

Jacqueline Schwergold

**Growth study of *Enhydra lutris kenyoni* at the
Oceanário de Lisboa**



UNIVERSIDADE DO ALGARVE

Faculdade de Ciências e Tecnologia

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Mestrado em Biologia Marinha

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Declaro ser a autora deste trabalho, que é original e inédito. Autores e trabalhos consultados estão devidamente citados no texto e constam da listagem de referências incluída.

Jacqueline Schwergold

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Resumo

A lontra-marinha-do-Norte (*Enhydra lutris lutris* e *Enhydra lutris kenyonii*) é um mamífero marinho que habita em águas frias do Oceano Pacífico desde a Rússia até ao Alasca e a costa de Washington. Pode-se diferenciar da lontra-marinha-do-Sul (*Enhydra lutris nereis*) devido à cor da pelagem, forma do crânio e na área de distribuição, já que estas vivem unicamente na costa da Califórnia. Contrariamente a outros mamíferos marinhos presentes em habitats similares, as lontras marinhas não apresentam uma camada de gordura, mas uma muito densa pelagem que as protege da perda de calor corporal. Adicionalmente, as lontras desenvolveram um metabolismo que pode ser até três vezes superior ao de mamíferos terrestres de tamanho semelhante. Para poderem manter o seu calor corporal, as lontras marinhas precisam de ingerir cerca de 25% do seu peso corporal em alimentos, em cada dia. Para isso, estes animais alimentam-se de presas com alto valor calórico, entre as quais estão o caranguejo, o polvo, as estrelas-do-mar, o ouriço-do-mar e pequenos peixes. Estes mamíferos marinhos habitam perto das costas, em lugares protegidos dos temporais e com acesso a alimento ou então em florestas de Kelp, algas marinhas presentes no Oceano Pacífico que servem de refúgio para as lontras e para as suas presas. Neste ecossistema, as lontras são a espécie-chave que mantém o equilíbrio nestas florestas. As lontras foram caçadas durante muitos anos até quase à sua extinção devido ao valor da sua pelagem durante os séculos XVIII e XIX. Também foram sujeitas a eventos de “bottleneck”, captura com redes de pesca e intoxicações que reduziram o número de indivíduos e a diversidade genética das populações. Por esta razão, promoveram-se estudos sobre estes animais sociais para assim se poder conhecer a sua biologia e desenvolver projetos de recolonização em distintos lugares. Com estes estudos, os investigadores chegaram à conclusão que é muito importante estudar lontras em aquários para a sua conservação. No presente trabalho, que foi desenvolvido no Oceanário de Lisboa, estudámos lontras de distintas instituições concentrando-nos na sua alimentação, nos padrões de crescimento e no metabolismo. O estudo foi desenvolvido para os primeiros 2500 dias de vida (aproximadamente, sete anos) já que depois deste período, as lontras são consideradas adultas e terminam a fase de crescimento. O crescimento neste período foi dividido em três etapas distintas. A primeira contém os primeiros 500 dias de vida; a segunda entre os 500 e 1500 dias e a terceira entre os 1500 e 2500 dias. Na primeira fase, o crescimento linear é muito parecido para todos os indivíduos durante os primeiros três meses. Os machos apresentam um crescimento de

cerca de 37,4 gramas por dia e as fêmeas crescem 39,4 gramas por dia. Na segunda fase, o crescimento é muito menos pronunciado e quase se estabiliza para as fêmeas (4,5 gramas por dia), enquanto que os machos apresentam um crescimento que se ajusta mais a uma curva logarítmica. Na última fase, as fêmeas alcançaram a assíntota e apresentam uma taxa de crescimento inferior comparativamente à fase anterior (3,5 gramas por dia) e os machos continuam a crescer até alcançar a sua assíntota. As fêmeas podem alcançar um peso médio máximo de 25 Kg, com cerca de 1000 dias de vida. Depois disto, o crescimento ponderal estabiliza-se, pois foi alcançada a assíntota de crescimento. Os machos alcançam um máximo superior e que pode chegar até os 35 Kg, mas isto acontece mais lentamente e mais tarde do que nas fêmeas. A assíntota é alcançada cerca dos 1800 dias de vida, mais de dois anos mais tarde do que as fêmeas. Um segundo estudo foi efetuado para analisar as diferenças no metabolismo entre dois lontras fêmeas do OdL. Assim, encontramos que os animais que apresentam uma taxa metabólica alta podem precisar de ingerir uma maior quantidade de alimento para manter um peso inferior enquanto que as lontras com uma taxa metabólica inferior apresentam um peso inferior, mas comem uma maior quantidade de alimento, o que foi observado nas fêmeas Maré e Micas do Oceanário de Lisboa (OdL). A primeira precisa de ingerir uma maior percentagem de comida (14,33%) para manter um peso inferior (21,02 Kg de média no ano 2020) do que a Micas ingeriu um 11,58% de comida para manter uma média de peso no ano 2020 de 27,26 Kg. A análise estatística demonstrou que existe uma diferença significativa entre o crescimento dos machos e das fêmeas e entre Maré e Micas no estudo do metabolismo pois nos dois casos, as barras de erro nos gráficos de caixas não se sobrepõem. O presente projeto devia constar de cinco meses de atividade prática nas instalações do Oceanário de Lisboa, de modo a desenvolver aprendizagem sobre preparação das refeições, participação nos treinos diários, nas tarefas de alimentação das lontras e na obtenção informação sobre lontras de outras instituições. No entanto, devido à situação sanitária atual, apenas foi possível desenvolver trabalho no OdL durante o mês de fevereiro 2020. Por esta razão, demorou mais tempo do que o previsto a terminar o trabalho pois o Oceanário ficou fechado algum tempo e foi mais complicado tratar os dados. Ainda assim, com a ajuda do pessoal do OdL foi possível ter acesso aos dados das outras lontras que foram estudadas e fomos capazes de obter os dados apresentados nesta tese. Com este trabalho, estabelecemos as primeiras diretrizes para a criação e manutenção da lontra-marinha-do-Norte em condições controladas de modo a manter as condições adequadas de bem-estar animal e que se deverão aproximar, o mais parecido

possível, das condições observadas em meio natural. No entanto, importa promover estudos adicionais sobre este tópico. Por exemplo, será importante estudar os efeitos que tem a lactação nas fêmeas e da castração dos machos no crescimento das lontras-marinhas-do-Norte assim como os padrões de crescimento em lontras de idades mais avançadas. Este trabalho poderá ser útil tendo em vista a sua utilização noutras instituições que acolham lontras-marinhas-do-Norte nos seus aquários, já que terão acesso a toda a informação sobre condições para o seu bem-estar, entre os quais estão a alimentação, os treinos, os padrões de crescimento e a temperatura da água.

