               | Groff (2004)                 |
| *Gadus spp.*                     | Alaska pollock               | Pseudobranchial adenomas                                                                                                      | Groff (2004)                 |
| *Galeocerdo cuvier*              | Tiger shark                  | Cutaneous neoplasms                                                                                                           | Robbins et al. (2014)       |
| *Ginglymostoma cirratum*         | Nurse shark                  | Melanoma                                                                                                                      | Robbins et al. (2014)       |
| *Hemichromis binaculatus*        | African jewelfish            | Osteochondroma                                                                                                               | Groff (2004)                 |
| *Hippocampus abdominalis*        | Pot-bellied sea horse         | Reticuloendothelial hyperplasia                                                                                                | LePage et al. (2012)        |
| *Hippocampus erectus*            | Lined sea horse              | Fibrosarcoma of the brood pouch                                                                                               | LePage et al. (2012)        |
| *Hippocampus kuda*               | 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                      |
|-----------------------------------|-----------------------|-------------------------------------------------------------------------------------------------------------------------------|---------------------------------|
| Hippocampus kuda and Phyllopteryx taeniolatus | Sea horse hybrids     | Cardiac rhabdomyosarcoma, renal adenocarcinoma, renal adenoma, lymphomas, exocrine pancreatic carcinoma, intestinal carcinoma | LePage et al. (2012)            |
| Ictalurus nebulosus               | Brown bullhead        | Hepatobiliary neoplasms                                                                                                     | Groff (2004)                    |
| Ictalurus punctatus               | Channel catfish       | Osteosarcoma                                                                                                                  | Groff (2004)                    |
| Kryptolebias marmoratus           | Mangrove rivulus      | Chondrosarcomas, hemangiomas, hemangioendotheliomas, hemangioendotheliosarcomas                                                | Groff (2004)                    |
| Lepomis sp.                       | Sunfish               | Cutaneous carcinoma                                                                                                          | Groff (2004)                    |
| Limanda limanda                   | Common dab            | Papillomas                                                                                                                    | Groff (2004)                    |
| Microgadus tomcod                 | Atlantic tomcod       | Hepatic neoplasm                                                                                                              | Groff (2004)                    |
| Morone saxatilis                  | Striped bass          | Nephroblastomas                                                                                                               | Groff (2004)                    |
| Mustelus canis                    | Smooth dogfish        | Cutaneous neoplasms                                                                                                           | Groff (2004)                    |
| Nebrius ferrugineus               | Tawny nurse shark     | Cutaneous osteoma                                                                                                             | Groff (2004)                    |
| Oncorhynchus kisutch              | Coho salmon           | Plasmacytoid leukemia (marine anemia), lymphomas                                                                            | Groff (2004)                    |
| Oncorhynchus mykiss               | Rainbow trout         | Hepatobiliary neoplasms, nephroblastoma, adenopapillomas, lymphomas                                                          | Groff (2004)                    |
| Oncorhynchus tshawytscha          | Chinook salmon        | Plasmacytoid leukemia (marine anemia)                                                                                         | Groff (2004)                    |
| Oryzias latipes                   | Medaka                | Lymphohematopoietic neoplasms, cutaneous lymphoma, adenomas, adenocarcinomas, retinoblastomas, teratoid medulloepitheliomas, neoplasms of embryonal origin, or teratomas | Groff (2004)                    |
| Osmerus eperlanus                 | European smelt        | Papillomas and squamous cell carcinomas                                                                                       | Groff (2004)                    |
| Osmerus mordax                    | Rainbow smelt         | Papillomas and squamous cell carcinomas                                                                                        | Groff (2004)                    |
| Pagrus major                      | Japanese seabream     | Leukemia                                                                                                                      | Groff (2004)                    |
| Perca flavescens                  | Yellow perch          | Ovarian and testicular leiomyomas and fibroleiomyomas                                                                       | Groff (2004)                    |
| Phyllopteryx taeniolatus          | Weedy sea dragon      | Rhabdomyosarcoma                                                                                                              | LePage et al. (2012)            |
| Plecoglossus altivelis            | Ayu                   | Rhabdomyoma                                                                                                                   | Groff (2004)                    |
| Plectropomus leopardus            | Coral trout           | Melanomas                                                                                                                     | Sweet et al. (2012)             |
| Poecilia formosa                  | Amazon molly          | Pigment cell neoplasms (or chromatophoromas)                                                                                   | Groff (2004)                    |
| Poecilia reticulata               | Guppy                 | Epidermal cystadenoma, adenomas, adenocarcinomas, neoplasms of embryonal origin, or teratomas                                 | Groff (2004)                    |
| Pseudopleuronectes obscurus       | Flatfish              | Papillomas (wild)                                                                                                             | Groff (2004)                    |
| Pterophyllum scalare              | 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 |
|------------|-------------|-------------------------------------------------|-------------|
| *Salmo salar* | Atlantic salmon | Fibrosarcomas of the swimbladder, cutaneous papillomas, sarcomas | Groff (2004) |
| *Sparus aurata* | Gilt-head bream | Osteochondroma | Groff (2004) |
| *Stizostedion vitreum* | Walleye | Dermal sarcomas | Groff (2004) |
| *Tilapia spp.* | Tilapia | Adenocarcinomas, lymphomas | Groff (2004) |
| *Xiphophorus maculatus* | Southern platyfish | Melanoma, neoplasms of embryonal origin, or teratomas | Groff (2004) |
| *Xiphophorus maculatus* and *X. helleri* | Platfish and swordtail hybrid | Pigment cell neoplasms | Groff (2004) |

**Amphibians**

| Latin name | Common name | Neoplasia (including benign and malignant abnormal cell growths) | References |
|------------|-------------|-------------------------------------------------|-------------|
| *Ambystoma tigrinum* | Tiger salamander | Tumorous growths, type not specified | Rose (1976); Rose and Harshbarger (1977) |
| *Bufo japonicus × Bufo raddei* | Toad hybrids | Renal cell carcinomas | Masahito et al. (2003) |
| *Calotriton arnoldi* | Montseny brook newt | Pigmented skin tumors, melanophoroma, chromatophoromas | Martinez-Silvestre et al. (2011) |
| *Litoria aurea* | Green and golden bell frog | Nephroblastoma, carcinoma | Ladds (2009) |
| *Litoria caerulea* | Green tree frog | Renal adenocarcinoma, cutaneous papilloma and fibropapilloma of the maxillary region and upper lip, hepatoma, metastatic pancreatic adenocarcinoma, coelomic adenoma | Ladds (2009) |
| *Litoria infrafrenata* | Giant (white-lipped) tree frog | Lymphoma, renal tubular adenoma, squamous cell carcinoma, papilloma, sebaceous gland carcinoma | Ladds (2009) |
| *Litoria lesueurii* | Lesueur’s frog | Melanoma | Ladds (2009) |
| *Paramesotriton hongkongensis* | Hong Kong warty newt | Seminoma | Chu et al. (2012) |
| *Xenopus laevis* | 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) |

