# *Lutra lutra* (Carnivora: Mustelidae)

**Nancy Hung and Chris J. Law**

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*Presentation High School, San Jose, CA 95125, USA; nhung@presentationhs.org (NH)*
*Department of Ecology and Evolutionary Biology, Long Marine Laboratory University of California, Santa Cruz, 100 Shaffer Road, Santa Cruz, CA 95060, USA; cjlaw@ucsc.edu (CJL)*
*Present address of NH: Massachusetts Institute of Technology, Cambridge, MA 02139, USA*

**Abstract:** *Lutra lutra* (Linnaeus, 1758), commonly known as the Eurasian otter, is the most widely distributed of the lutrinids (otters). *L. lutra* is primarily a piscivorous predator but also preys on amphibians, crustaceans, small mammals, birds, and reptiles. Extant populations of this semiaquatic mustelid occur in a wide variety of aquatic freshwater and marine habitats throughout Asia, all of Europe, and parts of northern Africa. Despite the large distribution, habitat loss has led to dwindling *L. lutra* populations, particularly in Asia, and the species is currently listed as "Near Threatened" by the International Union for Conservation and Nature and Natural Resources.

**Key words:** Asia, Eurasian otter, Europe, Lutrinae, mustelid, river otter

## *Lutra lutra* (Linnaeus, 1758)

### Eurasian Otter

*Mustela lutra* Linnaeus, 1758:45. Type locality "Europae aquis dulcibus, fluviis, flagnis, piscinis;" restricted to "Upsala" [Sweden] by Thomas (1911:138).

*Lutra vulgaris* Erxleben, 1777:448. Type locality "Europae atque Asiae Americaeque borealis aquis dulcibus, fluuiis, stagnis, piscinis, non in mari. Est quoque in Persia [= In freshwaters of North America, Europe and Asia, with the rivers, dams, reservoirs, and not in the sea. It is also in Persia]."

*M[ustela] lutra piscatoria* Kerr, 1792:173. Type locality "Europe, North America, Asia, as far south as Persia."

*Lutra fluviatilis* Leach, 1816:6. Type locality unknown.

*Lutra barang* Cuvier, 1823:246. Type locality "Java…Sumatra."

*Lutra nair* Cuvier, 1823:247. Type locality "qui les a rapportes de Pondichery, ou pespece est nommee nir-nayie. [= Pondicherry, India]."

*[Lutra vulgaris] marinus* Billberg, 1827:28. Type locality "Scandinaviae."

*Viverra lutra* Pallas, 1831:76. Type locality "Per omnem Rossiam et Sibiram ad usque Camtschatcam…In Americam quoque transiit…in Caucaso ad Cyrum praesertim fluvium, in Persia et per omnem tatariam magnam, forte ad Indos usque."

*Lutra nudipes* Melchior, 1834:50. Type locality "Meget almindelig paa Sokysterne i det nordlige Norge, for- nemmelig i Nordlandene; sindes udentvivl ogsaa i Danmark lige- ledes i Sverrig [= Sokysterne, Norway as well as Denmark and Sweden]."



**Fig. 1.**—Adult *Lutra lutra* from Biotop Wildpark Anholter Schweiz, Germany. Photograph by Arjan Haverkamp used with permission.

*Lutra roensis* Ogilby, 1834:111. Type locality "Ireland."
*Lutra chinensis* Gray, 1837:580. Type locality "China."
*Lutra indica* Gray, 1837:580. Type locality "Bombay."
[*Lutra*] *monticolus nobis* Hodgson, 1839:28. Type locality "Nepal."
[*Lutra*] *auro-brunneus nobis* Hodgson, 1839:29. Type locality "Nepal."
*Lutra kutab* Schinz, 1844:354. Type locality "Kashmir."
*Lutra simung* Horsfield, 1851:116. Type locality "Sumatra and Borneo."
L[*utra*]. *sinensis* Hodgson, 1855:126. Type locality "lower [region of the Himalayas]."
*Barangia nepalensis* Gray, 1865:124. Type locality "Nepaul."
*Lutonectes whiteleyi* Gray, 1867:180. Type locality "Japan."
*Leutronectes whiteleyi* Gray, 1869:107. Incorrect subsequent spelling of *Lutonectes whiteleyi* Gray, 1867.
*Lutra angustifrons* Lataste, 1885:115. Type locality "Algeria."
*Lutra lutra*: Lataste, 1885:116. First use of current name combination.
[*Lutra*] *japonica* Nehring, 1887:22. Type locality "japanischen."
*Lutra hanensis* Matschie, 1906:150. Type locality "Hing-an-fu [China]."
*Lutra lutra splendida* Cabrera, 1906:360. Type locality "Mogador [Essaouira, Morocco]."
*Lutra seistanica* Birula, 1912:274. Type locality "Gil'mend River, Seistan, Iran."
*Lutra lutra oxiana* Birula, 1915:21. Type locality "Pamir [Mountains]."
*Lutra intermedia* Pohle, 1920:62. Type locality "Sumatra."
*Lutra l. ceylonica* Pohle, 1920:72. Type locality "Ceylon."
*Lutra vulgaris* var. *amurensis* Dybowski, 1922:349. Type locality "Amur, Ussuri," Russia.
*Lutra vulgaris* var. *baicalensis* Dybowski, 1922:349. Type locality "Okolice Baikal," Russia.
*Lutra vulgaris* var. *kamtschatica* Dybowski, 1922:349. Type locality "Kamchatka," Russian Far East.
*Lutra meridionalis* Ognev, 1931:374. Type locality "Teheran."
*Lutra stejnegeri* Goldman, 1936:164. Type locality "from near Petropavlovsk, Kamchatka," Russian Far East.
*Lutra lutra borealis* Stroganov, 1960:156. Type locality "Tyumen Province [Russia]."
*Lutra hainana* Xu et al., 1983:299. Type locality "Hainan Island."
*Lutra nippon* Imaizumi and Yoshiyuki, 1989:178. Type locality "Nenokubi Seaside, Shimoda, Nakamura City, Kôchi Prefecture," Japan.

CONTEXT AND CONTENT. Order Carnivora, family Mustelidae, subfamily Lutrinae. Seven to 28 subspecies of *Lutra lutra* have been recognized (Larivière and Jennings 2009). In addition, the now extinct *L. l. nippon* has been considered a distinct species based on previous phylogenetic analyses (Suzuki et al. 1996); however, these analyses were not well supported and additional information is required to determine its taxonomic status. We recognized the following 12 extant subspecies, as well as the extinct *L. l. nippon* (Wozencraft 2005).