Abstract

The Northern sea otters (*Enhydra lutris lutris* and *Enhydra lutris kenyoni*) are marine mammals that inhabit cold waters of the Pacific Ocean from Russia to Alaska and the coast of Washington. Contrary to other marine mammals present in similar habitats, sea otters do not present a fat layer, but a very dense fur that protects from body heat loss. They also have developed a metabolism that can be up to three times higher than that of land mammals of similar size. Sea otters were hunted for several years almost to extinction due to their fur and experienced bottle neck events that reduced the number of individuals and the genetic diversity of the populations. For this reason, several biologists started to study these social animals in order to understand their biology and developed recolonization projects. In this thesis, we studied otters from different institutions focusing on their feeding and growth patterns. Results indicated that females reach weights up to 25 Kg in average with around 1000 days of life, after which the growth stabilizes as they approach the asymptotic weight. On the other side, males attain higher weights of up to 35 Kg but later than females (the asymptote is approached around the 1800 days of life). The results also showed that some differences between the individuals can be due to differences in metabolism: individuals with a higher metabolic rate need to ingest a bigger amount of food to maintain a lower body weight than otters that have lower metabolic rates. This was observed between the females Maré and Micas present at the Oceanário de Lisboa. The statistical analysis demonstrated that there was enough difference between males and females in the growth study and between Micas and Maré in the metabolic study. As a result of this investigation, the first guidelines on how Northern sea otter should be raised in aquariums have been established. However, some complementary information is still necessary and future studies should focus, for example, on how lactation and castration affects feeding.

Key words: sea otter; growth rates; aquarium-maintained; feeding; calories.

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Introduction

Sea otter's biology

Sea otters, *Enhydra lutris* (Linnaeus, 1758), are marine mammals living in cold waters of the Pacific Ocean (Estes, 1980; Benz, 1982; Anderson *et al.*, 1996; Cronin *et al.*, 1996) where they occur together with *Lontra canadensis* (Kruuk, 2006). The species includes three subspecies: *Enhydra lutris lutris* (Linnaeus, 1758); *Enhydra lutris nereis* (Merriam, 1904) and *Enhydra lutris kenyoni* Wilson, 1991.

Sea otters are very susceptible to hypothermia as water conducts heat 25 times faster than air. According to Kruuk (2006), they live on a knife-edge regarding their energetical exchanges. To prevent important heat loss, these animals have developed two strategies. The densest fur of any mammal (Tarasoff, 1973; Costa and Kooyman, 1982; AZA, 2019) that is more efficient than the fat layer present in other marine mammals, and a very high metabolism that helps them to maintain their body temperature. Thanks to these adaptations they can survive to the cold temperatures of the oceans they inhabit. The fur, composed of scarce guard hairs and a dense underfur (Estes, 1980) prevents the water penetration to the skin (Tarasoff, 1973). This isolation is maintained thanks to grooming and a hard work of maintaining the air trapped into the hairs during most part of the day. The fur is composed of pelage units. Each pelage unit is composed of a guard hair, 70 underfur hairs, one sweat gland and two sebaceous glands (Estes, 1980). Thermoregulation depends upon efficient insulation and increased metabolism (Costa and Kooyman, 1982). This particular skill of being able to regulate the production of heat is called mogenesis (Cortez *et al.*, 2016).

Sea otters present a metabolic rate that is two to three times higher than terrestrial mammals of similar size. For that, they need to consume, on a daily basis, circa 25% of their body size in high caloric food (Kenyon, 1969; Jessup *et al.*, 2004; Pearson *et al.*, 2005; Kruuk 2006; Gilkinson *et al.*, 2011). Thanks to this ability, they can spend most part of their life in the water, where they eat, rest and hunt for several hours.

The North Pacific Ocean is an adequate habitat for sea otters since there are no disturbances and there is enough space and food for the development of sea otter populations (Estes, 1990). The first experimental translocation of individuals of *Enhydra lutris* were made in this ocean, in 1951.

As they live near the coast, in habitats with a high food availability, conflicts with the shellfish industry might occur as they can devastate huge populations (Garshelis *et al.*, 1986). For this reason, populations of sea otter must be controlled and managed. As mentioned above, sea otters inhabit coastal waters. Thus, the presence of deep channels between the islands, where they cannot find food, may contribute to preventing the populations dispersion (Kenyon, 1969; Gorbics and Bodkin, 2001). Nevertheless, sea otters can swim long distances (over 400 Km) to colonize new suitable habitats (Gallo-Reinoso and Rathbun, 1997; Larson *et al.*, 2012).

Enhydra lutris kenyoni

The subspecies *Enhydra lutris kenyoni*, commonly referred as the Alaska sea otter (Brennan and Houck, 1996), can be found in habitats with cold water and high abundance of prey: the Aleutian Islands, north to Pribilof Islands, eastern Pacific Ocean from Alaskan Peninsula and along the coast of Oregon. (Benz, 1982; Anderson *et al.*, 1996; Pizarro, 2014). The Northern and Southern limits are established by temperature as sea otters do not occur in habitats where the sea water temperature is higher than 22 °C (Estes, 1980).

After hunting and extermination of different populations, reintroduction works have been carried out in southeastern Alaska, British Columbia, Washington, the Pribilof Islands and Oregon. Nevertheless, most of the translocations failed due to a lack of knowledge on the otter's biology (Kenyon, 1969). The first successful recolonization was made in 1956 at the Pribilof Islands. The success of the translocations depends on the number of otters that are translocated (a minimum of thirty otters is necessary to have positive results); a low post-release mortality (natural or human induced); the reproductive success (in order to ensure the replace of old individuals and the growth of the population); the emigration rates and finally, the suitability and quality of the habitat that was chosen for the colonization (these marine mammals present a high affinity for a particular home range) (Jameson *et al.*, 1982). In a study on the sea otters of Mexican waters, Gallo-Reinoso (2013) concluded that entanglements with fishing nets make reintroductions difficult and this fact can be extended also for the north American otters.