**Reptiles**

| Latin name | Common name | Neoplasia (including benign and malignant abnormal cell growths) | References |
|------------|-------------|-------------------------------------------------|-------------|
| *Acanthophis antarcticus* | Death adder | Leukemic lymphoma, melanoma | Mader (1996); Ladds (2009) |
| *Acrochordus javanicus* | Elephant trunk snake | Fibroma | Mader (1996) |
| *Agkistrodon contortrix* | Southern copperhead | Myeloid leukemia, cholangiocarcinoma, hemangiosarcoma | Catão-Dias and Nichols (1999) |
| *Agkistrodon halys brevicaudus* | Korean mamushi | Adenocarcinoma, neurofibrosarcoma | Mader (1996) |
| *Agkistrodon piscivorus* | Cottonmouth | Squamous cell carcinoma, sarcoma, fibroma | Mader (1996) |
| *Alligator mississippiensis* | American alligator | Papilloma, seminoma, fibrosarcoma | Mader (1996); Elsey et al. (2013) |
| *Anolis carolinensis* | Carolina anole | Reticulum sarcoma | Hernandez-Divers and Garner (2003) |
| *Apalone ferox* | 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                                                                 |
|-------------------------------------|---------------------------------------|-------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------|
| *Arizona elegans occidentalis*      | California glossy snake               | Pheochromocytoma                                                                                                              | Mader (1996)                                                              |
| *Aspidites melanocephalus*          | Black-headed python                   | Gastric adenocarcinoma, angiolipoma                                                                                           | Ladds (2009); Dietz et al. (2016)                                        |
| *Aspidites ramsayi*                 | Woma                                  | Lymphoma, colonic adenocarcinoma                                                                                              | Ladds (2009)                                                              |
| *Basiliscus plumifrons*             | Green basilisk                        | Fibrosarcoma                                                                                                                  | Hernández-Divers and Garner (2003)                                        |
| *Bitis arietans*                    | Puff adder                            | Leukemic lymphoma, adenoma                                                                                                   | Mader (1996)                                                              |
| *Bitis gabonica*                    | Gaboon viper                          | Transitional cell carcinoma, carcinoma, adenocarcinoma, fibrosarcoma, lymphoma, squamous cell carcinoma                     | Mader (1996); Catão-Dias and Nichols (1999)                                |
| *Bitis nasicornis*                  | Rhinoceros viper                      | Lymphoma, leukemic lymphoma, leukemia                                                                                         | Mader (1996)                                                              |
| *Boa constrictor*                   | 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)                                          |
| *Boa cookii*                        | Cook’s tree boa                       | Hemangiosarcoma                                                                                                               | Mader (1996)                                                              |
| *Boiga dendrophila*                 | Mangrove snake                        | Fibrosarcoma                                                                                                                  | Mader (1996)                                                              |
| *Bothrops atrox*                    | Common lancehead                      | Adenocarcinoma                                                                                                                | Mader (1996)                                                              |
| *Caretta caretta*                   | Loggerhead                            | Fibropapilloma, lymphoblastic lymphoma                                                                                       | Ladds (2009)                                                              |
| *Chalcides ocellatus*               | Ocellated skink                       | Lymphoma                                                                                                                      | Chu et al. (2012)                                                         |
| *Chamaeleo dilepis*                 | Flap-necked chameleon                 | Hepatoma                                                                                                                       | Hernández-Divers and Garner (2003)                                        |
| *Chelonia mydas*                    | 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) |
| *Chilabothrus inornatus*            | Yellow tree boa                       | Squamous cell carcinoma, hematoma, leiomyosarcoma                                                                             | Mader (1996)                                                              |
| *Chondropython viridis*             | Green tree python                     | Lymphoid leukemia, fibrosarcoma, chromatophoroma (small intestine), thymoma, myeloid leukemia, lymphoma                      | Catão-Dias and Nichols (1999)                                              |
| *Clelia clelia*                     | Mussurana                             | Hepatoma                                                                                                                      | Mader (1996)                                                              |
| *Cnemidophorus uniparens*           | Desert grassland whiptail lizard      | Teratoma                                                                                                                       | Hernández-Divers and Garner (2003)                                        |
| *Coleonyx mitratus*                 | Central American banded gecko         | Coelom                                                                                                                        | Hernández-Divers and Garner (2003)                                        |
| *Corallus caninus*                  | Emerald tree boa                      | Leiomyosarcoma, lymphoma, adenocarcinoma, malignant peripheral nerve sheath tumor                                            | Catão-Dias and Nichols (1999); Dietz et al. (2016)                        |
| *Cordylus polyzonus*                | Karoo girdled lizard                  | Adenoma                                                                                                                       | Hernández-Divers and Garner (2003)                                        |
| *Crocodylus acutus*                 | American crocodile                    | Lipoma                                                                                                                        | Mader (1996)                                                              |
| *Crocodylus porosus*                | Saltwater crocodile                   | Lymphoma, papilloma, cancer of the cerebellum, squamous cell carcinoma                                                        | Reichenbach-Klinke (1963); Hill et al. (2016)                             |
| Latin name                  | Common name                  | Neoplasia (including benign and malignant abnormal cell growths)                                                                 | References                                                                 |
|-----------------------------|------------------------------|---------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------|
| Crocodylus siamensis        | Siamese crocodile            | Fibrosarcoma                                                                                                                  | Hernandez-Divers and Garner (2003)                                        |
| Crotalus atrox              | Western diamondback rattlesnake | Fibrosarcoma                                                                                                                  | Mader (1996)                                                              |
| Crotalus horridus           | Timber rattlesnake            | Adenoma, adenocarcinoma, fibrosarcoma, leukemia, mesothelioma, hemangioma                                                     | Mader (1996)                                                              |
| Crotalus mitchelli pyrrhus  | Southwestern speckled rattlesnake | Adenocarcinoma                                                                                                                  | Mader (1996)                                                              |
| Crotalus ruber              | Red diamond rattlesnake       | Sarcoma                                                                                                                       | Mader (1996)                                                              |
| Crotalus viridis helleri    | Prairie rattlesnake           | Hemangioma                                                                                                                    | Mader (1996)                                                              |
| Crotalus viridis viridis    | Prairie rattlesnake           | Fibrosarcoma                                                                                                                  | Mader (1996)                                                              |
| Cyclura cornuta             | Rhinoceros iguana             | Chondro-osteofibroma                                                                                                           | Hernandez-Divers and Garner (2003)                                        |
| Cyclura ricordi             | Hispaniolan ground iguana    | Biliary adenoma                                                                                                                | Hernandez-Divers and Garner (2003)                                        |
| Diplosaurus dorsalis        | Desert iguana                 | Adenoma, adenocarcinoma                                                                                                        | Hernandez-Divers and Garner (2003)                                        |
| Dispholidus typus           | Boomslang                     | Adenoma                                                                                                                       | Mader (1996)                                                              |
| Drymarchon corais           | Eastern indigo snake          | Melanophoroma                                                                                                                 | Mader (1996)                                                              |
| Drymarchon couperi          | Eastern indigo snake          | Adenocarcinoma                                                                                                                | Mader (1996)                                                              |
| Drymarchon melanurus erubennus | Texas indigo snake            | Leiomyosarcoma                                                                                                                | Mader (1996)                                                              |
| Echis carinatus             | Saw-scaled viper              | Hepatocarcinoma                                                                                                               | Catão-Dias and Nichols (1999)                                             |
| Elaphe guttata guttata      | 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)         |
| Elaphe obsoleta             | Western rat snake             | Adenocarcinoma, adenoma, fibrosarcoma, rhabdomyosarcoma                                                                       | Mader (1996); Catão-Dias and Nichols (1999)                                |
| Elaphe obsoleta rossalleni  | Everglades rat snake          | Melanoma                                                                                                                      | Mader (1996)                                                              |
| Elaphe obsoleta quadrivittata| Yellow rat snake              | Transitional cell carcinoma                                                                                                     | Mader (1996)                                                              |
| Elaphe taeniura             | Beauty snake                  | Hepatocarcinoma                                                                                                               | Catão-Dias and Nichols (1999)                                             |
| Elaphe taeniura friesei     | Taiwan beauty rat snake       | Malignant chromatophoroma                                                                                                       | Chu et al. (2012)                                                         |
| Elaphe vulpina              | Fox snake                     | Adenocarcinoma                                                                                                                | Mader (1996)                                                              |
| Emys orbicularis            | European pond turtle          | Squamous cell carcinoma, fibroadenoma                                                                                           | Mader (1996)                                                              |
| Epicrates cenchria          | Rainbow boa                   | Histiocytoma, lymphoma, adenoma, myelomonocytic leukemia, squamous cell carcinoma                                              | Catão-Dias and Nichols (1999)                                             |
| Epicrates subflavus         | Jamaican boa                  | Malignant peripheral nerve sheath tumor, malignant perivascular wall tumor                                                     | Dietz et al. (2016)                                                      |
| Eryx conicus                | Common sand boa               | Squamous cell carcinoma, mixed cell tumor                                                                                        | Mader (1996)                                                              |
| Eublepharis macularis       | Leopard gecko                 | Cholangiocarcinoma                                                                                                             | Hernandez-Divers and Garner (2003)                                        |
| Latin name               | Common name             | Neoplasia (including benign and malignant abnormal cell growths)                                                                 | References                                                                 |
|-------------------------|-------------------------|---------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------|
| *Eumeces fasciatus*     | Five-lined skink        | Hepatocarcinoma                                                                                                                  | Hernandez-Divers and Garner (2003)                                         |
| *Eunectes murinus*      | Green anaconda          | Lymphoma, fibrosarcoma, granulosa cell tumor                                                                                            | Mader (1996)                                                              |
| *Eunectes notaeus*      | Yellow anaconda         | Cystadenoma                                                                                                                       | Catão-Dias and Nichols (1999)                                             |
| *Geochelone carbonaria* | Redfoot tortoise        | Adenoma                                                                                                                          | Mader (1996)                                                              |
| *Gopherus agassizii*    | Mojave desert tortoise  | Adenoma, interstitial tumor                                                                                                | Mader (1996)                                                              |
| *Gopherus trijuga*      | Ceylon terrapin         | Carcinoma, squamous cell carcinoma                                                                                                  | Mader (1996)                                                              |
| *Heloderma suspectum*   | Gila monster            | Squamous cell carcinoma, melanoma                                                                                                  | Hernandez-Divers and Garner (2003)                                         |
| *Heterodon nasicus*     | Western hognose snake   | Sarcoma, lymphoma                                                                                                                 | Mader (1996)                                                              |
| *Hydrosaurus amboinensis* | Amboina sailfin lizard | Lymphoma, plasma cell tumor                                                                                                        | Hernandez-Divers and Garner (2003)                                         |
| *Iguana iguana*         | Green iguana            | Lymphoma, hepatoma, cholangioma, adenocarcinoma, ovarian teratoma, adenoma                                                                 | Hernandez-Divers and Garner (2003)                                         |
| *Indotestudo elongata*  | Yellow-headed tortoise  | Leukemia                                                                                                                         | Chu et al. (2012)                                                         |
| *Lacerta agilis*        | Sand lizard              | Papilloma, squamous cell carcinoma                                                                                                | Reichenbach-Klinke (1963); Hernandez-Divers and Garner (2003)              |