*L. l. angustifrons* Lataste, 1885. See above; *splendida* Cabrera, 1906 is a synonym.
*L. l. aurobrunnea* Hodgson, 1839. See above; *auro-brunneus* Hodgson, 1839 and *nepalensis* Gray, 1865 are synonyms.
*L. l. barang* Cuvier, 1823. See above; *simung* Horsfield, 1851 and *intermedia* Pohle, 1920 are synonyms.
*L. l. chinensis* Gray, 1837. See above; *hanensis* Matschie, 1906 and *sinensis* Hodgson, 1855 are synonyms.
*L. l. hainana* Xu et al., 1983. See above.
*L. l. kutab* Schinz, 1844. See above.
*L. l. lutra* (Linnaeus, 1758). See above; *fluviatilis* Leach, 1816, *marinus* Billberg, 1827, *nudipes* Melchior, 1834, *roensis* Ogilby, 1834, *stejnegeri* Goldman, 1936, and *vulgaris* Erxleben, 1777 are synonyms.
*L. l. meridionalis* Ognev, 1931. See above.
*L. l. monticolus* Hodgson, 1839. See above.
*L. l. nair* Cuvier, 1823. See above; *ceylonica* Pohle, 1920 and *indica* Gray, 1837 are synonyms.
*L. l. seistanica* Birula, 1912. See above; *oxiana* Birula, 1915 is a synonym.
*L. l. whiteleyi* Gray, 1867. See above; *japonica* Nehring, 1887 and *nippon* Imaizumi and Yoshiyuki, 1989 are synonyms.

NOMENCLATURAL NOTES. Other vernacular names for *Lutra lutra* are European otter, European river otter, common otter, old world otter, loutre commune, loutre de rivere, loutre d'Europe, nutria, and nutria común. The synonyms for *Lutra* include *Mustela*, *Viverra*, *Barangia*, and *Lutonectes*.

## DIAGNOSIS

*Lutra lutra* does not occur sympatrically with other lutrinid species in Europe and the majority of Asia and can be differentiated from other mustelids by its fully webbed feet, long tapered tail, and larger size (head-body length and body mass up to 90 cm and 12 kg, respectively; all other mustelids are < 82 cm in head-body length and < 6 kg in body mass). In Southeast Asia, *L. lutra* occurs sympatrically with the hairy-nosed otter *Lutra sumatrana*, the smooth-coated otter *Lutrogale perspicillata*, and the Asian small-clawed otter *Aonyx cinerea*. Body sizes and pelage coloration are similar between *L. lutra* and *L. sumatrana*; the key difference between these 2 sister species is the presence of a hair-covered rhinarium as well as the whitish coloration of the lips, chin, and upper throat found in *L. sumatrana*. In contrast, several characteristics distinguish the smooth-coated otter from *L. lutra*, including the more massive head, short smooth fur, naked rhinarium, dark brown pelage with a clearly demarcated light underbelly, and dorso-ventrally flattened tail of *L. perspicillata* (Hwang and Larivière 2005). Lastly, the Asian small-clawed otter can be easily differentiated from *L. lutra* due to the former's much smaller size (body mass < 3.8 kg; head-body length < 45 cm) and reduction of claw size on all feet (Larivière 2003).

## GENERAL CHARACTERS

Physically, *Lutra lutra* is similar to other otters in having a broad, round head with whiskers and semiwebbed feet such that toes are visible (Fig. 1). Its body is elongate and ends with a cone-shaped tail (Kruuk 2006). The pelage is dense and dark brown throughout, though lighter on the underside (Larivière and Jennings 2009). Due to the wide extent of geographical distribution of *L. lutra*, intraspecific variation is substantial. *L. lutra* that resides in Asia has shorter hair and lighter-colored fur (Sivasothi and Nor 1994) with a few light patches near the throat (Kruuk 2006) than individuals found in other parts of the distribution area.

*Lutra lutra* is sexually dimorphic in that males are 50% larger than females (Larivière and Jennings 2009). Body mass is 5.45–11.4 kg for males and 3.36–7.6 kg for females (Conroy et al. 2000). Head-body length is 60–90 cm for males and 59–70 cm for females, and tail length is 36–47 cm for males and 35–42 cm for females (Macdonald 1993). Hind foot length is 11–13.5 cm (Macdonald 1993).

Mean skull measurements (mm; with range and *n*) for adult males and females, respectively, from East Germany were: condylobasal length, 117.41 (106.1–124.3, 102), 109.57 (104.1–121.0, 64); zygomatic breadth, 73.87 (65.9–81.5, 96), 67.33 (61.8–74.8, 58); braincase breadth, 51.09 (45.8–56.1, 101), 48.61 (45.5–52.9, 64); skull height without sagittal crest, 35.43 (32.5–38.2, 101), 33.36 (29.8–38.0, 62); length of upper toothrow (C–M1), 35.68 (32.4–39.5, 121), 33.41 (30.4–36.9, 80); angular length, 75.19 (66.9–82.0, 132), 68.88 (63.5–76.9, 91); length of lower toothrow (C–M2), 43.42 (38.4–47.9, 138), 40.28 (37.5–44.2, 95); M1 length, 13.55 (11.3–15.4, 145), 12.71 (10.5–14.4, 98); and M1 breadth, 6.82 (5.9–7.7, 147), 6.36 (5.8–7.1, 97—Ansorge and Stubbe 1995; Fig. 2).

## DISTRIBUTION

*Lutra lutra* is the most widely distributed otter species in the world, with extant populations occurring throughout Asia, all of Europe, and parts of northern Africa (Fig. 3). Historical populations originally extended from Japan in the east to Portugal in the west, and from the Arctic regions of Asia and Europe to as far south as Indonesia (Foster-Turley et al. 1990). Although extant populations remain widespread, *L. lutra* numbers, particularly in Europe, are in great decline due to the presence of environmental pollution, habitat fragmentation, direct persecution, and accidental trappings of otters in fishing nets (Koelewijn et al. 2010).

In Southeast Asia, *L. l. chinensis* resides in China, Indochina, Thailand, Malaysia, Vietnam, Ryukyu, and the Tawushan Nature Reserve in southeast Taiwan (Harris 1968; Lai and Nepal 2006). Two additional subspecies are found in Southeast Asia: *L. l. barang* in Thailand, Vietnam, and Sumatra (Koepfli et al. 2008) and *L. l. hainana* in Hainan, China. Four subspecies are endemic to the Indian subcontinent: *L. l. aurobrunneus* in the lower and central hilly region of Nepal; *L. l. kutab* in Kashmir; *L. l. monticolus*



**Fig. 2.**—Dorsal, ventral, and lateral views of skull and lateral view of mandible of an adult female *Lutra lutra*. Photograph taken by Chris Conroy at the Museum of Vertebrate Zoology, University of California, Berkeley (Museum of Vertebrate Zoology [MV] Mamm:34264) used with permission. Total skull length is 10.9 cm.

in Punjab, Kumaon, Sikkim, and Assam, India; and *L. l. nair* in Pondicherry, Sri Lanka, and southern India (Harris 1968; Romanowski et al. 2010). In the Middle East, *L. l. meridionalis* occurs in the vicinity of Tehran, northern Iran; from Georgia through Armenia; Iran to the Persian Gulf; and in Azerbaijan (Harris 1968; Kasumova and Askerov 2009). *L. l. seistanica* occurs in the Helmand River (in Afghanistan), Sistan, Eastern Iran, Kazakhstan, Uzbekistan, and Turkmenistan (Harris 1968; Conroy et al. 1998). One subspecies, *L. l. angustifrons*, is endemic to Africa and occurs in Morocco and Algeria (Broyer et al. 1988).