It is possible to differentiate this subspecies from the other *Enhydra lutris* thanks to the following characteristics. The subspecies *E. l. kenyoni* is characterized by longer mandibles and they present a prominent frontal notch. Their colors vary from brownish

mixed with black presenting a paler color from the neck and all over the head. Older individuals can present a grizzled appearance thanks to the presence of sparse hairs of dark or silvery grey. (Wilson *et al.*, 1911; Kirkpatrick *et al.*, 1955; Estes, 1980).

Schuler *et al.* (2018) established that sea otters of *E. l. kenyoni* must be considered as subadults when they reach the first year of life and become adults when they attain the sexual maturity. Pizarro (2014) established that sexual maturity is attained when body size is greater than 80 cm and Kruuk (2006) pointed out that females reach sexual maturity at age 4-5 years old. They normally give birth to a single pup as the newborns require lots of attention and care from their mothers. When a female sea otter gives birth to twins, normally only one will survive (Estes, 1980). An adult male can weigh between 21.80 Kg and 45 Kg (maximum recorded) and sizes of 148 cm of body length whereas females weigh between 14.5 Kg and 32,7 Kg and 140 cm of body length (Estes, 1980; Peigné *et al.*, 2008).

Thanks to its morphology, *Enhydra lutris kenyoni* is the most adapted of the otters to live in sea water as it is the only species that spends its entire life in the water and drinks sea water (Kruuk, 2006). Contrary to other otter species, they use the hind paws and undulatory movements of their body to swim (Tarasoff, 1973; Peigné *et al.*, 2008). They belong to rocky shores and kelp beds where they can find protection and food (Benz, 1982; Kruuk, 2006; AZA, 2019). They present a very dense pelage in the hind feet with dark and very vascularized skin that prevents heat loss. These characteristics also allow thermal absorption by direct solar radiation (Tarasoff, 1973).

Food web

Sea otters of the subspecies *E. l. kenyoni* are included in a food web where they represent a keystone species (Figure 1) (Jessup *et al.*, 2004; Fisheries and Oceans Canada, 2014) as predators that are directly related to the presence and abundance of sea urchins that control the abundance of kelp (Estes, 1980; Kruuk, 2006). Due to this relationship, when benthic communities are reduced due to environmental disorders sea otters die or need to move to a suitable habitat with enough food (Voronov, 1969). The top-down effects of sea otters in the food web can cross several trophic levels and attain apex predators like the Bald eagle (*Haliaeetus leucocephalus*), that hunt sea otter pups, and fishes living in kelp forests. These fish species can only grow when sea otters are present in the

ecosystem, as they eat the sea urchins that can end up with a whole kelp forest (Anthony *et al.*, 2008).

After a decrease of an otter population, massive increases of benthic communities were observed. These include clams, crabs, sea urchins and abalones (Estes, 1990; Doroff and DeGange, 1994). In presence of otters, there is a reduction in the sea urchin, crab, abalone and sea stars populations that eat the kelp. If sea urchins and other herbivores are controlled by sea otters, then kelp can grow and the species related to this habitat are favored (Estes, 1990).

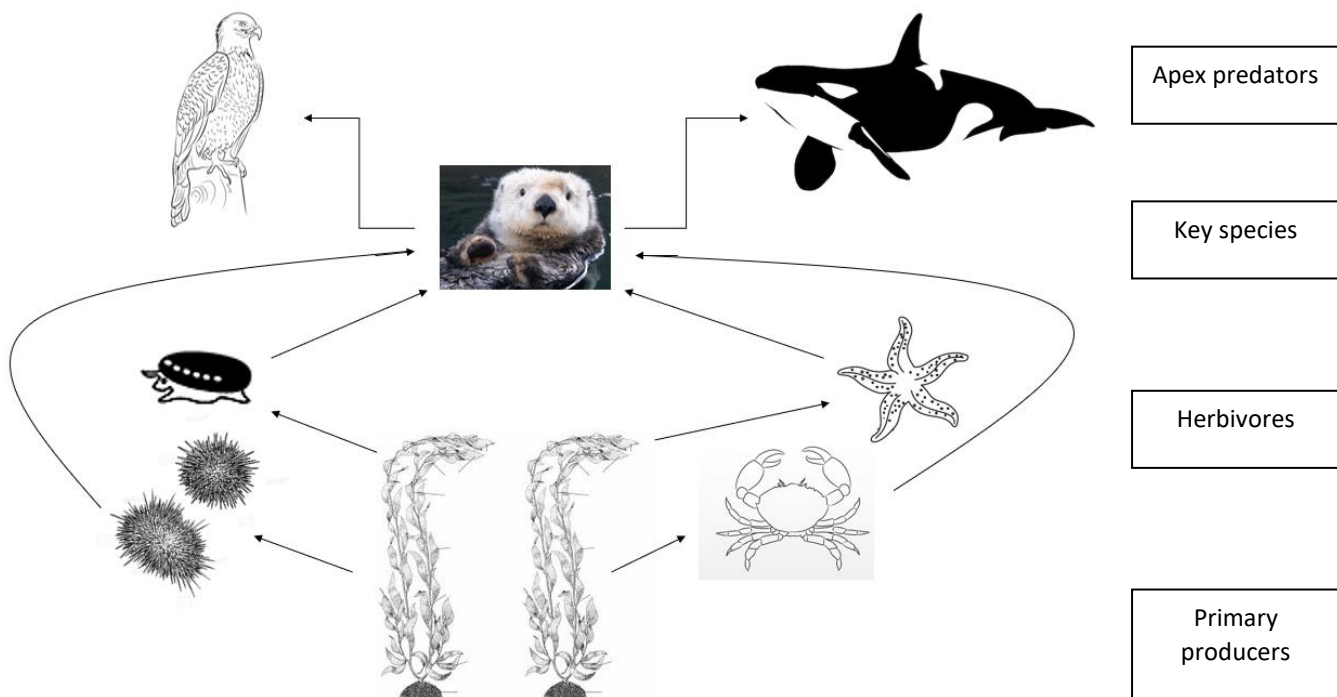


Figure 1. Kelp forest food web including the herbivores eaten by the otters and the apex predators that eat the otters. Adapted from <http://acer.disl.org/news/2016/11/09/word-wednesday-top-down-or-bottom-up/>.