| *Lacerta lepida*        | Ocellated lizard         | Papilloma                                                                                                                         | Reichenbach-Klinke (1963)                                                 |
| *Lacerta viridis*       | Green lizard             | Papilloma, osteosarcoma                                                                                                           | Reichenbach-Klinke (1963); Hernandez-Divers and Garner (2003)              |
| *Lampropeltis getula californiae* | Eastern kingsnake | Adenoma, carcinoma, lymphoma, squamous cell carcinoma, cholangiocarcinoma, melanoma, malignant peripheral nerve sheath tumor | Mader (1996); Dietz et al. (2016)                                         |
| *Lampropeltis getula getula* | Eastern kingsnake | Tubular adenoma                                                                                                                   | Catão-Dias and Nichols (1999)                                             |
| *Lampropeltis getula holbrooki* | Speckled kingsnake | Adenoma                                                                                                                          | Mader (1996)                                                              |
| *Lampropeltis triangulum annulata* | Mexican milk snake | Sarcoma                                                                                                                          | Mader (1996)                                                              |
| *Lampropeltis triangulum sinaloa* | Sinaloan milk snake | Myxosarcoma, sarcoma, hepatoma                                                                                                     | Mader (1996); Catão-Dias and Nichols (1999)                                |
| *Lampropeltis triangulum triangulum* | Eastern milk snake | Adenocarcinoma, adenoma                                                                                                          | Catão-Dias and Nichols (1999)                                             |
| *Morelia viridis*       | Green tree python        | Multicentric lymphoma, soft tissue sarcoma, fibrosarcoma, cholangiocarcinoma, coelomic carcinoma                                  | Ladds (2009)                                                             |
| *Morelia spilota*       | Carpet python            | Myxosarcoma, monocytic leukemia of azurophilic type, lymphoid leukemia                                                            | Ladds (2009)                                                             |
| *Morelia spilota spilota* | Diamond python         | Myxosarcoma, monocytic leukemia of azurophilic type, lymphoid leukemia                                                            | Ladds (2009)                                                             |
| *Morelia spilota variegata* | Darwin carpet python | Cholangiocarcinoma                                                                                                               | Mader (1996)                                                             |
| *Morelia viridis*       | Green tree python        | Ossifying fibrosarcoma                                                                                                            | Mader (1996); Ladds (2009)                                                |
| *Naja naja*             | 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                                                   |
|-----------------------------------|------------------------------|-------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------|
| Naja nigricollis                  | Black-necked spitting cobra  | Adenoma, lymphoma                                                                                                               | Mader (1996)                                                 |
| Naja nivea                        | Cape cobra                   | Adenocarcinoma                                                                                                                 | Mader (1996)                                                 |
| Natrix natrix                     | Grass snake                  | Pancreatic adenocarcinoma, malignant peripheral nerve sheath tumor                                                               | Reichenbach-Klinke (1963); Dietz et al. (2016)               |
| Ophiophagus hannah                | King cobra                   | Tubular adenoma                                                                                                                | Catão-Dias and Nichols (1999)                               |
| Pantherophis alleghaniensis       | Black rat snake              | Ameloblastoma                                                                                                                  | Comolli et al. (2015)                                        |
| Pelomedusa subrufa                 | African helmeted turtle      | Leukemia                                                                                                                       | Mader (1996)                                                 |
| Pelusios subniger                 | East African black mud turtle| Carcinoma                                                                                                                      | Mader (1996)                                                 |
| Pituophis melanoleucus            | Pine snake                   | Adenocarcinoma, malignant chromatophoroma, carcinoma, adenoma                                                                     | Mader (1996)                                                 |
| Pituophis melanoleucus mugitus    | Florida pine snake           | Rhabdomyosarcoma, adenoma, adenocarcinoma, melanoma                                                                             | Mader (1996)                                                 |
| Pituophis melanoleucus sayi       | Bullsnake                    | Papilloma, adenocarcinoma, malignant melanoma                                                                                   | Reichenbach-Klinke (1963); Mader (1996)                      |
| Podarcis muralis                  | Common wall lizard           | Papilloma                                                                                                                      | Hernandez-Divers and Garner (2003)                          |
| Pogona vitticeps                  | Bearded dragon               | Adenocarcinoma of the liver, disseminated myelogenous leukemia, monocyctic leukemia, malignant nerve sheath tumor               | Hernandez-Divers and Garner (2003); Ladds (2009)            |
| Podarcis sicula                   | Italian wall lizard          | Lymphoma, fibrosarcoma, undifferentiated mesenchymal tumor                                                                     | Hernandez-Divers and Garner (2003)                          |
| Pseudochis porphyriacus           | Red-bellied black snake      | Cutaneous papillomas, adenomatous proliferation, adenoma of the bile duct                                                      | Mader (1996); Ladds (2009)                                  |
| Pseudonaja affinis                | Dugite                       | Melanoma                                                                                                                       | Ladds (2009)                                                 |
| Pseudonaja nuchalis               | Western brown snake          | Leukemic lymphoma                                                                                                               | Ladds (2009)                                                 |
| Python molurus                    | Indian rock python           | Ameloblastoma, fibroma                                                                                                           | Mader (1996)                                                 |
| Python molurus bivittatus         | Burmese python               | Carcinoma, adenocarcinoma, interstitial cell tumor, osteosarcoma                                                               | Mader (1996)                                                 |
| Python molurus molurus            | Indian python                | Sarcoma, lymphoma, leukemia                                                                                                      | Mader (1996)                                                 |
| Python regius                     | Ball python                  | Fibrosarcoma                                                                                                                   | Mader (1996)                                                 |
| Python reticulatus                | Reticulated python           | Carcinoma, melanoma, lymphoma                                                                                                    | Mader (1996)                                                 |
| Python sebae                      | African rock python          | Adenoma                                                                                                                        | Mader (1996)                                                 |
| Rhampiophis oxyrhynchus           | Rufous beaked snake          | Hemangiosarcoma, lymphoma, fibrosarcoma                                                                                         | Catão-Dias and Nichols (1999)                               |
| Sistrurus catenatus               | Massasauga                   | Adenoma, hemangioma, carcinoma                                                                                                   | Mader (1996)                                                 |
| Spilotes pullatus                 | Yellow rat snake             | Adenocarcinoma                                                                                                                 | Mader (1996)                                                 |
| Strophurus spinigerus             | Spiny-tailed gecko           | Neuroblastoma                                                                                                                  | Ladds (2009)                                                 |
| Terrapene carolina                | Common box turtle            | Adenocarcinoma                                                                                                                 | Mader (1996)                                                 |
| Testudo graeca                    | Spur-thighed tortoise        | Adenoma                                                                                                                        | Mader (1996)                                                 |
| Testudo hermanni                  | Hermann’s tortoise           | Lymphoma, neurilemmoma                                                                                                          | Mader (1996)                                                 |
| Testudo horsfieldii               | Afghan tortoise              | Fibroma, fibroadenoma                                                                                                           | Mader (1996)                                                 |
| Thamnophis sauritus               | Ribbon snake                 | Lipoma                                                                                                                         | Dietz et al. (2016)                                          |
| Latin name                        | Common name                  | Neoplasia (including benign and malignant abnormal cell growths)                                                                                                                                                                                                 | References                                      |
|----------------------------------|------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------|
| *Thamnophis sirtalis*            | 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)               |
| *Thamnophis elegans terrestris*  | Coast garter snake           | Malignant chromatophoroma                                                                                                                                                                                                                                | Mader (1996)                                    |
| *Tiliqua rugosa*                 | Shingle-back lizard          | Subcutaneous osteoma, liposarcoma                                                                                                                                                                                                                           | Ladds (2009), Hernandez-Divers and Garner (2003) |
| *Trachemys scripta elegans*      | Red-eared slider             | Carcinoma, leukemia                                                                                                                                                                                                                                | Mader (1996)                                    |
| *Tupinambis nigropunctatus*      | Tegu                         | Squamous cell carcinoma                                                                                                                                                                                                                                | Hernandez-Divers and Garner (2003)              |
| *Tupinambis rufescens*           | Argentine red tegu           | Hepatoma                                                                                                                                                                                                                                                     | Hernandez-Divers and Garner (2003)              |
| *Tupinambis teguixin*            | Golden tegu                  | Squamous cell carcinoma                                                                                                                                                                                                                                | Hernandez-Divers and Garner (2003)              |
| *Uromastyx acanthinura*          | Bell’s dabb lizard           | Lymphoma                                                                                                                                                                                                                                                     | Hernandez-Divers and Garner (2003)              |
| *Uromastyx aegyptia*             | Egyptian mastigure           | Lymphoid neoplasia                                                                                                                                                                                                                                          | Gyimesi et al. (2005)                           |
| *Varanus bengalensis*            | Bengal monitor               | Leukemia, osteochondroma, enchondroma                                                                                                                                                                                                                       | Hernandez-Divers and Garner (2003)              |
| *Varanus exanthematicus*         | Savannah monitor             | Lymphoma                                                                                                                                                                                                                                                     | Hernandez-Divers and Garner (2003)              |
| *Varanus komodoensis*            | Komodo dragon                | Carcinoma, adenoma, islet cell tumor, pheochromocytoma, interstitial cell tumor                                                                                                                                                                               | Hernandez-Divers and Garner (2003)              |
| *Varanus niloticus*              | Nile monitor                 | Plasma cell tumor                                                                                                                                                                                                                                           | Hernandez-Divers and Garner (2003)              |
| *Varanus salvator*               | Water monitor                | Lymphoma                                                                                                                                                                                                                                                     | Hernandez-Divers and Garner (2003)              |
| *Vipera ammodytes*               | Horned viper                 | Adenocarcinoma                                                                                                                                                                                                                                               | Mader (1996)                                    |
| *Vipera palestine*               | Palestine viper              | Adenocarcinoma                                                                                                                                                                                                                                               | Mader (1996)                                    |
| *Vipera russelli*                | Russell’s viper              | Fibrosarcoma, leukemia, myofibroma                                                                                                                                                                                                                          | Mader (1996)                                    |
| *Walterinnesia aegyptia*         | Desert cobra                 | Pheochromocytoma                                                                                                                                                                                                                                             | Mader (1996)                                    |