Of the 12 extant subspecies, *L. l. lutra* is the most widely distributed in Europe and Asia, with populations spanning from Portugal to South Korea (Kruuk 2006). Countries with recovering or stable populations of *L. l. lutra* include Britain (Crawford 2010), Denmark (Elmeros et al. 2006), France (Janssens et al. 2006), Germany (Honnen et al. 2011), northwestern Greece and Corfu Island (Ruiz-Olmo 2006; Karamanlidis et al. 2014), Italy (Marcelli and Fusillo 2009), Portugal (Trindade 1994), Spain (García Diaz 2008), Slovakia (Urban et al. 2011), and Sweden (Roos et al. 2012). In addition, *L. l. lutra* has expanded in northern Upper and Lower Austria and in the south, across the Danube River; the northern population is comparatively larger in size, differing from the southern
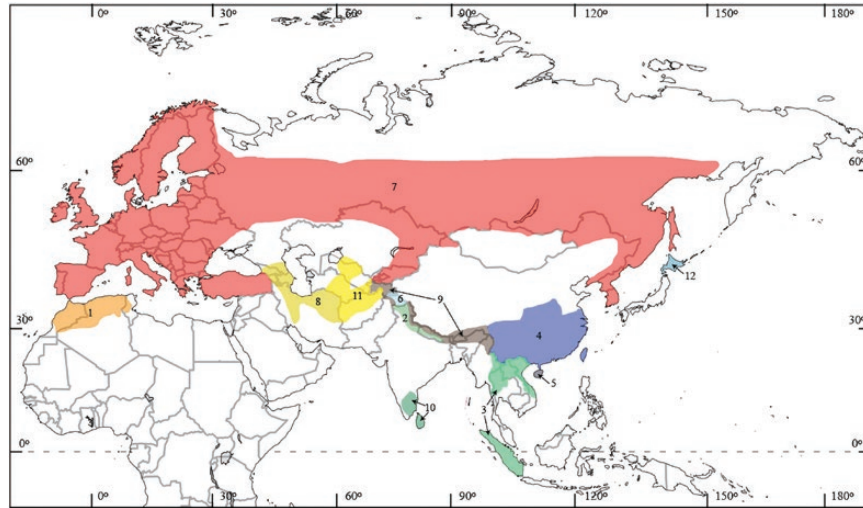
**Fig. 3.**—Geographic distribution of *Lutra lutra*. Map redrawn from (Romanowski et al. 2010). Subspecies are: 1, *L. l. angustifrons*; 2, *L. l. aurobrunnea*; 3, *L. l. barang*; 4, *L. l. chinensis*; 5, *L. l. hainana*; 6, *L. l. kutab*; 7, *L. l. lutra*; 8, *L. l. meridionalis*; 9, *L. l. monticolus*; 10, *L. l. nair*; 11, *L. l. seistanica*; and 12, *L. l. whiteleyi*.

Austrian population, though there is evidence that both populations meet in the Northern Limestone Alps (Conroy and Chanin 2000). In Britain, *L. l. lutra* populations have greatly recovered over the last 35 years and are now present in every county (Crawford 2010). Though more abundant in lower altitudinal areas, *L. l. lutra* may also be found in the midst of mountainous habitats in European countries as well as in Tibet at 4,120 m (Ruiz-Olmo 2007).

Recently, *L. l. lutra* has been reintroduced to areas where its population remains low, such as the Netherlands (Koelewijn et al. 2010), Spain (Saavedra and Sargatal 1998), Sweden (Sjöåsen 1996), Switzerland (Conroy and Chanin 2000), and in specific areas in Britain (Mason and Macdonald 2004). Breeding and immigration in these areas in Britain led to a population annual growth rate of 1–7% with rapid growth following natural colonization and slower growth as the population reached carrying capacity (Mason and Macdonald 2004). Though *L. lutra* has re-expanded in Italy, suitable habitat in the northern area of Italy remains uninhabited, suggesting a need to expand conservation efforts to those areas (Marcelli and Fusillo 2009). Populations remain in decline in several countries such as Israel (Cohen et al. 2013) and Georgia (Gorgadze 2013), and there are several areas that lack demographic information (Conroy and Chanin 2000).

## FOSSIL RECORD

The genus *Lutra* is known from the late Miocene (Greece and Spain) and early Pliocene (France), with *Lutra affinis* appearing in the fossil record approximately 5.8 million years ago (Koufos 2011; Montoya et al. 2011). *Lutra palaeindica*, from the Pleistocene sediments of the Upper Siwalik Group, Pakistan, is believed to be ancestral to extant *Lutra lutra* and *Lutra sumatrana* due to the close resemblance and locality (Willemsen 2006). *L. lutra* is hypothesized to have originated in Asia and dispersed into Europe during the latest Pleistocene and

early Holocene (Willemsen 1992). The oldest *L. lutra* fossils are known from several Holocene localities in Europe, but no fossil specimens are known in Asia (Willemsen 1992). It has also been suggested this species has an earlier origin; however, the majority of *L. lutra* specimens of Pleistocene age have been assigned to the extinct species *Lutra simplicidens*, based on differences in the dentition and postcranial skeleton (Willemsen 1992).

## FORM AND FUNCTION

The dental formula of *Lutra lutra* is i 3/3, c 1/1, p 4/3, m 1/2, total 36 (Larivière and Jennings 2009). Mean measurements (mm) of P4 (upper carnassial blade) from 7 adult specimens were: greatest length, 10.93; greatest width, 8.01; length of carnassial shearing blade, 5.79; and greatest length of lingual sulcus, 6.31. Mean measurements (mm) of M1 from 7 specimens were: length of buccal surface, 6.97; and greatest width, 10.62. Mean measurements of m1 (lower carnassial blade) from 7 specimens were: greatest length, 12.47; greatest width, 5.66; and length of carnassial shearing blade, 5.34 (Sealfon 2007). Bite forces calculated using the dry skull method are estimated to be 147.8 and 216.0 N at the canine and carnassial, respectively (Christiansen and Wroe 2007).

Ovarian follicle size for immature females, nonbreeding mature females, and breeding mature females were 1.0–1.6 mm (mean ± *SD* 1.30 ± 0.24), 1.2–2.6 mm (mean 1.72 ± 0.32), and 1.0–2.4 mm (mean 1.66 ± 0.36), respectively (Hauer et al. 2002). The largest follicular diameter in ovaries of estrous females measured 2.0 mm (Heggberget and Christensen 1994). The primary corpus luteum is derived from an ovulated follicle, and the corpus luteum verum is derived from the primary corpus luteum, which is functionally related to an implanted embryo (Heggberget and Christensen 1994). Corpus lutea can also be differentiated into thriving corpus lutea, which is affiliated with

embryo implantation (filling 75% of the ovary), and regressing corpus lutea, which is characterized by placental scars (filling at least 10% of the ovary—Hauer et al. 2002). Uterine horn lengths are 17–54 mm in immature females and 26–81 mm in mature females (Heggberget 1988). The left ovary (168 ± 22 mg) weighs more than the right (140 ± 16 mg—Heggberget 1988). Uterus lengths range from (mean ± *SD*) 45.1 ± 9.2 for immature females, 62.1 ± 18.1 for nonreproductive, and 65.1 ± 15.3 for reproductive females (Hauer et al. 2002).