Causes of mortality

Enhydra lutris is under the protection of the International Fur Trade Treaty of 1911 (Anderson *et al.*, 1996) and classified as endangered by the IUCN, with the higher mortality rates associated with stranding in fishing nets (Gallo-Reinoso, 2013; Schramm *et al.*, 2014).

Due to high economic value of their fur, sea otters suffered from commercial hunting during the 18th and 19th century, mostly in the Kodiak Archipelago (Southwest Alaska) until they almost reached the extinction as only 1-2% of the population survived (Kenyon, 1969; Jameson *et al.*, 1982; Doroff and DeGange, 1994; Anderson *et al.*, 1996; Gilkinson

et al., 2011). After this fur trade, only 1% of the otter's populations remained in eleven isolated habitats (Larson *et al.*, 2012). In present days, 40% of sea otter's mortality is due to different infections produced by pathogens and parasites that seem to be of anthropogenic origin. These infections are produced through the bivalves that filter contaminated waters and that are lately eaten by the sea otters (Kreuder *et al.*, 2003; Jessup *et al.*, 2004). They can also be poisoned by chemical components that can be found in the residual waters that are poured into the ocean (Walker *et al.*, 2008; Hart *et al.*, 2009).

As mentioned before, fur insulation is very important in sea otters as they do not present a fat layer. Nevertheless, this insulation can be reduced due to oil contamination. When the fur cannot be cleaned due to the oil drops, water penetrates into the fur, reaches the skin, and sea otters die of hypothermia. Contaminated waters are an important threat nowadays for these mammals as the thermal conductance of a saturated fur can be more than four times higher than a well cleaned one (7,64 over 25,21 W(m².C°)) (Williams *et al.*, 1998). In 1989, the Exxon Valdez oil spill in Prince William Sound triggered the death of thousands of individuals of sea otters (Brennan and Houck, 1996; Kruuk, 2006).

Predation by other animals is also an important cause of mortality in sea otters. From 1990 onward, an important reduction (more than 90% of the population) was caused by predation of killer whales (Kruuk, 2006) and pups can be hunted by Bald eagles (Anthony *et al.*, 2008).

Mortality rates can vary depending on the season and on the age of the individuals. Some authors reported that there is a higher mortality during winter and pups present higher mortality rates related to malnutrition (Garshelis *et al.*, 1986).

Social life

Sea otters are characterized by living alone but some groups of up to two hundred animals composed essentially by males, that are gregarious have been observed (Kruuk, 2006).

Social life can differ between sexes and depending on the activity they are carrying out in a specific moment. When adults, males and females occupy different territories of a same habitat where they perform several activities for different time duration (Estes, 1980; Pearson *et al.*, 2005). They present a well-defined cycle of activity that has a more or less stable daily routine (Yeates *et al.*, 2007). This cycle of activity includes the following tasks: 1) first dives to find food just after the sunrise; 2) intercalated periods of

feeding, grooming and resting until late morning; 3) a few hours' sleep at midday where again they intercalate feeding, rest and grooming until midafternoon; 4) a sleep for circa one hour; 5) feeding activities until the sunset and, 6) a whole night sleep (Kenyon, 1969). Regarding these activities, Gilkinson *et al.* (2011) observed that, when they are focused on feeding activities, they become asocial. Also, feeding and resting areas are different, they choose locations poor of benthic communities for resting whereas the contrary is chosen for feeding (Walker *et al.*, 2008). For this, they tend to form colonies in areas where they can find bottoms with enough invertebrates they can eat and that present comfortable and sheltered resting areas (Kenyon, 1969). Resting is the activity that takes more time along the day, it represents 49% of the day, to compensate the energy cost of foraging that is the second activity more carried out during the day (Yeates *et al.*, 2007). Sea otters are polygynous, they are mate with different partners along their lives. Males can be territorial but do not present aggressive behavior. They only share the territory with females during breeding periods (Estes, 1980).

Feeding habits in wild

As sea otters live exclusively in the water, they are exposed to environmental changes that have an impact on the benthic resources (such as “El Niño” events) and so on the availability of prey. To prevent situations facing a deficiency in food, these animals choose a non-specific diet and are versatile over the environmental conditions (Pizarro, 2014).

As explained in the previous paragraph, sea otters spend different moments of the day searching for food and eating. They spend 3,5 more time foraging than other terrestrial mammals of similar size (Yeates *et al.*, 2007). These activities have special attention and are carried out in very specific ways.

The main items contributing to the diet are sea stars, crabs, clams, mussels, octopus, sea cucumber, other bivalves and sea urchins (Garshelis *et al.*, 1986; Walker *et al.*, 2008). Nevertheless, some authors assure that the preferred ones are sea urchins, abalone, cancer crabs and large clams (Walker *et al.*, 2008; Groc, 2016) for which they have a special dentition (Peigné *et al.*, 2008). They hunt at maximum depths of 40 m (maximum of 100 meters of depth recorded) using their paws and sometimes taking the prey directly with the mouth (Tarasoff, 1973; Estes, 1980; Kruuk, 2006). Once they choose the item, sea

otters return to the surface placing the prey in a “pocket” made of skin present under the forelimbs (Estes, 1980).

Walker *et al.* (2008) observed that these mammals are able to understand the impact of their foraging on the benthic communities. They change the time and foraging tactics depending on the influence that this activity has on the structure of the community where they hunt. Following what seems logic, they spend more time looking for prey items that have a higher caloric content, like red abalone, so they need less dives and time to reach the caloric requirements. They choose their feeding site depending on this characteristic (Walker *et al.*, 2008). There are differences regarding the quantity of food that is eaten during day and night (Garshelis *et al.*, 1986), during different seasons (higher caloric requirement during winter observed by Garshelis *et al.*, (1986) and Kenyon (1969)), during mating period, males eat much more food (more than 10000 calories) (Mal’kovich, 1937). Feeding of the pups is very important for the survivorship. Sea otter females need to eat a higher amount of food in order to produce enough milk for their offspring that may consume up to 7% to 8% of their body mass in milk during the first 90 days of life (Cortez *et al.*, 2016).