**Birds**

| Latin name                        | Common name                  | Neoplasia (including benign and malignant abnormal cell growths)                                                                                                                                                                                                 | References                                      |
|----------------------------------|------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------|
| *Acanthagenys rufogularis*       | Spiny-cheeked honeyeater     | Nephroblastoma                                                                                                                                                                                                                                                | Ladds (2009)                                    |
| *Agapornis lilianae*             | Nyasa lovebird               | Fibromas and fibrosarcomas of integument and/or skeletal muscle, Sertoli cell tumors                                                                                                                                                                           | Reece (1992); Ladds (2009)                      |
| *Agapornis roseicollis*          | 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)                      |
| *Ailuroedus crassirostris*       | Green catbird                | Myelocytomas                                                                                                                                                                                                                                                  | Reece (1992); Ladds (2009)                      |
| *Aix sponsa*                     | North American wood duck     | Malignant melanoma                                                                                                                                                                                                                                            | Chu et al. (2012)                               |

(Continued)
| Latin name                      | Common name       | Neoplasia (including benign and malignant abnormal cell growths)                                                                 | References                        |
|--------------------------------|-------------------|-----------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|
| *Alectoris graeca*             | Chukar partridge  | Liposarcomas, cholangiomas                                                                                                       | Reece (1992); Ladds (2009)       |
| *Alisterus scapularis*         | Australian king parrot |                                                                                                                   | Reece (1992); Ladds (2009)       |
| *Anas castanea*                | Chestnut teal     | Lymphocytic lymphomas and mixed-cell lymphomas, metastatic abdominal adenocarcinomas                                          | Reece (1992); Ladds (2009)       |
| *Anas cyanoptera*              | Cinnamon teal     | Adenocarcinoma                                                                                                                  | Snyder and Ratcliffe (1966)       |
| *Anas novaehollandiae*         | New Zealand scaup | Dermal squamous cell carcinomas                                                                                                  | Reece (1992); Ladds (2009)       |
| *Anas platyrhynchos*           | Mallard, domestic duck | Intraabdominal lipomas, chondromas, osteomas, lymphoblastic lymphomas, seminomas, metastatic abdominal adenocarcinomas, astrocytoma | Reece (1992); Ladds (2009); Chu et al. (2012) |
| *Anas superciliosa*            | Pacific black duck | Myxomas and myxofibromas, malignant melanomas                                                                                   | Reece (1992); Ladds (2009)       |
| *Anhinga novaehollandiae*      | Darter            | Hemangiomas                                                                                                                     | Reece (1992); Ladds (2009)       |
| *Anser anser*                  | Graylag goose     | Chondromas                                                                                                                      | Reece (1992); Ladds (2009)       |
| *Anser domesticus*             | Domestic goose    | Fibrosarcoma                                                                                                                    | Ratcliffe (1933)                  |
| *Aprosmictus scapularis*       | King parrot       | Fibrosarcoma                                                                                                                    | Ratcliffe (1933)                  |
| *Ara militaris*                | Military macaw    | Squamous cell carcinoma                                                                                                          | Ratcliffe (1933)                  |
| *Barnardius barnardi*          | Mallee ring-neck  | Lymphoblastic lymphomas                                                                                                          | Reece (1992); Ladds (2009)       |
| *Barnardius zonarius*          | Port Lincoln parrot | Plasma cell tumors                                                                                                               | Reece (1992); Ladds (2009)       |
| *Barnardius zonarius semitorquatus* | Twenty eight parrot | Plasma cell tumors                                                                                                               | Ladds (2009)                     |
| *Brotogeris tirica*            | Plain parakeet    | Fibrosarcoma                                                                                                                    | Ratcliffe (1933)                  |
| *Bubo virginianus*             | Great horned owl  | Myelogenous leukemia                                                                                                             | Wiley et al. (2009)               |
| *Buteo jamaicensis*            | Red-tailed hawk   | Cholangiocarcinoma                                                                                                               | Hartup et al. (1995)              |
| *Cacatua galerita*             | 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 carcinomas, adenocarcinomas | Reece (1992); Ladds (2009); Ratcliffe (1933) |
| *Cacatua leadbeateri*          | Pink cockatoo     | Dermal squamous cell carcinomas                                                                                                  | Reece (1992); Ladds (2009)       |
| *Cacatua moluccensis*          | Gang-gang cockatoo | Lymphomas                                                                                                                       | Ratcliffe (1933)                  |
| *Cacatua roseicapilla*         | Galah             | Subcutaneous lipomas, intraabdominal lipomas, granulosa cell tumors                                                            | Reece (1992); Ladds (2009)       |
| *Cacatua sanguinea*            | Little corella    | Intraabdominal lipomas, lymphoblastic lymphomas                                                                                   | Reece (1992); Ladds (2009)       |
| *Callocephalon fimbriatum*     | Gang-gang cockatoo | Visceral fibromas and fibrosarcomas, osteosarcomas, plasma cell tumors                                                           | Reece (1992); Ladds (2009)       |
| *Calyptrorhynchus baudinii*    | White-tailed black cockatoo | Myeloblastomas                                                                                                                 | Reece (1992); Ladds (2009)       |
| *Casuarius casuaris johnsonii* | Southern cassowary | Papilliform mesotheliomas, gastrointestinal adenocarcinomas                                                                         | Reece (1992); Ladds (2009)       |
| *Centropus phasianinus*        | Pheasant coucal   | Hepatoma, hepatocarcinoma, cholangioma                                                                                           | Ladds (2009)                     |
| *Cereopsis novaehollandiae*    | 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                                      |
|---------------------------------|-------------------|-------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------|
| Chalcophaps indica              | Emerald dove      | Pinealoma                                                                                                                    | Reece (1992); Ladds (2009)                     |
| Chloephaga leucoptera           | Upland goose      | Adenocarcinoma                                                                                                               | Snyder and Ratcliffe (1966)                     |
| Chrysolophus pictus             | Golden pheasant   | Adenocarcinoma, adenoma                                                                                                       | Ratcliffe (1933)                                |
| Columba livia                   | Domestic pigeon   | Fibromas and fibrosarcomas of integument and/or skeletal muscle, visceral fibromas and fibrosarcomas, subcutaneous lipomas, intraabdominal lipomas, liposarcomas, rhabdomyoma, leiomyomas and leiomyo-fibromas, 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) |
| Columba pulchricollis           | Ashy wood pigeon  | Cholangioma                                                                                                                  | Chu et al. (2012)                              |
| Coturus holochloris             | Green parakeet    | Carcinomatoid embryoma                                                                                                        | Ratcliffe (1933)                                |
| Coscoroba coscoroba             | Coscoroba swan    | Cholangiocarcinoma, renal cell carcinoma                                                                                      | Chu et al. (2012)                              |
| Coturnix australis              | Brown quail       | Subcutaneous lipomas                                                                                                          | Reece (1992); Ladds (2009)                     |
| Coturnix chinensis              | King quail        | Fibromas and fibrosarcomas of integument and/or skeletal muscle, hepatocarcinomas, seminomas, metastatic abdominal adenocarcinomas | Reece (1992); Ladds (2009)                     |
| Coturnix coturnix japonica      | 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)                     |
| Cynoramphus novaezelandia       | Red-fronted parakeet | Intraabdominal lipomas                                                                                                         | Reece (1992); Ladds (2009)                     |
| Cygnus atratus                  | Black swan        | Myxomas and myxofibromas, osteosarcoma                                                                                        | Reece (1992); Ladds (2009); Chu et al. (2012)  |
| Cygnus olor                     | Mute swan         | Myxomas and myxofibromas                                                                                                       | Reece (1992); Ladds (2009)                     |
| Dacelo novaeguineae             | Laughing kookaburra | Intraabdominal lipomas, cholangiomas                                                                                           | Reece (1992); Ladds (2009)                     |
| Dendrocygna autumnalis          | Black-bellied whistling duck | Adenocarcinoma                                                                                                                  | Snyder and Ratcliffe (1966)                     |
| Dromaius novaehollandiae        | Emu               | Pancreatic adenocarcinomas                                                                                                     | Reece (1992); Ladds (2009)                     |
| Dryonastes berthemyi             | Buffy laughingthrush | Fibrosarcoma                                                                                                                  | Ratcliffe (1933)                                |
| Egretta novaehollandiae         | White-faced heron | Lymphoma                                                                                                                      | Ladds (2009)                                   |
| Emberiza icterica               | Red-headed bunting | Lipoma                                                                                                                        | Ratcliffe (1933)                                |
| Emblema temporalis              | Red-browed firetail | Esophageal papilloma                                                                                                           | Reece (1992); Ladds (2009)                     |
| Eolophus roseicapilla           | Galah             | Lipomas                                                                                                                       | Ratcliffe (1933)                                |
| Erythraea gouldiae              | Gouldian finch    | Adrenocortical adenomas                                                                                                        | Reece (1992); Ladds (2009)                     |
| Erythraea trichroa              | Blue-faced parrot finch | Renal adenoma, adenocarcinoma                                                                                                 | Ladds (2009)                                   |
| Eudyptula minor                 | Little penguin    | Lymphocytic lymphomas and mixed-cell lymphomas, fibroma, fibrosarcoma, cutaneous papillomas                                   | Reece (1992); Ladds (2009)                     |