*Lutra lutra* exhibits several adaptations to survive in cold environments, such as those in northern Europe and Asia, where water temperatures are usually below 20°C during the summer and close to 0°C during the winter (Kruuk et al. 1997). Fur serves as the primary thermo-insulating mechanism for *L. lutra* (Kruuk 2006). *L. lutra* exhibits hair density of about 70,000 hairs/cm² throughout the body that insulates and regulates internal body temperature by absorbing air (Kuhn et al. 2010). The majority of the coat is comprised of secondary hairs, whereas primary hairs make up only 1.26% of the coat; the coat composition is not influenced by sex or seasonal variation (Kuhn et al. 2010).

*Lutra lutra* displays continuous molting (Kruuk 2006; Kuhn et al. 2010). Grooming and drying occurs in undisturbed places which are associated with a trail, well-worn from rolling, leading from the water (Erlinge 1967). *L. lutra* regularly grooms after exiting the water to eliminate parasites by rubbing on the ground or shaking its fur (Kruuk 2006; Kuhn et al. 2010). Grooming time doubles in a sea water environment compared to when in a freshwater environment due to the interference of sea water with the ability to retain air in the fur underwater (Kruuk and Balharry 1990). In seawater, fur soaks up water rather than air, which is counterproductive for insulation, as the crystals stiffen guard hairs and result in the hair forming small bundles, which could interfere with the spread of lipid secretions from the skin glands (Kruuk and Balharry 1990).

*Lutra lutra* has a mean internal body temperature of 38.1°C, ranging from 35.9°C to 40.4°C (Kruuk et al. 1997). Upon entering cold water, individuals exhibited a body cooling rate of 2.3°C per hour (Kruuk et al. 1997). Infrared thermography revealed that *L. lutra* primarily dissipates heat through its feet rather than its trunk, with temperatures at the surface of the feet rising up to 20°C above the temperature at the surface of the trunk (Kuhn and Meyer 2009). Infrared thermography also revealed that the ears, peripalpebral region, and vibrissal pads remained consistently warm and never dropped below 15°C despite being in water temperatures as low as 4°C (Kuhn and Meyer 2009). Kuhn and Meyer (2009) suggest that high temperatures are maintained to ensure functioning of the sensory organs.

*Lutra lutra* exhibits a high basal metabolism compared to other mammals of similar sizes. On land, resting metabolic rate in *L. lutra* is 4.1 W/kg (38–48% higher than similar-sized terrestrial mammals), and in water, resting metabolic rate is 6.4 W/kg (Pfeiffer and Culik 1998; Kruuk 2006). Mean (± *SE*) energy expenditure during swimming ranged from 10.3 ± 3.3 W/kg at speeds of 0.5 m/s to 14.8 ± 4.5 W/kg at speeds of 1.5 m/s (Pfeiffer and Culik 1998).

*Lutra lutra* most often dives in shallow areas 0–3 m deep with a mean (± *SE*) descending velocity of 0.62 ± 0.02 m/s at an angle of 70° with respect to the surface (Nolet et al. 1993). An adult female *L. lutra* is estimated to swim at maximum speeds of 1.3–1.5 m/s when underwater and swim at about 0.26 m/s when searching for food (Nolet et al. 1993; Pfeiffer and Culik 1998). However, *L. lutra* prefers to swim at speeds of 0.89 m/s (Pfeiffer and Culik 1998).

## ONTOGENY AND REPRODUCTION

Young are mostly born during the summer and early autumn in northern Europe and during the winter and spring in southern Europe (Ruiz-Olmo et al. 2002). Young are born blind and covered in short gray fur and each weigh 100–120 g, measure 12 cm (Wayre 1979; Heggberget and Christensen 1994; Mason and Macdonald 2009). At 30–35 days old, young weigh 700–800 g and their eyes have opened (Mason and Macdonald 2009). By 2 months, young weigh 1,075–1,250 g and begin hunting and eating solid food (Ruiz-Olmo et al. 2002). *Lutra lutra* young stay in the den until 2–3 months of age, when they accompany their mother on their 1st fishing trips (Ruiz-Olmo et al. 2002). Young also begin to interact with other dyads, such as the occasion of feeding or playing together (Kruuk 1995). Rearing of young lasts until at least the age of 5–6 months, and the litter reaches independence by 9–12 months (Heggberget and Christensen 1994). Adult body size is reached by their 1st spring (Ruiz-Olmo et al. 2002), and sexual maturity is attained after 2–3 years (Mason and Macdonald 2009). Mortality of young is high, with 42% survival within the 1st year and 33% survival within the 2nd year; only 25% live longer than 2 years (Stubbe 1969; Jenkins 1980).

*Lutra lutra* is continuously polyestrous, with mating occurring throughout the year in England and Wales (Mason and Macdonald 2009). However, some populations—including Norway (Heggberget and Christensen 1994), Denmark (Elmeros and Madsen 1999), Shetland (Kruuk 1995), and Sweden (Erlinge 1968a)—exhibit breeding seasons coinciding with favorable climate conditions that generate greater prey availability (Liles 2000). Individuals of 6–9 years of age form the bulk of reproductively active females, followed by 10- to 15-year-olds and then 3- to 5-year-olds (Hauer et al. 2002). The frequency of ovulation and the frequency of pregnancy per mature female per year is 2.0 and 1.1, respectively (Heggberget and Christensen 1994).

Females are receptive 14 days during the 40- to 45-day estrous cycle (Wayre 1979). Gestation lasts 61–74 days, and peak birth occurs from late summer to late autumn during the months of August through November (Heggberget and Christensen 1994; Hauer et al. 2002). Two to 3 (mean ± *SD* = 2.5 ± 0.3) young are born per litter, with mean litter size slightly increasing with the mother's age (Hauer et al. 2002).

## ECOLOGY

***Population characteristics.***—Distribution of *Lutra lutra* is widespread across Europe and Asia, though population density

is uneven in these areas. In southern Sweden, population density is about 1 individual per 0.7–1.1 km$^2$ of water, 2–3 km of lake shore, and 5 km of stream (Erlinge 1968a). In Shetland, based on a stratified random sample survey, densities reach an estimated 1 adult per 1.2 km and a total of 718 adults with 392 resident females (Kruuk 2006). A survey conducted in the mid-1980s estimated 6,600 *L. lutra* in Scotland and 750 in England and Wales (Kruuk 2006). Using 8 radiotracked individuals along the Norwegian coastline, Heggberget (1995) estimated 0.4–0.6 individuals per km on islands and 0.1–0.2 individuals per km on the mainland for a total of 10,000–15,000 individuals in the area (Heggberget 1995).

In Germany, Norway, and mainland Shetland, subadults and adults comprise 8.5–33% and 14.0–43%, respectively, of the population, whereas juveniles represent 31.7–42.0% of the population (Ruiz-Olmo et al. 1998). Total mortality rates, which are correlated with body condition, culminate in November–December at 43.2% and decline to a minimum of 3.4%, in May–June (Ruiz-Olmo et al. 1998). Juveniles are the most susceptible age class to death, as 18.6% die before the age of 1 year (Kruuk 2006). The average life span is generally 12 years; however, a maximum of 16 years has been recorded in a single individual from the British Isles (Gorman et al. 1998). In Britain, a study on road mortality estimated a male:female sex ratio of 1.28:1 (*n* = 673—Philcox et al. 1999).