When searching for food, tactile sense is more important than vision for the selecting prey (Kenyon, 1969). Once an appropriate food is caught, otters come back to surface where they place the item on the belly and eat. In intervals of 20-30 seconds, they roll over in order to clean the fur of food remains. Often, tools like rocks to open and broke hard items like shells might be used (Tarasoff, 1973; Kruuk, 2006).

In 1986, Garshelis *et al.* (1986) calculated 306 Kcal/Kg as the mean daily caloric consumption and this was the first account on the food and the caloric intake of these marine mammals.

Captivity

Karl Kenyon (1969) provides the most extensive and detailed study on the behavior of sea otters under controlled conditions and Mal’kovich (1937), successfully maintained and raised otters in the same conditions.

Raising sea otters under controlled conditions is important for their conservation as they represent the genetic diversity of otters that we have nowadays in wild habitats (Brennan and Houck, 1996). Some differences have been observed between wild and aquarium-raised otters. The assimilation efficiency is lower than in wild (Garshelis *et al.*, 1986)

they also spend less time feeding than wild otters, but only when the food supply is abundant (Kenyon, 1969). The same author observed that sea otters spent more time grooming in captivity (48% of the activity time) than in wild (11% of activity time). Also, differences between males and females can appear as Wild and Ames (1974) observed that males adapted quicker than females to captive life, surely due to the presence of those last ones.

It is very important to respect the good conditions of the enclosure in order to be sure that the animals are in good physical and mental health. They need to have access to abundant clean water with dry areas and free air circulation (Kirkpatrick *et al.*, 1955). If not enough cool water is available, there is a decrease in food ingestion, they get stressed and they cannot clean their fur so they become hypothermic (Kenyon, 1969; Brennan and Houck, 1996). The time budgets that are associated to each of the different tasks may be influenced by factors such as water conditions and temperature (Garshelis *et al.*, 1986).

Regarding the feeding activity, sea otters act in a specific way. When otters have the food, they first lick it in order to know which is the tastier for them and this will be the first one that they will eat. They never eat underwater, they always take the items and place them on their belly while floating and begin to eat (Kenyon, 1969). It is necessary to be careful with the items they eat since some infections with parasites can be enhanced with fish items (Kenyon, 1969). For this reason, Fish is frozen at least 24h before consumption. Kenyon (1969) established the first feeding necessities of *E. l. kenyoni* in captivity: a minimum of 190 Kcal/Kg/day and a maximum of 259 Kcal/Kg/day. It is very important to ensure these values as starvation can produce a very rapid loose of weight that can lead to gastroenteritis. Three different factors must be taken in mind regarding sea otter feeding in captivity: the quantity of food that the otter receives, how much they eat, and how much is assimilated (Malkovich, 1937).

Cortez *et al.* (2016) defined three groups of pups in captivity based on the growth rate. The first one was defined by the individuals with at most 30 days of life that presented a growth rate of 35 g/day, with a lower and non-linear phase during the first 15 days of life. After this first stage, the growth rate is higher and becomes linear. These authors demonstrated that bigger animals (with the same age) presented a higher growth rate and in the same way, their behavior is more similar to the adult one.

There are no previous studies on how Northern sea otters (*Enhydra lutris lutris* and *Enhydra lutris kenyoni*) grow in captivity. However, there are several institutions all over the world that own individuals of those species. The Oceanário de Lisboa (OdL) houses sea otters since the opening date (May 1998), when they started recording information about the food intake and weight (among other information), and thus allowing to contribute to this area of the specie's biology that has not been studied yet. For this reason, we decided to collect data and develop an investigation to provide additional guidelines of how the Northern sea otter would grow when raised in an aquarium. This will hopefully provide guide-lines to otter trainers and comparisons on how their individuals are growing with the models we created in order to be sure that the animals are in good health and in the best welfare conditions.

With these objectives in mind, the following research questions and hypothesis will be considered in this study:

Is it possible to establish different and marked stages of growth with different growth rates?

Do males and females present statistical differences in their growth rates?

Hypothesis:

- There are 3 stages of growth. The first one from birth to 500 days of life with linear growth, high growth rate. The second one between 500 and 1500 days of live with lower growth rate followed by a period of stabilization. After 2500 days of life, almost no growth is observed.
- There are significant differences between the growth rates and how long the different stages last when comparing males and females. Males present higher growth rates and longer stages than females.
- There are significant differences between the metabolic rates presented by individuals of same sex and similar age.

Materials and methods

At the Oceanário de Lisboa

The Oceanário de Lisboa (OdL) was inaugurated in May 1998 as one of the infrastructures contributing to the Expo 98 World Exhibition. It includes a total of four habitats, as follows: Atlantic; Arctic; Pacific and Indic. The Northern sea otters belong to the fourth habitat (Pacific Ocean) and a total of four individuals, Maré and Micas (Figure 2) (two female sisters), Kasilof (Figure 3) and Odiak (Figure 4) (both males) of *Enhydra lutris kenyoni* are currently settled in this habitat. The two females are daughters of Amália and Eusébio, the first two otters that entered the OdL when it was opened, and so were born in captivity there. Maré is the oldest one, born on the 2nd of May in 1998 and is now 22 years old. Micas was born two years later (26/7/2001) and she is now 19 years old. These two otters have travelled between different institutions. Maré was sent to Antwerp in 1999 and then to Rotterdam in 2005 where she was reunited with Micas that was at the Rotterdam aquarium since 2002. In November 2010 both came back to the Oceanário de Lisboa. The two males were born wild and found in Alaska by the Alaska Sealife Center. Thus, it is impossible to know their exact date of birth but an estimate might be given. Odiak was born around the 10th of July 2017 whereas Kasilof's is estimated on the 6th of July 2017. They arrived to the OdL on the 15th of March 2018. Since then, the four individuals live together in the Pacific habitat of the OdL.



Figure 2. Maré (on the right) and Micas (on the left) swimming together in the tank at the OdL. Author's photography.



Figure 3. Kasilof during a grooming session. Photo by Pedro Pina.