(Continued)
| Latin name                  | Common name                        | Neoplasia (including benign and malignant abnormal cell growths)                                                                                                                                                                                                 | References                                      |
|-----------------------------|------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------|
| Falco naumanni              | Lesser kestrel                     | Malignant intracranial teratoma                                                                                                                                                                                                                                 | Lopez and Murcia (2008)                        |
| Gennaeus nycthemerus        | Silver pheasant                    | Adenocarcinoma                                                                                                                                                                                                                                                   | Ratcliffe (1933); Snyder and Ratcliffe (1966)   |
| Geopelia cuneata            | Diamond dove                       | Leiomomas and leiomyofibromas                                                                                                                                                                                                                                     | Reece (1992); Ladds (2009)                     |
| Geopelia humeralis          | Bar-shouldered dove                 | Osteosarcomas                                                                                                                                                                                                                                                     | Reece (1992); Ladds (2009)                     |
| Geopelia placida            | Peaceful dove                      | Leiomomas and leiomyofibromas                                                                                                                                                                                                                                     | Reece (1992); Ladds (2009)                     |
| Ginnaeus swinhoei           | Swinhoe’s pheasant                 | Visceral fibromas and fibrosarcomas                                                                                                                                                                                                                               | Reece (1992); Ladds (2009)                     |
| Gracula religiosa           | Greater hill mynah                 | Chondrosarcoma                                                                                                                                                                                                                                                    |                                                 |
| Gymnorhina tibicen          | Australian magpie                  | Fibromas and fibrosarcomas of the integument and/or skeletal muscle, myeloblastomas, lymphocytic lymphomas, and mixed-cell lymphomas                                                                                                                                 | Reece (1992); Ladds (2009)                     |
| Larus novaehollandiae       | Silver gull                        | Lymphocytic lymphomas and mixed-cell lymphomas                                                                                                                                                                                                                  | Reece (1992); Ladds (2009)                     |
| Larus pacificus             | Pacific gull                       | Chondromas, myelocytomas                                                                                                                                                                                                                                          | Reece (1992); Ladds (2009)                     |
| Leipoa ocellata             | Malleefowl                         | Lymphomas                                                                                                                                                                                                                                                         | Ladds (2009)                                   |
| Leptolophus hollandicus     | Cockatiel                          | Lipomas                                                                                                                                                                                                                                                            | Ratcliffe (1933)                                |
| Lonchura castaneothorax     | Chestnut-breasted mannikin         | Lymphocytic lymphomas and mixed-cell lymphomas                                                                                                                                                                                                                  | Reece (1992); Ladds (2009)                     |
| Lopholaimus antarcticus     | Topknot pigeon                     | Lymphomas                                                                                                                                                                                                                                                         | Ladds (2009)                                   |
| Macropygia amboinensis      | Cuckoo-dove                        | Gastrointestinal adenocarcinomas                                                                                                                                                                                                                                  | Ladds (2009)                                   |
| Malurus cyaneus             | Superb fairy-wren                   | Lymphocytic lymphomas and mixed-cell lymphomas                                                                                                                                                                                                                  | Reece (1992); Ladds (2009)                     |
| Mareca sibilatrix           | Chiloe wigeon                      | Adenocarcinoma                                                                                                                                                                                                                                                    | Snyder and Ratcliffe (1966)                     |
| Megaquiscalus major         | Boat-tailed grackle                | Adenocarcinoma                                                                                                                                                                                                                                                    | Ratcliffe (1933)                                |
| Meleagris gallopavo         | Wild turkey                         | Adenocarcinoma                                                                                                                                                                                                                                                    | Ratcliffe (1933)                                |
| Melopsittacus undulatus     | 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, leiomomas 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                  |
|-----------------------------------|-------------------|-------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|
| Neochmia ruficauda                | Star finch        | Myxomas and myxofibromas                                                                                                          | Reece (1992); Ladds (2009) |
| Neophema pulchella                | Turquoise parrot  | Lymphocytic lymphomas and mixed-cell lymphomas                                                                                      | Reece (1992); Ladds (2009) |
| Neoscephus bourkii                | Bourke’s parrot   | Plasma cell tumors                                                                                                                 | Reece (1992); Ladds (2009) |
| Northiella haematogaster          | Blue bonnet       | Plasma cell tumors                                                                                                                  | Reece (1992); Ladds (2009) |
| Nycticorax caledonicus            | Rufous night heron| Myelocytomas                                                                                                                         | Reece (1992); Ladds (2009) |
| Nymphicus hollandicus             | Cockatiel         | Liposarcomas, renal adenocarcinomas, fibroma, fibrosarcoma                                                                          | Reece (1992); Ladds (2009) |
| Nyroca americana                  | Redhead duck      | Adenocarcinoma                                                                                                                       | Snyder and Ratcliffe (1966) |
| Oxyura australis                  | Blue-billed duck  | Cholangiomas, hepatoma, hepatocarcinoma                                                                                              | Reece (1992); Ladds (2009) |
| Padda oryzivora                   | Java sparrow      | Lymphocytic lymphomas and mixed-cell lymphomas, metastatic abdominal adenocarcinomas                                                | Reece (1992); Ladds (2009) |
| Palaeornis cyanoccephala          | Burmese parrakeet | Adenoma                                                                                                                              | Ratcliffe (1933)            |
| Palaeornis eupatrius              | Alexandrine parrakeet | Teratoma                                                                                                                              | Ratcliffe (1933)            |
| Paraoria cucullata               | Red crested cardinal | Myxosarcoma                                                                                                                          | Ratcliffe (1933)            |
| Passer domesticus                 | House sparrow     | Lymphocytic lymphomas and mixed-cell lymphomas                                                                                       | Reece (1992); Ladds (2009) |
| Pavo cristatus                    | Common peafowl    | Esophageal papilloma                                                                                                                | Chu et al. (2012)           |
| Plegadis falcinellus              | Glossy ibis       | Intracutaneous keratoacanthomas                                                                                                      | Reece (1992); Ladds (2009) |
| Phalacrocorax carbo               | Great cormorant   | Melanoma                                                                                                                             | Kusewitt and Ley (1996)     |
| Phaps chalcoptera                 | Common bronze-wing| Dermal squamous cell carcinomas                                                                                                       | Reece (1992); Ladds (2009) |
| Phasianus colchicus               | 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) |
| Phasianus versicolor              | Green pheasant    | Fibrosarcoma, lymphomas                                                                                                             | Ratcliffe (1933)            |
| Phylidonyris novaehollandiae      | New Holland honeyeater | Cutaneous papillomas                                                                                                               | Ladds (2009)                |
| Planestictus m. migratorius       | Three-legged robin | Nephroblastoma or renal carcinoma                                                                                                    | Ratcliffe (1933)            |
| Phalacrocorax elegans             | Crimson rosella   | Lymphocytic lymphomas and mixed-cell lymphomas, plasma cell tumors                                                                  | Reece (1992); Ladds (2009) |
| Platycercus eximius               | Eastern rosella   | Lymphocytic lymphomas and mixed-cell lymphomas                                                                                       | Reece (1992); Ladds (2009) |
| Plectorhyncha lanceolata          | Striped honeyeater | Nephroblastoma                                                                                                                       | Ladds (2009)                |
| Plectropterus gambensis            | Spur-winged goose | Fibrosarcoma                                                                                                                          | Ratcliffe (1933)            |
| Podargus strigoides               | Tawny frogmouth   | Intraabdominal lipomas                                                                                                              | Reece (1992); Ladds (2009) |
| Polytelis swainsonii              | Superb parrot     | Lymphoma, plasma cell tumors                                                                                                         | Reece (1992); Ladds (2009) |
| Prunella collaris                 | Alpine accentor   | Hepatoma                                                                                                                             | Chu et al. (2012)           |
| Psophotus dissimilis              | Hooded parrot     | Fibroma, fibrosarcoma                                                                                                                | Ladds (2009)                |
| Psophotus varius                  | Mulga parrot      | Fibromas and fibrosarcomas of integument and/or skeletal muscle                                                                    | Reece (1992); Ladds (2009) |
| Latin name          | Common name        | Neoplasia (including benign and malignant abnormal cell growths)                                                                                                                                                                                                 | References                                                                                   |
|---------------------|--------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|
| *Quelea quelea*     | Red-billed quelea | Teratoma                                                                                                                                                                                                                                                        | Ratcliffe (1933)                                                                              |
| *Serinus canaria*   | Canary             | Fibromas and fibrosarcomas of integument and/or skeletal muscle, visceral fibromas and fibrosarcomas, myxomas and myxofibromas, chordromas, leiomyomas and leiomyofibromas, lymphoblastic lymphomas, lymphocytic lymphomas and mixed-cell lymphomas, plasma cell tumors, dermal squamous cell carcinomas, intracutaneous keratoacanthomas, feather folliculomas, urospygial adenomas, proventricular adenocarcinomas, hepatocarcinomas, adenocortical adenomas, pituitary adenoma | Ratcliffe (1933); Reece (1992); Ladds (2009)                                                  |
| *Serinus canaria*   | Canary             | Fibromas and fibrosarcomas of integument and/or skeletal muscle, visceral fibromas and fibrosarcomas, myxomas and myxofibromas, chordromas, leiomyomas and leiomyofibromas, lymphoblastic lymphomas, lymphocytic lymphomas and mixed-cell lymphomas, plasma cell tumors, dermal squamous cell carcinomas, intracutaneous keratoacanthomas, feather folliculomas, urospygial adenomas, proventricular adenocarcinomas, hepatocarcinomas, adenocortical adenomas, pituitary adenoma | Ratcliffe (1933); Reece (1992); Ladds (2009)                                                  |
| Sicalis flaveola     | Saffron finch      | Adenocarcinoma                                                                                                                                                                                        | Ratcliffe (1933)                                                                              |
| *Spatula clypeata*  | Shoveler duck      | Adenocarcinoma                                                                                                                                                                                        | Snyder and Ratcliffe (1966)                                                                   |
| *Strepera spp.*     | Currawong          | Lymphocytic lymphomas and mixed-cell lymphomas                                                                                                                                                        | Reece (1992); Ladds (2009)                                                                  |
| Struthidea cinerea   | Apostlebird        | Plasma cell tumors                                                                                                                                                                                    | Reece (1992); Ladds (2009)                                                                  |
| *Struthio camelus*  | Ostrich            | Papilliform mesotheliomas                                                                                                                                                                             | Reece (1992); Ladds (2009)                                                                  |
| Taedoma radjah      | Radjah shelduck    | Oviduct adenomas, nephroblastoma                                                                                                                                                                       | Reece (1992); Ladds (2009)                                                                  |
| *Taedoma variagata* | Paradise shelduck  | Plasma cell tumors                                                                                                                                                                                    | Reece (1992); Ladds (2009)                                                                  |
| Taeniopygia bichenovii | Double-barred finch | Fibroma, fibrosarcoma                                                                                                                                                                                  | Ladds (2009)                                                                                 |
| Taeniopygia castanotis | Zebra finch        | Adenocarcinoma, teratoma                                                                                                                                                                              | Ratcliffe (1933)                                                                              |
| *Thraupis palmarum* | Palm tanager       | Lipoma                                                                                                                                                                                                | Ratcliffe (1933)                                                                              |
| Torgos tracheliotus | African eared vulture | Adenocarcinoma                                                                                                                                   | Snyder and Ratcliffe (1966)                                                                   |
| *Trichoglossus chloropictus* | Scaly-breasted lorikeet | Pancreatic adenocarcinomas                                                                                                                                                                         | Reece (1992); Ladds (2009)                                                                  |
| *Trichoglossus rubritorquis* | Red-collared lorikeet | Intraabdominal lipomas, hepatocarcinomas, metastatic abdominal adenocarcinomas                                                                                                                     | Reece (1992); Ladds (2009)                                                                  |
| Turdoides terricolor | Jungle babbler     | Adenoma                                                                                                                                                                                               | Ratcliffe (1933)                                                                              |
| Turdus merula       | Blakbird           | Nephroblastoma or renal carcinoma (hypernephroma)                                                                                                                                                     | Ratcliffe (1933)                                                                              |
| Turnix melanogaster | Black-breasted button-quail | Metastatic abdominal adenocarcinomas                                                                                                                                                                | Reece (1992); Ladds (2009)                                                                  |
| Vanellus miles      | Masked lapwing     | Lymphoma                                                                                                                                                                                              | Ladds (2009)                                                                                 |

**Mammals**

| Latin name                             | Common name          | Neoplasia (including benign and malignant abnormal cell growths)                                                                                     | References                                                                                   |
|-----------------------------------------|----------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|
| *Acinonyx jubatus*                     | Cheetah              | Myometrial leiomyomas, uterine fibroleiomyoma                                                                                                                                                           | Munson et al. (1999); Walzer et al. (2003)                                                   |
| *Acrobates pygmaeus*                   | Feathertail glider   | Biliary adenocarcinoma                                                                                                                                                                                   | Ladds (2009)                                                                                 |
| *Addax nasomaculatus*                  | Addax                | Intestinal tubulopapillary carcinoma                                                                                                                                                                     | Chu et al. (2012)                                                                            |
| *Aepyceros melampus*                   | Rufous rat-kangaroo  | Thyroid adenoma, lymphoma, hemangiomomas, carcinoma                                                                                                                                                      | Ladds (2009)                                                                                 |
| *Ammotragus lervia*                    | Barbary sheep        | Lymphoma                                                                                                                                                                                               | Chu et al. (2012)                                                                            |
| *Antechinus stuartii*                  | Brown antechinus     | Squamous cell carcinoma, trichoeplthelioma                                                                                                                                                              | Canfield et al. (1990)                                                                       |
| *Antechinus laniger spenceri*          | Kultarr              | Pulmonary adenomatosis                                                                                                                                                                                  | Attwood and Woolley (1973)                                                                   |
| Latin name               | Common name                     | Neoplasia (including benign and malignant abnormal cell growths)                                                                 | References                                      |
|-------------------------|---------------------------------|---------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------|
| Antechinus minimus      | Swamp antechinus                | Renal pelvic transitional cell proliferation                                                                           | Canfield et al. (1990)                         |
| Arctictis binturong     | Binturong                       | Hepatocarcinoma                                                                                                             | Chu et al. (2012)                               |
| Arctocephalus forsteri  | New Zealand fur seal            | Renal adenocarcinoma, papilloma, basal cell carcinoma, osteosarcoma, anaplastic renal adenocarcinoma, neuroblastoma          | Ladds (2009)                                    |
| Arctocephalus pusillus  | 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)           |
| Atelerix albiventris    | 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) |
| Atherurus macrourus     | Brush-tailed porcupine          | Inflammatory myofibroblastic tumor                                                                                          | Chu et al. (2012)                               |
| Balaena mysticetus      | Bowhead whale                   | Lipoma                                                                                                                        | Newman and Smith (2006)                         |
| Balaenoptera borealis   | Sei whale                       | Melanocytoma (possibly hamartoma)                                                                                           | Newman and Smith (2006)                         |
| Balaenoptera musculus   | Blue whale                      | Mediastinal ganglioneuroma, mucinous cystadenoma, granulosa cell tumor, gastric lipoma, fibroma of the pleura                | Newman and Smith (2006); Ladds (2009)           |
| Balaenoptera physalus   | 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)           |
| Bassariscus astutus     | Ringtail cat                    | Basal cell carcinoma                                                                                                        | Ratcliffe (1933)                                |
| Bison bison             | Bison                           | Adenocarcinoma                                                                                                               | Ratcliffe (1933)                                |
| Bos bubalis             | Buffalo                         | Adenoma                                                                                                                      | Ratcliffe (1933)                                |
| Bos taurus              | Domestic cattle                 | Esophageal papilloma, cutaneous squamous cell carcinoma                                                                    | Chu et al. (2012)                               |
| Boselaphus tragocamelus | Nilgai                          | Fibroma                                                                                                                      | Ratcliffe (1933)                                |
| Callimico goeldii       | Goeldi’s marmoset               | Myelolipoma                                                                                                                  | Porter et al. (2004)                            |
| Callithrix jacchus      | Common marmoset                 | Myelolipoma                                                                                                                  | Porter et al. (2004)                            |
| Callophus ursinus       | Northern fur seal               | Granulosa cell tumor, lymphoma, lipoma, fibrosarcoma, squamous cell carcinoma, ganglioneuroblastoma, rhabdomyosarcoma        | Newman and Smith (2006)                         |
| Camelus bactrianus      | Bactrian camel                  | Hemangioma                                                                                                                   | Ratcliffe (1933)                                |
| Canis anthus            | Senegalese wolf                 | Medullary carcinoma                                                                                                          | Ratcliffe (1933)                                |
| Canis latrans           | Coyote                          | Chondrosarcoma                                                                                                               | Ratcliffe (1933)                                |
| Canis lupus baileyi     | Mexican wolf                    | Basal cell carcinoma, squamous cell carcinoma, nephroblastoma, adenocarcinoma                                                 | Ratcliffe (1933)                                |