***Space use.***—*Lutra lutra* primarily lives in coastal or riparian habitats throughout Europe and Asia and parts of northern Africa. The home ranges of groups of female *L. lutra* extend 1–14 km linearly along the coast (Kruuk and Moorhouse 1991). Although individual *L. lutra* within the group shares home ranges, each individual spends the majority of its time within a 0.5–1.6 km core area. Home ranges of up to 19.3 km have been reported for males and oftentimes these overlap with female home ranges (Kruuk and Moorhouse 1991). In southern Italy, genotyped spraint analyses with a sample of 214 otter spraints identified at least 15 individuals within Pollino National Park (1,930 km$^2$ in area—Prigioni et al. 2006). Prigioni et al. (2006) estimated maximum watercourse usage ranged from 0.02 to 34.8 km between individuals. Genotyped spraint analyses suggest home ranges between up to 4–6 individuals partially overlap 0.02–14.1 km (Prigioni et al. 2006). In the Mediterranean climate of southern Portugal, *L. lutra* may use reservoirs for food and a constant water source, especially during the intense droughts of the dry season (Basto et al. 2011).

In Pertshire Scotland, 2 radiotracked adult females exhibited home ranges of 16 and 22.4 km of waterway, respectively, a single radiotracked adult male exhibited home ranges of 39.1 km of waterway, and 2 radiotracked subadult males exhibited home ranges of 20 and 31.6 km of waterway, respectively (Green et al. 1984). Individuals did not use all locations evenly (Green et al. 1984). In addition, individuals used a number of resting sites within their home ranges within a single 24-h period (Green et al. 1984). Traveling between resting sites usually occurred at night;

the 2 radiotracked adult females' longest distance traveled between resting sites were 3.8 and 8.9 km (mean distance traveled per night was 1 and 2.5 km), respectively, and the radiotracked adult male's longest distance traveled per night was 16.2 km (mean distance traveled per night was 3.8 km—Green et al. 1984).

*Lutra lutra* primarily utilizes a narrow strip of water along the shore for food and rarely ventures > 2 km away from the shoreline (Kruuk 2006). An observational survey of 500 dives off the coast of Shetland revealed that coastal *L. lutra* dives for food within 20 m of the shore 62% of the time, within 50 m 84% of the time, and within 80 m 98% of the time (Kruuk and Moorhouse 1991). *L. lutra* prefers to dive in shallow waters (0–3 m) and rocky intertidal areas where benthic prey are more abundant (Kruuk and Moorhouse 1990). A study of 2 captive *L. lutra* in Italy indicated a preference for water close to river banks covered by trees for hunting, swimming, or playing (Fumagalli 1995).

*Lutra lutra* may travel long distances, up to 20 km during the winter, to find shelter (Erlinge 1967). Throughout the year, *L. lutra* uses eutrophic coves for feeding sites, and fishing holes in frozen-over lakes during the winter (Erlinge 1967). Once the lakes are frozen, streams become its primary feeding area (Erlinge 1967). *L. lutra* tends to be more transient during autumn and spring and more residential during summer and winter (Erlinge 1968a).

Although most individuals spend their time foraging for prey in the water, they emerge on land to raise their young in holts, or dens. Depending on the location, different types of vegetation are more important in constructing holts (Macdonald and Mason 1983). Bedding includes heather (*Calluna vulgaris*), sea weed (*Ascophyllum nodosum*), and occasionally, plastic bags (Kruuk 2006). In Shetland, *L. lutra* prefers to make holts most commonly within peats that contain freshwater pools rather than areas with cliffs and agricultural plots (Kruuk 2006). Mature ash and sycamore trees are important for *L. lutra* in Wales and the West Midlands of England; bankside bramble (*Rubus*) and reef swamps are significant components in its habitat in Greece (Macdonald and Mason 1983). In southern Sweden, *L. lutra* uses burrows made by rabbits that are located close to water (Erlinge 1967). Natal holts are frequently further from the sea in unobtrusive entrances and are rarely marked by spraints (Kruuk 2006). *L. lutra* may dig a system of tunnels that reach up to 50 m in length and 0.5 m below the surface; it also uses tunnels created by erosion of soil, rock, or rabbit warrens (Kruuk 2006). Females with large young prior to dispersal tend to inhabit wider streams with rough waters and rich feeding areas, whereas females with small young select calm waters and the narrowest stretches of the stream (Ruiz-Olmo et al. 2005).

Some factors that limit the geographic distribution of *L. lutra* include prey abundance, available shelter, and human-induced influences. Natural factors that limit the spatial distribution of *L. lutra* include reproduction, birth, mortality, migration, and disease.

***Diet.***—The diet of *Lutra lutra* encompasses fish, amphibians, birds, small mammals, and aquatic invertebrates; however, diet composition is highly dependent on local prey abundance and availability (Kruuk 2006). In Europe, a clear latitudinal gradient in diet composition occurs, where the diet of northern European *L. lutra* is primarily piscivorous and that of Mediterranean *L. lutra* relies less on fish and more on aquatic invertebrates and reptiles (Clavero et al. 2003). Although the majority of northern *L. lutra* populations specialize on fish prey, some populations exhibit seasonal dietary variation. Along the Norwegian coast, *L. lutra* primarily eats fish (92.3% frequency of occurrence); spraint and stomach content analyses indicate that Gadidae (17.5%), Cottidae (12.8%), and *Pholis gunnellus* (12.4%) are the 3 top fish prey (Heggberget and Moseid 1994). In the Dee and Don rivers of Scotland, 95% of *L. lutra* spraint contained salmonids (*Salmo trutta* and *Salmo salar*), followed by the European eel (*Anguilla anguilla*—12%), and mammals (12%—Kruuk et al. 1993). Observations in Shetland found eelpout (*Zoarces viviparous*—34%), rocklings (*Ciliata*—17%), and sea scorpion (*Taurulus bubalis*—14%) are the most important prey species (Kruuk and Moorhouse 1990). In Portugal, *L. lutra* feeds mostly on small blennies (Blennidae), eels (*A. anguilla*), gobies (*Gobius*), rocklings (*Ciliata mustela* and *Guidropsarus*), wrasses (Labridae—Beja 1991). In Bialowieza National Park, Eastern Poland, carp species (Cyprinidae) comprise 49.7% of prey biomass during the spring and summer and the common frog (*Rana temporaria*) make up 65.8% of prey biomass in the autumn and winter (Brzezinski et al. 1993). In small watercourses in southwestern Hungary, *L. lutra* primarily eats fish (33.3–89.9% of total prey biomass), followed by amphibians (3.4–48.5—Lanszki et al. 2009); fish are eaten more in winter than in spring, whereas amphibian consumption is highest in winter and lowest in spring (Lanszki et al. 2009). In the Ebro Basin rivers of Spain, salmonids (*S. trutta*) and cyprinids (mainly *Barbus graellsi*, *B. haasi*, and *Chondrostoma toxostoma*) represent 85–100% of recorded prey items (Ruiz-Olmo 2007). However, the relative frequency of fish prey varies with elevation where *S. trutta* was the dominant prey at elevations > 500 m and cyprinids were the dominant prey at elevations < 500 m (Ruiz-Olmo 2007).