Figure 4. Odiak playing with a toy. Photo by Pedro Pina

The same tank houses some fish species, such as, *Cymatogaster aggregate*, *Embiotoca jacksoni*, *Embiotoca lateralis* and *Hypsypops rubicundus*, that occur in the North Pacific Ocean, as well.

The habitat is composed by a main aquarium where are the otters, a smaller aquarium with other fish species (including sharks) of the Pacific Ocean and two tidal pools. The main aquarium is 3.5 meters deep (max), and the temperature is kept around 13.5°C. In this aquarium, there is a corridor where the meals are given (Figure 5) and all the back-stage area where the training and isolation sessions are made. This one is divided in a front back area (BAF- Back Area Frontal in Portuguese) (with direct access for the otters

to the tank and where are trained Maré and Micas) and a back-back area (BAT-Back Area Traseira in Portuguese) where Odiak and Kasilof are isolated whenever necessary and where their trainings are developed.



Figure 5. Alberto Fernandes, Ana Raposo and myself giving one of the meals to the otters at the Oceanário de Lisboa. Photo by Ana Luísa.

Daily feeding

As mentioned before, sea otters present very high caloric requests that are fulfilled with up to six meals per day and different ice treats with little items inside that are given along the day. The caloric requests can vary between the individuals depending on their age, sex and the season of the year.

The overall composition of the food items offered to the otters is indicated in Table 1 and indicates the meals, the items and their weight (in kilograms) given to the four sea otters.

The quantities of food that are given to the otters are analyzed and changed regularly depending on the observations made by the trainers. In every meal it is important to pay attention on how each individual eats the food, for example, if they reject any item (or part of it) or if they repeatedly steal items that are not in the alimentation and similar details.

Table 1. Quantity (in kilograms) of the items offered to the otters at each meal with the total given all over the day and the calories ingested by each individual.

Time	MARÉ		MICAS		ODIAK		KASILOF	
8h15	SHRIMP	0,350	SHRIMP	0,350	SHRIMP	1,100	SHRIMP	1,000
	MACKEREL	0,300	MACKEREL	0,300				
10h15	CUTTLEFISH	0,150	CUTTLEFISH	0,250	SQUID	(mix) 1,000	SQUID	(mix) 1,000
	CAPELIN	0,200	CAPELIN	0,200				
	RED FISH	0,350	RED FISH	0,250				
12h45	SHRIMP	0,300	SHRIMP	0,300	CUTTLEFISH	(mix) 0,950	CUTTLEFISH	(mix) 0,850
	HERRING	0,300	HERRING	0,300				
15h15	DAFFODIL	0,250	DAFFODIL	0,250	CLAM	(whole) 0,500	CLAM	(whole) 0,500
	SQUID	(fine) 0,350	SQUID	(fine) 0,350	MUSSEL	0,500	MUSSEL	0,500
18h30	HORSE MACKEREL	0,250	HORSE MACKEREL	0,250	HERRING	(whole) 0,800	HERRING	(whole) 0,750
	LING	0,350	LING	0,300				
Total	3,150	4278,000	3,100	4223,000	4,850	6290,000	4,600	5908,500

After each meal, the items that are not eaten are weighted and, following the trainer's criteria, added to a later meal or thrown away. Thus, it is possible to calculate the exact amount of food eaten by each individual in every meal and, thanks to the caloric table (Table 2), a daily register of the calories ingested by each otter is made.

Table 2. Caloric, protein, fat and cholesterol content of the sea otter food items.

	Kcal/100g	proteins (g)	total fat (g)	cholesterol (g)
CAPELIN	104	15	4	0,224
CLAM	78,6	10,66	1,6	
CUTTLEFISH	158	32	1,4	0,224
DAFFODIL	78	19,4	0,1	0
HERRING	235	16	16	
HORSE MACKEREL	105	20,3	2	0,053
LING	236	24	15	0,161
MACKEREL	167	19,3	9,36	0,064
MUSSEL	86	12	2,2	0,028
RED FISH	95	19	1,3	0,056
SHRIMP	106	20	1,7	0,152
SQUID	92	16	1,4	0,233

The daily meals are given at 8:00 am; 10:00 am; 12:45 pm; 3:15 pm and 6:00 pm and are prepared in the morning except for the first and last ones that need to be prepared the day before. All the items are stored frozen and are unfrozen with cold water before slicing into smaller pieces. After the first training, the rest of the meals are prepared in the right order, following the preferences of each otter (Odiak and Kasilof eat the little fish whole whereas Maré and Micas that are older only eat the parts without spines). For this step, no special material is needed, only good knives, plastic tables and gloves to manipulate the food items. None of these items are cooked and the food is always given raw as this is how they would find it in the wild.

Ice treats

At different moments along the day, different ice treats are given to the all the otters even if Maré and Micas due to their age have some difficulty to break the ice with their teeth. The ice treats can contain even little food items (unshelled mussels, whole shrimps, whole clams) or toys. In this case, some of the items, like the clams, are given with the shell so that the animals train how to open them (they hit them on the floor or with the rocks of the tank). The ice treats are given to the young otters after the morning training and after the isolation sessions (every Monday, Wednesday and Friday) as a reward for good behavior.

Ice treats also are used as the hydration way for the sea otters as they do not drink water (except Maré) so after each meal, a little reservoir is filled with ice cubs that they eat.

Overall, these treats do not represent a significant contribution to the diet and thus they are not accounted for.

Vitamins

All the individuals need a daily supplement of vitamins (Table 3). For the two males and Micas, those are mixed with mashed mussels and presented under as ice cubes (two per individual). In the case of Maré, which is not able to eat ice, the vitamins are mixed with water and injected in the shrimps. For all the four individuals, the vitamins are given at the beginning of the second meal, at 10:00 am.

Table 3. Composition of the vitamins administrated to the otters.