(Continued)
| Latin name                        | Common name        | Neoplasia (including benign and malignant abnormal cell growths)                                                                 | References                                      |
|----------------------------------|--------------------|----------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------|
| *Canis lupus dingo*              | Dingo              | Lymphoma, thymoma, lipoma of subcutis, fibromatous epulis, perianal adenoma, sebaceous adenoma, squamous cell carcinoma, bronchial adenoma | Ladds (2009)                                   |
| *Canis mesomelas*                | Black-backed jackal| Osteoma, hemangiosarcoma                                                                                                       | Chu et al. (2012)                               |
| *Canis rufus*                    | Red wolf           | Adenocarcinoma, carcinomas                                                                                                      | Snyder and Ratcliffe (1966); Seeley et al. (2016) |
| *Capra hircus*                   | Domestic goat      | Lymphoma                                                                                                                         | Ratcliffe (1933)                                |
| *Caracal caracal*                | Caracal            | Osteochondroma                                                                                                                  | Ratcliffe (1933)                                |
| *Cebus albifrons*                | White-fronted capuchin | Cholangiocarcinoma                                                                                                           | Porter et al. (2004)                            |
| *Cebus apella fatuellus*         | Tufted capuchin    | Adenoma                                                                                                                         | Ratcliffe (1933)                                |
| *Cercocerus atys*                | Sooty mangabey     | Hepatocarcinoma                                                                                                                 | Porter et al. (2004)                            |
| *Cercocerus atys lunulatus*      | White-naped mangabey| Hepatocarcinoma                                                                                                                 | Porter et al. (2004)                            |
| *Cercopithecus aethiops*         | African green monkey| Hepatoma, mixed hepatocellular and cholangiocellular carcinoma, uterine leiomyoma                                                   | Porter et al. (2004); Chu et al. (2012)          |
| *Cercopithecus diana*            | Diana monkey       | Cholangiocarcinoma                                                                                                               | Porter et al. (2004)                            |
| *Cercopithecus mitis*            | Blue monkey        | Biliary adenoma/cystadenoma                                                                                                      | Porter et al. (2004)                            |
| *Cercopithecus mitis ssp. albogularis* | White-throated guenon | Biliary adenoma/cystadenoma                                                                                                      | Porter et al. (2004)                            |
| *Cercopithecus mona*             | Mona monkey        | Biliary adenoma/cystadenoma                                                                                                      | Porter et al. (2004)                            |
| *Chalinolobus gouldii*           | Gould’s wattled bat| Cutaneous papilloma of the wing                                                                                                 | Ladds (2009)                                   |
| *Chlorocebus sabaeus*            | Green monkey       | Adenocarcinoma                                                                                                                  | Ratcliffe (1933)                                |
| *Connochaetes gnou*              | Black wildebeest   | Squamous cell carcinoma                                                                                                          | Ratcliffe (1933)                                |
| *Cuniculus paca*                 | Lowland paca       | Lymphoma                                                                                                                         | Ratcliffe (1933)                                |
| *Cynomys ludovicianus*           | Black-tailed prairie dogs | Hepatocarcinoma, hepatoma, biliary cystadenoma, cholangiocarcinoma, odontoma (elodontoma), lingual squamous cell carcinoma, salivary gland adenocarcinoma, gingival squamous cell carcinoma, intestinal leiomyma, multencentric lymphoma, malignant round cell tumor, high grade lymphoma of liver and gall bladder, cutaneous lymphoma, malignant thymoma, atrial hemangiosarcoma, splenic hemangiomma, thoracic lipoma, thyroid adenocarcinoma, pancreatic adenocarcinoma, cystadenocarcinoma, adenocarcinoma, probably mammary, basal cell tumor, squamous cell carcinoma, bronchialolaveolar carcinoma | Thas and Garner (2012)                          |
| *Dasycercus cristicauda*         | Mulgara            | Prostatic carcinoma                                                                                                             | Canfield et al. (1990)                          |
| *Dasykaluta rosamondae*          | Little red kaluta  | Splenic myeloid hyperplasia                                                                                                      | Canfield et al. (1990)                          |
| *Dasyprocta albida*              | Agouti             | Uterine fibroleiomyoma                                                                                                           | Chu et al. (2012)                               |
| *Dasyprocta azarae*              | 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                                                                 |
|-----------------------|------------------------------|-----------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------|
| *Dasyuroides byrnei*  | 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)          |
| *Dasyurus Geoffroii*  | Western quoll                | Metastatic facial fibrosarcoma                                                                                               | Canfield et al. (1990)                                                   |
| *Dasyurus Hallucatus* | Northern quoll               | Lymphoma, squamous cell carcinoma of test, lymphocytic leukemia, histiocytoma                                                | Canfield et al. (1990); Ladds (2009)                                     |
| *Dasyurus Maculatus*  | 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) |
| *Dasyurus Viverrinus* | 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) |
| *Delphinus Delphis Ponticus* | Short-beaked common dolphin | Fibroma of the epididymis, Leydig cell tumor, testicular neoplasia                                                          | Newman and Smith (2006); Ladds (2009); Diaz-Delgado et al. (2012)         |
| *Dendrolagus Bennetitianus* | Bennett’s tree kangaroo    | Generalized sarcoma                                                                                                           | Ladds (2009)                                                             |
| *Didelphis Marsupialis* | Common opossum               | Adenocarcinoma, squamous cell carcinoma                                                                                      | Ratcliffe (1933); Snyder and Ratcliffe (1966)                              |
| *Didelphis Virginiana* | 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) |
| *Dorcopsis Muelleri*  | Brown forest wallaby         | Pulmonary metastasis of carcinoma                                                                                            | Ladds (2009)                                                             |
| *Elaphurus Davidianus* | Père David’s deer            | Cutaneous squamous cell carcinoma                                                                                             | Chu et al. (2012)                                                        |
| *Elephas Maximus*     | Asian elephant               | Cutaneous fibrosarcoma, uterine leiomyoma                                                                                     | Chu et al. (2012)                                                        |
| *Enhydra Latris Nereis* | Southern sea otter           | Osteosarcoma, osteoma                                                                                                         | Rodriguez-Ramos Fernandez et al. (2012)                                   |
| *Equus Asinus*        | Donkey                       | Renal hemangiosarcoma                                                                                                          | Chu et al. (2012)                                                        |
| *Equus Ferus Przewalski* | Przewalski’s wild horse      | Uterine adenocarcinoma                                                                                                         | Thompson et al. (2014)                                                   |
| *Equus Quagga*        | Common zebra                 | Fibrosarcoma                                                                                                                   | Ratcliffe (1933)                                                         |
| *Equus Zebra Zebra*   | Mountain zebra               | Sarcoïd tumors                                                                                                                 | Sasidharan (2006); Sasidharan et al. (2011)                               |