Dietary diversification of Mediterranean *L. lutra* may be correlated to the unpredictable prey availability in the Mediterranean, a region that is characterized by hot and humid summers with little surface water and irregular interannual precipitation and temperatures (Clavero et al. 2003). The irregular climate contributes to the fluctuations of droughts and floods that ultimately lead to unstable fish availability (Clavero et al. 2003). In Serra de Monfurado of southern Portugal, *L. lutra* diet varies seasonally, where American crayfish (*Procambarus clarkia*) and fruit are consumed in the dry season and fish (*Lepomis gibbosus*, *Gambuzia holbrooki*, and *Micropterus salmoides*) and amphibians are consumed during the wet season (Basto et al. 2011). In Doñana National Park, Spain, fish (*A. anguilla*, *Gambusia affinis*, and *Cobitis paludicola*) occur in 94.3% of spraint, followed by red-swamp crayfish *Procambarus* (80.3%), insects (32.3%),

amphibians (28.1%), and reptiles (7.2%—Adrian and Delibes 1987). In Morocco, *L. lutra* mainly eats fish (76% of frequency of occurrence), amphibians (22%), and insects (8%—Broyer et al. 1988). Spraint analysis of *L. lutra* associated with the Jajrood River in Iran revealed that *L. lutra* mainly feeds on fish, preferring *Leuciscus cephalus*, *Alburnoides bipunctatus*, and *Capoeta* (Mirzaei et al. 2014). Seasonal variation in prey availability induces more feeding on birds during the cold season and more insects during the warm season, although the proportion of crab consumed remained constant throughout the year (Mirzaei et al. 2014).

Diet of Asian *L. lutra* populations is not as well known. In Sri Lanka, spraint analyses show *L. lutra* feeds on freshwater crabs *Potamon* (81.2% of occurrence), fish (37.5%), and frogs (8.7%—Silva 1996). Diet of *L. lutra* from the Huay Kha Khaeng River, Uthai Thani Province, Thailand, is composed of fish (76% of spraint), amphibians (64%), and small mammals (11%—Kruuk et al. 1994). Medium (10–15 cm in length) fish are preferred—accounting for 51% of total consumed fish—followed by small (< 10 cm) fish (34%) and large (> 15 cm) fish (14%—Kruuk et al. 1994). Females taking care of young bring back larger prey to their young but consume smaller prey themselves (Kruuk 2006).

*Lutra lutra* dive with a tail-flip in areas usually less than 50 m from the shore and less than 8 m deep and bring their prey one at a time back to the surface of the water to finish eating, with dives lasting up to 96 s (Nolet et al. 1993). Hunting usually occurred in periods of about 13.7 min interspersed with grooming and resting (Nolet and Kruuk 1989). *L. lutra* brings prey to land if difficult to manage, such as when eating sea scorpions or crabs. Though young oftentimes dive with their mother, *L. lutra* seldom exhibits cooperative fishing (Kruuk 2006).

***Diseases and parasites.***—Diseases of wild *Lutra lutra* populations are poorly understood due to limited examination by veterinary pathologists. In South West England, adiaspiromyocis, which is caused by inhaling the fungus *Emmonsia*, was the most common infectious disease that *L. lutra* exhibits (Simpson 2000). Adrenocortical nodular hyperplasia is also commonly found in *L. lutra* and is attributed to stress (Simpson 2000). Other recorded conditions include Aleutian disease, arteriosclerosis, arteritis, distemper virus, hepatic adenocarcinoma, leiomyoma, renal calculi, *Salmonella* infection, and tuberculosis (Keymer et al. 1988; Wells et al. 1989; Madsen et al. 2000; Simpson 2000).

*Lutra lutra* is susceptible to endoparasites such as nematodes (*Angiostrongylus vasorum*, *Anisakis*, *Aonchotheca putorii*, *Cryptosporidium*, *Eucoleus schvalovoj*, *Dirofilaria immitis*, and *Strongyloides lutrae*), protozoans (*Giardia* and *Gigantorhynchus*), and trematodes (*Phagicola*—Madsen et al. 2000; Torres et al. 2004; Méndez-Hermida et al. 2007).

***Interspecific interactions.***—The distribution range of *Lutra lutra* overlaps with the invasive American mink (*Neovison vison*) in several regions across Europe and Asia (McDonald 2007). In contrast to what is normally associated with invasions, native *L. lutra* appears to regulate invading American

mink populations (Bonesi and Macdonald 2004a, 2004b). Increased populations of *L. lutra* lead to decreased population size and distribution range of American mink through food theft (Bonesi et al. 2000), direct aggression (Simpson 2006), and dietary competition (Clode and Macdonald 1995; Bueno 1996; Bonesi and Macdonald 2004a). In locations where the 2 species are sympatric, American mink altered its diet from predominately aquatic prey (e.g., Anguillidae and Gadidae) to more terrestrial prey (birds and mammals), whereas *L. lutra* maintained its primarily piscivorous diet (Clode and Macdonald 1995; Bueno 1996; Melero et al. 2008). There are no known natural predators to adult *L. lutra*.

In Southeast Asia, *L. lutra* occurs sympatrically with the smooth-coated otter, and the Asian small-clawed otter. Direct competition may be minimized due subtle differences in resource use and prey specialization. Although *L. lutra* and the smooth-coated otter both feed on fish, *L. lutra* exhibits a relatively more generalist diet and consumes amphibians and small mammals, whereas the smooth-coated otter exhibits a more piscivorous specialized diet and typically feeds on larger fish than *L. lutra* (Kruuk et al. 1994). In addition, *L. lutra* dominates more rapid-flowing rivers, whereas the smooth-coated otter occurs more frequently in slow meandering rivers (Kruuk et al. 1994). The Asian small-clawed otter, on the other hand, is predominantly a crab specialist and inhabits shallower bodies of water such as rice fields (Larivière 2003). Lastly, very little is known about the smooth-coated otter because of low population numbers and its rather elusive nature; thus, interspecific interactions between *L. lutra* and the smooth-coated otter are virtually unknown (Wright et al. 2008).

## HUSBANDRY

Zoos worldwide hold *Lutra lutra* in captivity for the purpose of public education and breeding. Captive breeding success of *L. lutra* was initially very low until the Otter Trust successfully raised a litter of *L. lutra* young in 1972 (Sivasothi and Nor 1994). Beginning in 1985, the European breeding program for self-sustaining captive populations (Europaisches Erhaltungszucht Programm) has successfully bred many *L. lutra* individuals and reintroduced them back to the species' once degraded habitats (Vogt 1995). Full husbandry and management guidelines can be found in the Europaisches Erhaltungszucht Programm's *Eurasian Otter* Lutra lutra, *Husbandry Guidelines, EEP/ Studbook for* Lutra lutra (Melissen 2000) as well as International Union for Conservation of Nature and Natural Resources Otter Specialist Group's *Summary of Husbandry Guidelines for the Eurasian Otter in Captivity* (Heap et al. 2010).