Vitamin A	Vitamin H
Vitamin D3	d-Pantotenate Ca
Vitamin E	Inositol
Vitamin C	Iron (Fe)
Vitamin B1	Iodine (I)
Vitamin B2	Magnesium (Mg)
Vitamin B6	Manganese (Mn)
Vitamin B9	Zinc (Zn)
Vitamin B12	Nicotinic acid

Training

A morning training is carried out every day, from Monday to Friday, at 8:00 am, during which the first meal is given. Trainings take place in the back area: at the BAT for Odiak and Kasilof and at the BAF for Maré and Micas. During these sessions, different commands are trained, especially for the two males that are younger and still need to learn. Some commands like “stay” and “scale” are done with hand signals and vocal instructions whereas other ones (“target”; “follow”) need the use of a target composed of a tube with a colored ball at the end (blue for Micas and Maré, red for Odiak and yellow for Kasilof). In this case, the food is given in the belly and the otters eat in the dry areas. During these sessions, two times per week, the animals are weighted (to the nearest 10 grams) using a scale available at the BAF to have a control on the evolution of each individual.

During the other meals, some other commands like “Go” (that consists in assuring that the individual goes to the end of the tank and stays there) are trained with Odiak and Kasilof. During the trainings, the food items are given as a reward for positive behavior or after completing a command.

Daily registers

At the end of each day, the data collected since the morning is added to the daily registers. This is divided per individual (Maré; Micas; Odiak and Kasilof) and contains the information about the quantity (in kilograms) of food eaten by each animal (quantity of each item, total quantity per meal, total quantity per day); the quantity of calories (divided in the same scheme as the food quantity) and the weight of each otter. The quality of the fur along the day (classified in a scale from 1 to 3 in which 1 is a bad condition of the fur and 3 is a very good condition of the fur) and the quality of the behavior of each individual (evaluated in the same way as the condition of the fur) are also registered. For this study, only the data regarding the quantity of food, calories and animal corporal weight are important as they are the ones used to compare how the different individuals (from this institution and from others) grow.

Data collection and unification

A total of 27 otters (10 females and 17 males) from various institutions have been considered for the growth and metabolic studies.

In order to have a larger sample and thus a global appreciation of how the Northern sea otter grows, data from the individuals of other institutions was analyzed. Table 4 shows the information of all the individuals that were used in this study. Some data was not available as the otters come from different institutions and some of them were born in wild.

Table 4. Historic information about the otters studied for this work.

Sea Otter name	Sp.	Male/ Female	Age(Y)today	Age(Y)Death	Birth date	Place of birth	Death date
1	<i>Enhydra lutris kenyoni</i>	M	22		01/09/1999	Wild	
2		F	8		07/04/2013		
3	<i>Enhydra lutris kenyoni</i>	M	16		06/12/2005	Aquarium	
4		F	19		16/09/2002		
5		M	4		31/10/2017	Wild	
6		F	18		04/07/2003		
7	<i>Enhydra lutris kenyoni</i>	M	15		14/05/2006	Wild	
8	<i>Enhydra lutris kenyoni</i>	M		7	03/03/2005	Aquarium	31/07/2012
9		M	3		15/06/2018		
10	<i>Enhydra lutris kenyoni</i>	M		16	15/07/2001	Wild	01/04/2017
11	<i>Enhydra lutris kenyoni</i>	F		6	12/05/2010	Wild	22/04/2016
12	<i>Enhydra lutris kenyoni</i>	M	4		06/07/2017	Wild	
13		F	24		01/05/1997		
14	<i>Enhydra lutris lutris</i>	F	23		02/05/1998	Aquarium	
15	<i>Enhydra lutris kenyoni</i>	M	6		08/01/2015	Wild	
16		M	9		09/02/2012	Wild	
17	<i>Enhydra lutris lutris</i>	F	20		26/07/2001		
18		F	7		25/06/2014		
19	<i>Enhydra lutris kenyoni</i>	M	11		01/05/2010	Wild	
20	<i>Enhydra lutris kenyoni</i>	M	4		10/03/2017	Wild	
21	<i>Enhydra lutris kenyoni</i>	M	6		25/05/2015	Wild	
22		F	3		28/05/2018	Wild	
23		M	3		27/09/2018		
24	<i>Enhydra lutris kenyoni</i>	F	9		14/01/2012	Aquarium	
25		M	1		03/01/2020	Aquarium	
26	<i>Enhydra lutris kenyoni</i>	M	6		17/11/2015	Wild	
27	<i>Enhydra lutris kenyoni</i>	M		5	27/05/2010	Wild	09/07/2015

For an easier and faster treatment, all the data from the different animals were, first of all, unified and placed in a unique Excel book. In this one, the information about the weight and age (in days) of each individual until 2500 days of life was analyzed in order to obtain the necessary graphics to compare the growth rates in three different phases (0-500 days; 500-1500 days and 1500-2500 days).

Statistical analysis

Using the program SPSS, a t-Student test for independent samples was used to investigate on eventual differences in weight between sexes and differences were considered significant for $p < 0.001$.

Hypothesis:

$$H_0: \mu_1 - \mu_2 = 0$$
$$H_1: \mu_1 - \mu_2 \neq 0$$

Where μ_1 is the mean of male growth and μ_2 is the mean of female growth.

The same test was used to evaluate the differences in the metabolism between Maré and Micas.

Results

GROWTH RATES

We studied the growth rate of both male and female separated in three different phases (0 to 500 days of life; 500 to 1500 days of life and 1500 to 2500 days of life). Figure 6 shows the average growth rates along the three stages we studied of all the individuals together (Figure 6A); males (Figure 6B) and females (Figure 6C). The 3 figures show the same trend: a first stage of linear and fast grow of the animals; a second stage where this rate slows down and at the end, the animals reach an asymptote and maintain (more or less) the same weight.