(Continued)
| Latin name                  | Common name                      | Neoplasia (including benign and malignant abnormal cell growths)                                                                 | References                          |
|-----------------------------|----------------------------------|---------------------------------------------------------------------------------------------------------------------------------|-------------------------------------|
| Erethizon dorsatum          | North American porcupine         | Chorion epithelioma                                                                                                              | Ratcliffe (1933)                    |
| Erinaceus europaeus         | Hedgehog                         | Adenocarcinoma, uterine leiomyoma                                                                                               | Chu et al. (2012)                   |
| Eulemur fulvus              | Common brown lemur                | Hepatocarcinoma                                                                                                                  | Porter et al. (2004)                |
| Eulemur macaco              | Black lemur                       | Biliary adenoma/cystadenoma, hepatocarcinoma                                                                                     | Porter et al. (2004)                |
| Eulemur mongoz              | Mongoose lemur                    | Adenoma                                                                                                                          | Ratcliffe (1933)                    |
| Eumetopias jubatus          | Steller’s sea lion                | Fibroleiomyoma, adenocarcinoma                                                                                                   | Newman and Smith (2006)             |
| Galago crassicaudatus        | Greater galago                    | Hepatocarcinoma, uterine leiomyoma                                                                                               | Chu et al. (2012)                   |
| Galagoides demidoff         | Demidoff’s dwarf galago           | Cholangiocarcinoma                                                                                                                | Porter et al. (2004)                |
| Gazella dorcas              | Dorcas gazella                    | Osteoma                                                                                                                          | Ratcliffe (1933)                    |
| Gazella thomsonii           | Thomson’s gazelle                 | Hepatocarcinoma                                                                                                                  | Chu et al. (2012)                   |
| Genetta genetta             | Common genet                      | Basal cell carcinoma                                                                                                             | Ratcliffe (1933)                    |
| Gerbilliscus robustus       | Fringe-tailed gerbil              | Fibrosarcoma, squamous cell carcinoma                                                                                             | Ratcliffe (1933)                    |
| Globicephala macrorynchus   | Short-finned pilot whale          | Granulosa cell tumor                                                                                                              | Newman and Smith (2006)             |
| Globicephala melaena        | Long-finned pilot whale           | Fibroleiomyomas, leiomyoma                                                                                                      | Newman and Smith (2006)             |
| Gorilla gorilla gorilla     | Lowland gorilla                   | Uterine adenocarcinoma, squamous cell carcinoma of vulva, cervix, and uterus                                                     | Stringer et al. (2010)              |
| Herpestes urva              | Carb-eating mongoose              | Uterine leiomyoma                                                                                                                 | Chu et al. (2012)                   |
| Heterocephalus glaber       | Naked mole-rat                    | Adenocarcinoma possibly of mammary or salivary origin, neuroendocrine carcinoma                                                  | Delaney et al. (2016)               |
| Hyaena brunnea              | Brown hyena                       | Mammary gland adenocarcinoma                                                                                                     | Chu et al. (2012)                   |
| Hyaena hyaena               | Striped hyena                     | Lymphoma, bronchioloalveolar carcinoma                                                                                           | Chu et al. (2012)                   |
| Hydromys chrysogaster       | Water-rat                         | Mediastinal lymphoma, adenoma, pheochromocytoma                                                                                   | Ladds (2009)                       |
| Hydrurga leptonyx            | Leopard seal                      | Fibromatous epulis                                                                                                                | Ladds (2009)                       |
| Hystric brachyura longicauda| Malayan porcupine                 | Scirrhous carcinoma                                                                                                               | Ratcliffe (1933)                    |
| Hystric cristata            | Crested porcupine                 | Uterine leiomyosarcoma                                                                                                            | Chu et al. (2012)                   |
| Inia geoffrensis            | Amazon river dolphin              | Squamous cell carcinoma                                                                                                           | Newman and Smith (2006)             |
| Isoodon auratus             | Golden bandicoot                   | Unidentified cloacal neoplasia                                                                                                    | Canfield et al. (1990); Marrow et al. (2010) |
| Jaculus jaculus             | Lesser Egyptian jerboa            | Angiolipoma                                                                                                                      | Ratcliffe (1933)                    |
| Lagenorhynchus obliquidens  | Pacific white-sided dolphin        | Squamous cell carcinoma, eosinophilic leukemia, lymphoma, teratoma, fibroma                                                      | Newman and Smith (2006)             |
| Lagenorhynchus obscurus      | Dusky dolphin                     | Dysgerminoma, uterine leiomyomas, fibroleiomyomas                                                                               | Newman and Smith (2006); Ladds (2009) |
| Lagenorhynchus acutus        | Atlantic white-sided dolphin       | Fibropapilloma, adenoma, leiomyoma                                                                                               | Newman and Smith (2006)             |
| Lama glama                  | Llama                             | Gastric squamous cell carcinoma                                                                                                  | Chu et al. (2012)                   |
| Lemur catta                 | Ring-tailed lemur                  | Cholangiocarcinoma, biliary adenoma/cystadenoma, mammary gland                                                                 | 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                           |
|-----------------------------------|-------------------|-------------------------------------------------------------------------------------------------------------------------------|--------------------------------------|
| *Leopardus pardalis*              | Ocelot            | Hepatocarcinoma                                                                                                                | Miranda et al. (2015)                |
| *Leopardus wiedii*                | Margay            | Cholangiocarcinoma, vaginal leiomyoma                                                                                           | McClure et al. (1977)                |
| *Leporillus condition*            | Greater stick-nest rat | Sarcoma, mediastinal thymoma, adenocarcinoma                                                                                   | Ladds (2009)                         |
| *Lutra canadensis*                | North American otter | Squamous cell carcinoma                                                                                                        | Snyder and Ratcliffe (1966)          |
| *Lycaon pictus*                   | African wild dog  | Hemangioma                                                                                                                     | Ratcliffe (1933)                     |
| *Macaca fascicularis*             | Crab-eating macaque | Hepatocarcinoma, mixed hepatocellular and cholangiocellular carcinoma                                                          | Porter et al. (2004)                 |
| *Macaca fuscata*                  | Japanese macaque  | Biliary adenoma/cystadenoma, hepatocarcinoma, squamous cell carcinoma, adenoma                                                  | Ratcliffe (1933); Porter et al. (2004) |
| *Macaca sinica*                   | Toque macaque     | Papilloma                                                                                                                      | Ratcliffe (1933)                     |
| *Macropus agilis*                 | Agile wallaby     | Focal hepatobiliary proliferation, biliary adenoma                                                                               | Ladds (2009)                         |
| *Macropus giganteus*              | Eastern gray kangaroo | Dermal lymphoma, metastatic hemangiosarcoma, hepatoma, trichoepithelioma, bronchioloalveolar carcinoma, bronchial carcinoma | Ladds (2009); Chu et al. (2012)      |
| *Macropus parma*                  | Parma wallaby     | Osteochondromatous proliferation, squamous cell carcinoma of the cervix and vagina                                               | Canfield et al. (1990); Ladds (2009); Marrow et al. (2010) |
| *Macropus parryi*                 | Whiptail wallaby  | Lymphoblastic lymphoma                                                                                                         | Ladds (2009)                         |
| *Macropus robustus*               | Common wallaroo   | Hepatic vascular proliferation, hamartoma, biliary adenoma                                                                     | Ladds (2009)                         |
| *Macropus rufogriseus*            | Bennett’s wallaby | Oral melanoma, oral adenocarcinoma, lymphoma, bile duct proliferation                                                         | Brust (2013); Ladds (2009)           |
| *Macropus rufus*                  | Red kangaroo      | Adenocarcinoma, lymphoma, squamous cell carcinoma of the pouch, squamous cell carcinoma of the oral cavity, gastric carcinoma, pulmonary carcinoma | Brust (2013); Ratcliffe (1933); Ladds (2009) |
| *Macrotis lagotis*                | 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)       |
| *Manis pentadactyla*              | Pangolin          | Hepatocarcinoma, hepatoma                                                                                                       | Chu et al. (2012)                    |
| *Marmota monax*                   | Groundhog         | Adenoma                                                                                                                        | Ratcliffe (1933)                     |
| *Megaptera novaeangliae*          | Humpback whale    | Lipoma, fibroma                                                                                                                | Newman and Smith (2006)              |
| *Melomys burtoni*                 | Grassland mosaic-tailed rat | Fibrosarcoma, hepatoma, adenocarcinoma, carcinoima                                                                                 | Ladds (2009)                         |
| *Mephitis mephitis*               | Striped skunk     | Biliary cystadenoma, renal cell carcinoma, adenocarcinoma                                                                       | Snyder and Ratcliffe (1966); Chu et al. (2012) |
| *Mesembriomyys gouldii*           | Black-footed tree-rat | Thymic lymphoma, hepatoma                                                                                                      | Ladds (2009)                         |
| *Mesoplodon densirostris*         | Blainville’s beaked whale | Vaginal fibromas                                                                                                              | Newman and Smith (2006); Ladds (2009) |

(Continued)
| Latin name                          | Common name                          | Neoplasia (including benign and malignant abnormal cell growths)                                                                 | References                                      |
|------------------------------------|--------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------|
| Microcebus murinus                 | Gray mouse lemur                      | Hepatocarcinoma                                                                                                               | Porter et al. (2004)                           |
| Mirounga leonina                   | Southern elephant seals              | Adrenocortical adenoma, malignant granulosa cell tumor                                                                       | Ladds (2009)                                   |
| Mus musculus molossinus            | Japanese waltzing mice               | Adenocarcinoma, fibroadenoma                                                                                                 | Ratcliffe (1933)                               |
| Mustela putorius furo              | Ferret                               | Sebaceous carcinoma, adrenocortical carcinoma                                                                             | Chu et al. (2012)                              |
| Mustela vison                      | American mink                        | Cutaneous squamous cell carcinoma, hepatocarcinoma, adrenocortical carcinoma, lymphoma, hemangiosarcoma, hepatoma              | Chu et al. (2012)                              |
| Myocastor corpus                   | Nutria                               | Adenocarcinoma, fibroma                                                                                                       | Ratcliffe (1933)                               |
| Myrmecophaga tridactyla            | Giant anteater                       | Multicentric lymphoma                                                                                                         | Sanches et al. (2013)                          |
| Nasua nasua                        | South American coati                 | Squamous cell carcinoma                                                                                                       | Ratcliffe (1933)                               |
| Neofelis nebulosa                  | Clouded leopard                      | Pheochromocytoma, uterine leiomyoma, mesothelioma, hemangioma                                                                  | Snyder and Ratcliffe (1966); Chu et al. (2012) |
| Neophocaena phocaenoides           | Indo-Pacific finless porpoise         | Fibroma                                                                                                                         | Newman and Smith (2006)                        |
| Notomys alexis                     | Spinifex hopping mouse               | Fibroma, lipoma, rhabdomyosarcoma, cavernous hemangioma, thymic lymphoma, multicentric lymphoma, melanoma                    | Ladds (2009); Old and Price (2016)             |
| Nyctereutes procyonoides           | Raccoon dog                          | Adenocarcinoma                                                                                                                | Ratcliffe (1933)                               |
| Nycticebus coucang                 | Slow loris                           | Cholangioma, adrenocortical adenoma, myeloid leukemia                                                                         | Chu et al. (2012)                              |
| Nyctophilus geoffroyi              | Lesser long-eared bat                | Fibrosarcoma of the abdomen                                                                                                   | Ladds (2009)                                   |
| Odocoileus hemionus                | Mule deer                            | Intracerebral malignant plasma cell tumor                                                                                     | Clancy et al. (2016)                           |
| Odocoileus virginianus             | White-tailed deer                    | Fibroadenoma, oligodendrogliomas                                                                                            | Ratcliffe (1933); Gottdenker et al. (2012)     |
| Orcinus orca                       | Killer whale                         | Hodgkins-like lymphoma, papilloma                                                                                              | Newman and Smith (2006); Ladds (2009)          |
| Ornithorhynchus anatinus           | Duck-billed platypus                 | Papilloma, hepatoma, adrenocortical adenoma                                                                                   | Ladds (2009)                                   |
| Oryx gazella gazelle               | Gemsbok                              | Adrenocortical adenoma                                                                                                         | Chu et al. (2012)                              |
| Otolchirocrassicaudatus            | Brown greater galago                 | Cholangiocarcinoma, hepatoma                                                                                                | Porter et al. (2004)                           |
| Otospermophilus beecheyi           | California ground squirrel           | Osteoma                                                                                                                         | Ratcliffe (1933)                               |
| Pan troglodytes                    | Chimpanzee                           | Hepatocarcinoma, hepatoma, reproductive neoplasia, uterine leiomyomas                                                          | Stringer et al. (2010)                         |
| Panthera leo                       | Lion                                 | Gallbladder adenocarcinomas, mammary gland adenocarcinoma, uterine leiomyoma, hepatocarcinoma, biliary cystadenoma, malignant histiocytes, scirrhous carcinoma | Ratcliffe (1933); Sakai et al. (2003); Chu et al. (2012) |
| Panthera onca                      | Jaguar                               | Adrenocortical carcinoma, pancreatic islet cell carcinoma, metastatic leiomyosarcoma, leiomyoma, mammary fibroadenoma, lymphangioma | Port et al. (1981); Chu et al. (2012); Ratcliffe (1933) |
| Panthera pardus                    | Leopard                              | Hepatoma, parathyroid carcinoma, mammary gland adenocarcinoma, cholangiocarcinoma, lymphangioma                                 | Sakai et al. (2003); Chu et al. (2012); Ratcliffe (1933) |
| Latin name                     | Common name       | Neoplasia (including benign and malignant abnormal cell growths)                                                                 | References                       |
|-------------------------------|-------------------|----------------------------------------------------------------------------------------------------------------------------------|----------------------------------|
| Panthera tigris               | Tiger             | Mammary gland adenocarcinoma, adenomatous polyps, squamous cell carcinoma                                                      | Chu et al. (2012); Ratcliffe (1933) |
| Panthera tigris bengalensis   | Bengal tiger      | Endometrial adenocarcinoma                                                                                                     | Linnehan and Edwards (1991)     |
| Papio cynocephalus            | Yellow baboon     | Adenocarcinoma, fibroadenoma                                                                                                    | Ratcliffe (1933)                |
| Papio cynocephalus anubis     | Anubis baboon     | Cutaneous squamous cell carcinoma, trichofolliculoma                                                                             | Chu et al. (2012)               |
| Papio hamadryas               | Hamadryas baboon  | Gall bladder adenocarcinoma, biliary adenoma/cystadenoma                                                                         | Ratcliffe (1933); Porter et al. (2004) |
| Papio papio                   | Guinea baboon     | Gall bladder adenocarcinoma                                                                                                     | Porter et al. (2004)            |
| Papio sphinx                  | Mandrill          | Uterine leiomyosarcoma, cutaneous lipoma                                                                                            | Chu et al. (2012)               |
| Papio ursinus                 | Chacma baboon     | Gall bladder cystadenocarcinoma, fibrosarcoma                                                                                     | Ratcliffe (1933); Porter et al. (2004) |
| Paradoxurus hermaphroditus    | Asian palm civet  | Adenocarcinoma                                                                                                                    | Ratcliffe (1933)                |
| Parantechinus apicalis        | Dibbler           | Lymphoma (leukemic)                                                                                                               | Canfield et al. (1990)          |
| Perameles bougainville        | Western barred bandicoot | Pulmonary carcinoma, prostatic carcinoma, cutaneous papillomatosis, and carcinomatosis                          | Ladds (2009)                    |
| Perameles gunnii              | Eastern barred bandicoot | Colonic leiomyosarcoma and leiomyoma, leiomyosarcoma of skin and lymph nodes, fibrohistiocytoma, cutaneous histiocytoma, mast cell tumor, basal cell tumor of the larynx | Canfield et al. (1990); Ladds (2009); Marrow et al. (2010) |
| Perodicticus potto            | Potto             | Cholangiocarcinoma                                                                                                                | Porter et al. (2004)            |
| Perodipus richardsoni         | Kangaroo rat      | Fibrosarcoma, lymphoma                                                                                                            | Ratcliffe (1933)                |
| Peromyscus leucopus           | White-footed mouse | Fibrosarcoma, adenocarcinoma                                                                                                    | Ratcliffe (1933)                |
| Petaurus breviceps            | 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) |
| Phalanger gymnnotis           | Ground cuscus     | Cutaneous lymphoma                                                                                                                | Goodnight et al. (2008)         |
| Phascogale tapoatafa          | Brush-tailed phascogale | Hemangiopericytoma, trichoeplithelioma, fibrosarcoma, lymphoma, hemangioma, hemangiosarcoma, basal cell tumor, squamous cell carcinoma, hepatocarcinoma, melanoma | Canfield et al. (1990); Ladds (2009) |
| Phascolarctos cinereus        | Koala             | Lymphoma, meothelioma, tumors of the carilaginous 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, pilomatrixoma, chromophobe adenoma, adenoma of the frontal sinus, serosal adenocarcinoma | Ladds (2009)                    |