## BEHAVIOR

***Grouping behavior.***—*Lutra lutra* is generally described as territorial and solitary (Erlinge 1968a), and its shyness and sensitivity to human disturbances make behavioral studies difficult (Kruuk 1995; Garcia de Leaniz et al. 2006). *L. lutra* primarily exhibits intrasexual territorial behaviors (Erlinge 1968a; Ó Néill et al. 2009), and individual territories of the same sex rarely overlap (Erlinge 1968a; Quaglietta et al. 2014). In a study of 84 *L. lutra* interactions, 11% of these interactions were between males, 27% between females, 40% between male and female, and 21% between individuals of unknown sex (Kruuk and Moorhouse 1991).

Male territories are much larger than female territories (Ó Néill et al. 2009). In Ireland, mean (± *SD*) male territories was 13.2 ± 5.3 km with aquatic ranges of 30.2 ± 9.5 ha, whereas mean (± *SD*) female territories was 7.5 ± 1.5 km with aquatic ranges of 16.8 ± 7.0 ha (Ó Néill et al. 2009). A hierarchy exists among *L. lutra*, where dominate males obtain the best home ranges in the area and possibly encroach on the territories of other individuals while the subdominant males occupy less preferable areas (Erlinge 1968a). On rare occasions, interactions that occur between 2 male individuals result in aggressive behaviors with physical contact (Kruuk and Moorhouse 1991). Aggression between males involved fast-speed chases and high-pitched "wickering" and often resulted in the fleeing of the losing individual (Kruuk and Moorhouse 1991; Kruuk 1995). The results of aggressive encounters are dependent on body size, where smaller individuals usually portrayed a defensive posture or avoided larger conspecifics (Kruuk and Moorhouse 1991). Although scent and sound play a prominent role in communication, visual displays of males patrolling their territory and sprainting at certain sites, and swimming in a conspicuous manner parallel to the shore, 5–10 m out in the water (Kruuk 1995). Males expand their home range upon the death of neighboring male individuals (Ó Néill et al. 2009).

In contrast, interactions between female *L. lutra* are met with avoidance and "chittering" vocalization; aggression with physical contact was rare (Kruuk and Moorhouse 1991). Females within the same home range also exhibit playful behavior, such as making slides in the snow during winter (Wayre 1979).

Interactions between males and females vary from avoidance and defensive postures to friendly play (Kruuk and Moorhouse 1991). Females with young are territorial and aggressive toward adult males because of infanticide risk (Kruuk 1995; Simpson and Coxon 2000). However, males occasionally force a family group consisting of mother and young to relocate to another area (Erlinge 1968a). Recent investigation of sociospatial organization suggests that *L. lutra* may be more social than once believed (Quaglietta et al. 2014). Individuals of opposite sexes spent much time together resting, rearing young, and playing rather than merely converging to forage in high-density prey patches (Quaglietta et al. 2014).

***Reproductive behavior.***—Home ranges of adult males and females with young may overlap, suggesting a polygynous and polyandrous mating system and intrasexual territoriality (Mason and Macdonald 2009; Quaglietta et al. 2014). Male-biased dispersal also supports the possibility of polygynous mating systems (Quaglietta et al. 2013). Courtship involves play and mock fights both in the water and on land (Wayre 1979). In Shetland,

*Lutra lutra* mating occurs in the water and during the months of February until the end of May (Kruuk 2006). Although *L. lutra* is able to breed throughout the entire year, mating typically occurs when food is maximally available (Ruiz-Olmo et al. 2002). *L. lutra* in Britain are thought to breed once a year (Mason and Macdonald 2009), whereas it has been suggested the females can breed only every 2 year in Sweden (Erlinge 1968a). Estrus and subsequent mating can occur when young become grown and fully independent (Simpson and Coxon 2000). Females reach sexual maturity at 2 years of age and stay in breeding condition until 15 years of age (Hauer et al. 2002).

Litter size can range from 1 to 5, but females generally produce small litters of 1–2 young (Hauer et al. 2002; Ruiz-Olmo et al. 2011). Higher litter sizes are associated with thriving corpora lutea while lower litter sizes correlated with less implanted embryos and less appearances of placental scars, an indicator of giving birth to young (Hauer et al. 2002).

Females with young prefer their personal space and tend to stay outside of other females' home ranges, defending their own core areas (Kruuk and Moorhouse 1991; Kruuk 1995). Although mating pairs spent a few days together before and then after mating, the male plays little part in raising young, and females often turn aggressive toward males (Mason and Macdonald 2009). Males are kept away from the young by females because males may exhibit cannibalistic behavior toward unrelated young (Simpson and Coxon 2000). The suspected reason for this behavior is that males are interested in increasing their own reproductive fitness; killing young sired by another male would force the female into estrus, giving the male a chance to mate (Simpson and Coxon 2000).

*Communication.*—*Lutra lutra*, like most other lutrinids, uses spraints, small amounts of feces deposited at conspicuous vantage point, to claim an area along a strip of land for the purposes of foraging for food as well as to mark and signal entrances to holts or dens (Erlinge 1968a). A high amount of marking occurs when there is a high population density within an area (Erlinge 1968a). Some postulate that *L. lutra* spraints are used for signaling breeding status or maintaining territory boundaries (Kruuk 2006). However, an observational study in Shetland found no significant differences in sprainting rates between otters of different sex or status (Kruuk 1992). In addition, sprainting rates were not significantly different between territory boundaries and within the territory (Kruuk 1992). Instead, Kruuk (1992) suggests that sprainting is used to communicate food resources on a seasonal basis. Positive correlations between the percentage of spraints next to pools of water with high volume of prey items suggest that territory owners concentrate scent marks on key resources to drive potential competing conspecifics away (Kruuk 1995; Remonti et al. 2011). More than 30% of spraints occurred in the intertidal area, and thus the incoming tides limited the function of its communication for only a short time (Kruuk 1992). Furthermore, sprainting was seasonal, with high rates (10 times greater) coinciding with low prey availability during the winter compared to the summer (Kruuk 1992).

Vocally, the mother communicates with her young through whistling (Gnoli and Prigioni 1995; Kruuk 2006).

This melodious whistle is a common call that can carry over hundreds of meters (Kruuk 1995). Whereas a loud whistle is used at a distance to express uneasiness between a mother and its young, a feeble whistle, defined as a contact call at close range between 2 individuals, is used between 2 pups (Gnoli and Prigioni 1995). Similarly, a low cooing sound, described as a murmur, is emitted at close contact interpreted as a greeting exhibited between mother and young after a short period of separation (Gnoli and Prigioni 1995). When alarmed by humans or perhaps a predator, *L. lutra* exerts a "huff" sound with a quick exhalation of air or a noisy "blow" sound, with a frequency of 0–10 kHz (Kruuk 1995). Other, vocal calls include "wickering", which may occur when alarmed by an intruder on its territory, and the cat-like "caterwailing" when cornered during a fight (Kruuk 1995). Aggressive cries, which are characterized with frequencies higher than 16 kHz, may also occur when quarreling for food or territory, oftentimes uttered at close range of less than 1 m or during physical contact (Gnoli and Prigioni 1995).

*Miscellaneous behavior.*—*Lutra lutra* swims with only its eyes and some of its back showing above the surface of the water (Kruuk 2006). While swimming at the surface, *L. lutra* paddles with all 4 feet to keep afloat and uses the tail as a rudder (Wayre 1979). To dive, *L. lutra* flexes its body and propels down using 2–3 kicks with its hind feet (Wayre 1979).

Hunting bouts occupied a mean time of 13.7 min, with resting bouts averaging 17.0 min, grooming time 9.1 min, and sleep 6.6 min (Nolet and Kruuk 1989). Although diving behavior does not differ with depth, metabolic costs are greater at low temperatures, because *L. lutra* tends to dive for longer periods of time at shallow depths and shorter times at deeper depths (Nolet et al. 1993). During a dive, *L. lutra* swims toward the bottom of the river and then moves upward to attack its prey from below with an element of surprise (Wayre 1979).

*Lutra lutra* eats the head of fish first to quickly kill and consume the prey in a seemingly fixed action pattern (Erlinge 1968b). Young *L. lutra* spend much time playing with their prey before eating it, following fish at a distance of 0.2–0.3 m (Erlinge 1968b). *L. lutra* prefers live to dead prey and slower moving prey to fast-moving; however, hungry individuals will eat anything available, including dead fish (Erlinge 1968b).

*Lutra lutra* living in freshwater habitats tends to be more nocturnal than coastal individuals (Beja 1996; Karamanlidis et al. 2014). Depending on its prey's lifestyle, *L. lutra* is active during the opposite time of day so they can more easily prey on the animals in torpor (Kruuk and Moorhouse 1990). For example, important prey for *L. lutra* that are active during the night, but hide under rocks during the daytime, are vulnerable to hunting during the day (Kruuk and Moorhouse 1990).

## GENETICS

Despite being widely distributed in Europe, *Lutra lutra* populations exhibit low genetic variability. Network analyses using mitochondrial DNA (mtDNA) found no signal of phylogenetic

structuring despite high haplotype diversity (0.79 ± 0.037 *SD*—Mucci et al. 2010). Low nucleotide diversity (0.0014 ± 0.00012 *SD*) and average number of pairwise differences (2.25) suggest that extant *L. lutra* mtDNA lineages originated recently (Mucci et al. 2010). Autosomal microsatellites reveal moderate genetic diversity across European populations (Randi et al. 2003; Mucci et al. 2010). The average observed heterozygosity was ($H_o = 0.50$) with the lowest observed heterozygosity in Denmark ($H_o = 0.35$) and highest observed heterozygosity in Belarus, Finland, Latvia, and Sweden ($H_o > 0.65$) (Mucci et al. 2010). Furthermore, there was no evidence for geographical distribution within these European populations (Mucci et al. 2010).

*Lutra lutra* populations in Israel are genetically unique from European populations, indicating limited or absent gene flow between the 2 localities (Cohen et al. 2013). Similarly to European *L. lutra* populations, observed heterozygosity in Israeli *L. lutra* was moderate ($H_o = 0.482$—Cohen et al. 2013). Genetic diversity in other Asian *L. lutra* populations is poorly studied.

Because *L. lutra* is an elusive species that is hard to capture, noninvasive genetic monitoring from hair and feces can use DNA as a molecular "tag" to track the efforts of reintroduced populations (Mucci and Randi 2007; Seignobosc et al. 2011). Accounting for time, estimations of survival and reproduction rates may be able to predict how much mortality a population tolerates (Seignobosc et al. 2011).

Phylogenetic analyses using mitochondrial and nuclear DNA demonstrated that the genus *Lutra* consists of only *L. lutra* and *Lutra sumatrana* (Koepfli et al. 2008). *Lutra*, in turn, is sister to a clade containing *Aonyx* and *Lutrogale* (Koepfli et al. 2008).

## CONSERVATION

*Lutra lutra* is listed as "Near Threatened" by the International Union for Conservation of Nature and Natural Resources since 2004 (Roos et al. 2015) and under Appendix I by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES 2016). Additionally, *L. lutra* is protected by several European and Asian governments such as Appendix II of the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention 2016) and Wild Animals Protection Ordinance Cap 170 in Hong Kong (Wild Animals Protection Ordinance 2016).

During the 2nd half of the 20th century, many *L. lutra* populations in several European and Asian countries sharply declined due to hunting and pollution (Mucci et al. 2010). *L. lutra* was hunted for its prized pelt or for sport (Conroy et al. 2000). In addition, *L. lutra* was persecuted for being a nuisance to fisherman, eating fish and playing in rice fields, which resulted in profit loses for farmers (Rasooli et al. 2007). In Europe, contaminants such as polychlorinated biphenyl (PCB) severely diminished the population of *L. lutra* (Mason and Macdonald 1993).

Major threats to current populations of *L. lutra* are pollution and habitat alterations (Mucci et al. 2010). Originally, misled theories hypothesized that the steep *L. lutra* population decline in the 2nd half of the 20th century was caused by competition with the America mink. However, it is now well established that organochlorine pollution that peaked before the mink's arrival brought about *L. lutra* population decline (McDonald 2007). Organochlorines dieldrin (HEOD) and DDT/DDE, PCBs, and mercury are the main pollutants that pose a danger to *L. lutra* in western and central Europe (Roos et al. 2015). An average of 80 mg/kg of DDT, a substance that causes neuronal damage, was found in the bodies of *L. lutra* in Spain (Ruiz-Olmo et al. 2002). Bioaccumulation of organochlorines and heavy metals has also indirectly damaged *L. lutra* by harming its prey (Mucci et al. 2010). *L. lutra* is sensitive to pH changes in the water, with acidification affecting the carrying capacity in the area, and requiring large numbers of lakes and fjords for breeding uses (Madsen and Prang 2001). Anthropogenic habitat alterations—including mining, construction of river canals, dams, and aquacultures, and habitat degradation through drainage of wetlands and removal of—are all detrimental to *L. lutra* populations (Mucci et al. 2010). Lastly, *L. lutra* is occasionally accidentally caught in traps and cages meant for other species such as muskrats (*Ondatra zibethicus*) as well as hit by vehicles on the road (Madsen and Prang 2001).

Population surveys and monitoring through analyses of scat, spraint, and genetics have been conducted over most of Western Europe and in parts of Asia (Roos et al. 2015). These sampling efforts play a huge role in determining the status of *L. lutra* populations. Since the establishment of environmental protection efforts in 1974, the population in Europe has rebounded in many European countries including Britain (Crawford 2010), Denmark (Elmeros et al. 2006), France (Janssens et al. 2006), Germany (Honnen et al. 2011), northwestern Greece and Corfu Island (Ruiz-Olmo 2006; Karamanlidis et al. 2014), Italy (Marcelli and Fusillo 2009), Portugal (Trindade 1994), Spain (García Diaz 2008), Slovakia (Urban et al. 2011), and Sweden (Roos et al. 2012). However, although *L. lutra* are protected several governments and organizations, the improvements are at best minimal because of their unprotected habitat areas in remaining countries (Mucci et al. 2010). Pollution and exploitation of land areas diminish the ability of *L. lutra* to rebound in numbers (Sivasothi and Nor 1994). *L. lutra* continues to face the same problems in multiple countries and it is highly endangered or nearly extinct in countries such as Morocco, Austria, Slovenia, Poland, Tajikstan, and Uzbekistan; it is considered extinct in Albania, Slovakia, Hungary, Belarus, Romania, Bulgaria, Kazakhstan, Andorra, Luxeumbourg, and Switzerland (Conroy et al. 2000).

## ACKNOWLEDGMENTS

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