(Continued)
| Latin name                  | Common name      | Neoplasia (including benign and malignant abnormal cell growths)                                                                 | References                                                                 |
|-----------------------------|------------------|-------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------|
| Phocoena phocoena           | Harbor porpoise  | Papilloma, adenocarcinoma                                                                                                     | Newman and Smith (2006)                                                  |
| Physeter macrocephalus      | Sperm whale      | Uterine leiomyoma, fibroleiomyoma, fibroleiomyosarcoma, hemangioma, fibromas of the jaw and skin, penile papillomatosis       | Newman and Smith (2006); Ladds (2009)                                     |
| Planigale maculata          | Common planigale | Dermal spindle cell tumor, uterine adenocarcinoma, squamous cell carcinoma                                                     | Canfield et al. (1990)                                                   |
| Pongo pygmaeus              | Bornean orangutan| Malignant granulosa cell tumor                                                                                               | Stringer et al. (2010)                                                   |
| Presbytis entellus          | Gray langur      | Hepatoma                                                                                                                      | Porter et al. (2004)                                                     |
| Procyon cancrivorus         | Crab-eating raccoon| Adenocarcinoma                                                                                                                | Ratcliffe (1933)                                                         |
| Procyon lotor               | Raccoon          | Adenoma, adenocarcinoma, pancreatic exocrine adenocarcinoma, hepatocarcinoma, mammary gland adenocarcinoma, sweat gland adenocarcinoma | Ratcliffe (1933); Chu et al. (2012)                                       |
| Proteles cristatus          | Aardwolf         | Peritoneal mesothelioma                                                                                                      | Chu et al. (2012)                                                       |
| Pseudantechinus bilarni     | Sandstone antechinus| Lymphoma or splenic erythroid hyperplasia, sebaceous adenoma                                                                | Canfield et al. (1990)                                                   |
| Pseudantechinus macdonellensis| False antechinus | Lymphoma (leukemic)                                                                                                          | Canfield et al. (1990)                                                   |
| Pseudocheirus peregrinus    | Common ringtail possum| Lymphoma, metastatic adenocarcinoma                                                                                          | Ladds (2009)                                                            |
| Pseudomys albocinerea       | Ash-gray mouse   | Liposarcoma, lymphoma                                                                                                         | Ladds (2009)                                                            |
| Pseudomys australis         | Plains rat       | Hemangiosarcoma, adenocarcinoma, carcinoma                                                                                   | Ladds (2009)                                                            |
| Pteropus d. dasymallus      | Flying fox       | Hepatocarcinoma, chondrosarcoma, uterine adenocarcinoma                                                                       | Chu et al. (2012)                                                       |
| Pteropus poliocephalus      | Gray-headed flying fox| Metastatic carcinoma, fibropapilloma, subcutaneous fibrosarcoma, rhabdomyoma                                                  | Ladds (2009)                                                            |
| Puma concolor               | Mountain lion    | Fibrosarcoma, thyroid carcinoma                                                                                               | Chu et al. (2012)                                                       |
| Rangifer tarandus tarandus  | Reindeer         | Lymphoma                                                                                                                      | Jarplid and Rehbinder (1995)                                             |
| Rattus norvegicus           | Rat              | Mammary gland fibroadenoma                                                                                                     | Chu et al. (2012)                                                       |
| Rattus tunneyi              | Pale field rat   | Adenocarcinoma                                                                                                                | Ladds (2009)                                                            |
| Saguinus oedipus            | Cotton-top tamarin| Intestinal adenocarcinoma                                                                                                     | Chu et al. (2012)                                                       |
| Saimiri boliviensis         | Black-headed squirrel monkey| Hepatocarcinoma                                                                                                              | Porter et al. (2004)                                                    |
| Saimiri sciureus            | Squirrel monkey  | Cutaneous lipoma, adenocarcinoma of vaginal wall, hepatocarcinoma                                                             | Porter et al. (2004); Chu et al. (2012)                                  |
| Sarcophilus harrisii        | Tasmanian devil  | Papillomas, splenic erythroid hyperplasia, adenocortical 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 |
|------------|-------------|---------------------------------------------------------------|------------|
| Sciurus niger | Fox squirrel | Adenocarcinoma and adenoma of the kidney | Ratcliffe (1933) |
| Sciurus carolinensis penesieanicus | Northern gray squirrel | Hypernephroma | Ratcliffe (1933) |
| Setonix brachyurus | Quokka | Liposarcoma, papilloma | Ladds (2009) |
| Smithopsis crassicaudata | Fat-tailed dunnart | Dermal spindle cell tumor, splenic lymphoma, squamous cell carcinoma, round cell sarcoma of the upper forelimb | Canfield et al. (1990) |
| Stenella coeruleoalba | Striped dolphin | Myelogenous leukemia, squamous cell carcinoma | Newman and Smith (2006) |
| Suricata suricatta | Meerkat | Rhabdomyosarcoma | Chu et al. (2012) |
| Sus barbatus | Black small-eared pig | Uterine adenocarcinoma, uterine leiomyoma | Chu et al. (2012) |
| Sus scrofa | Pig | Adenocarcinoma | Ratcliffe (1933) |
| Tachyglossus aculeatus | Short-beaked echidna | Lymphoma of spleen, fibroma of subcutis, leiomyoma of the cloaca, pericloacal leiomyosarcoma, fibroma of the beak, myocardial lymphom, lymphoma with leukemia, cystic adenoma of the thyroid | Ladds (2009) |
| Taurotragus oryx | Common eland | Cutaneous lymphoma | Chu et al. (2012) |
| Taxidea taxus | American badger | Peritoneal epithelioid leiomyosarcoma, undetermined adenocarcinomas | Chu et al. (2012) |
| Thylacoma lagotis | Rabbit-eared bandicoot | Squamous cell carcinoma | Snyder and Ratcliffe (1966) |
| Thylacoleo billardierii | Tasmanian pademelon | Squamous tumor of the stomach, melanoma | Kusewitt and Ley (1996); Ladds (2009) |
| Tragelaphus eurycerus isaaci | Bongo | Uterine leiomyomas | Napier et al. (2005) |
| Tragelaphus strepsiceros | Greater kudu | Renal cell carcinoma | Chu et al. (2012) |
| Trichosurus vulpecula | Common brushtail possum | Thoracic chondrosarcoma | Ladds (2009) |
| Tupaia belangeri | Northern treeshrew | Hepatocarcinoma | Porter et al. (2004) |
| Tursiops truncatus | 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) |
| Urocyon cinereoargenteus | Gray fox | Adenoma, splenic myelolipoma, cutaneous squamous cell carcinoma, sweat gland adenoma of eyelid, lymphoma | Ratcliffe (1933); Chu et al. (2012) |
| Ursus americanus | American black bear | Medullary carcinoma, basal cell carcinoma | Ratcliffe (1933) |
| Ursus arctos | Brown bear | Bronchial adenoma, cholangiocarcinoma, hypernephroma | Ratcliffe (1933); Chu et al. (2012) |
| Ursus maritimus | Polar bear | Cutaneous lymphoma, adenocarcinoma | Ratcliffe (1933); Chu et al. (2012) |
| Ursus thibetanus | Asiatic black bear | Biliary cystadenoma | Chu et al. (2012) |

(Continued)
### TABLE 2.2 Cancer Prevalence in Wild Animals

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

*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 (cont.)

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

FP, Fibropapillomatosis.

*Significant temporal decrease in prevalence.

a, Epizootic, no data provided on exact prevalence.

b, 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 McKinney and Martin (1979) observed a gradual temporal decline in tumor prevalence and in 1978 no tumors were observed in 1216 dissected frogs. McKinney 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 (0.0–0.27%). No intersexual differences in tumor prevalence were recorded. Virus-like bodies, resembling herpes-type virus, were found in the cytoplasm of the epitheliomas, 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 km² 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 reticulendotheliosis 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%) where 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 leiomyomata (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 (CcPV1) 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).
The tumor frequencies observed in the three vertebrate classes revealed remarkable similarities. High 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).

### Table 2.4: Anatomical Percentage Distribution of Tumors in Three Vertebrate Classes in French Zoological Parks

|                  | Birds      | Mammals    | Reptiles   |
|------------------|------------|------------|------------|
|                  | (n = 46)   | (n = 271)  | (n = 26)   |
| 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        |

The prevalence of malignant tumors differed among taxa (χ² = 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

| Class   | Number of benign tumors | Number of malignant tumors |
|---------|-------------------------|----------------------------|
| 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 zoo- logical 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.

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