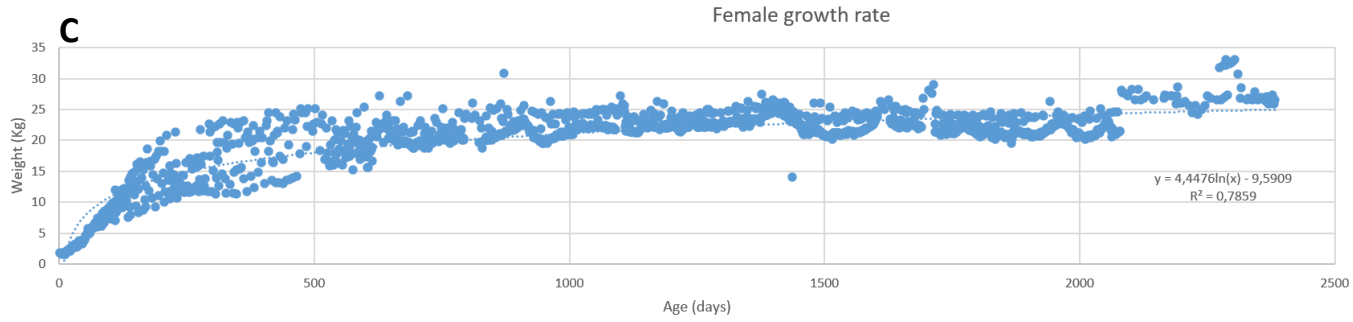
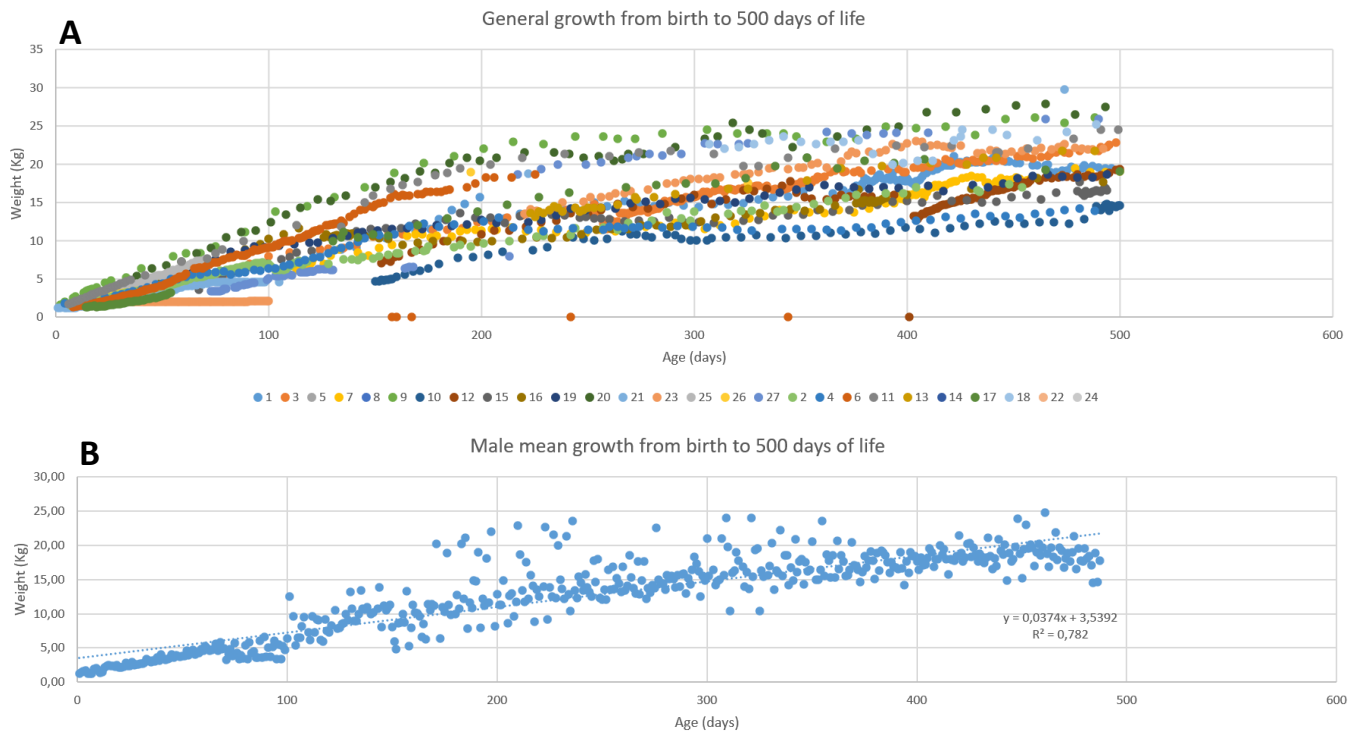


Figure 6. Growth rates of the otters studied during their 2500 first days of life. A: general growth rate with all the individuals. B: male growth rate. C: female growth rate.

Figure 7 shows the growth rates of the first stage, from birth to 500 days of life. In this first phase, the individuals studied present a linear growth rate as the pups grow very fast. As shown in Figure 7(A; B; C), during the first 100 days of life all the sea otters present a very similar growth rate. From 100 days and beyond, more disparities appear. Comparing the results indicated in Figures 7B and 7C we can observe that females present a higher growth rate in the beginning as the curve is steeper and they take more time to present disperse data. These figures also show a higher scattering of the data for females, when compared to males.



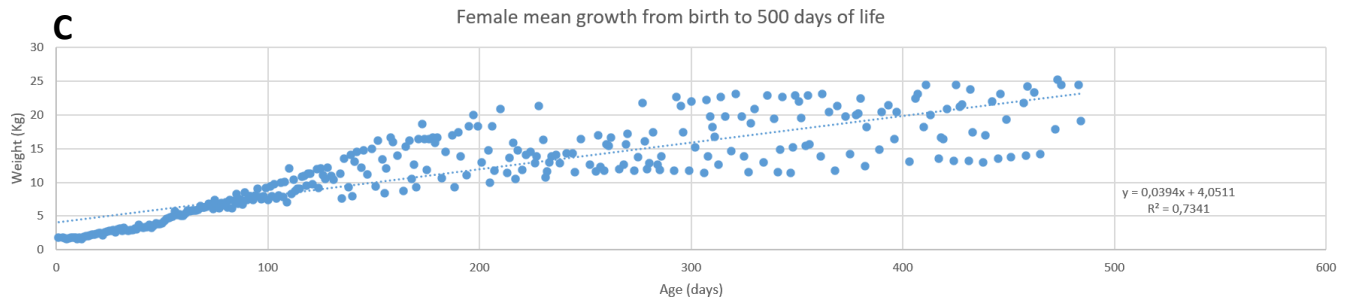


Figure 7. Growth rates of the otters studied during their 500 first days of life. A: general growth rate with all the individuals. B: male growth rate. C: female growth rate.

Figure 8 (A, B, C) shows the results obtained in the second phase. It shows a considerable decrease in the growth rate: from 0,0371 Kg/day to 0,0081 Kg/day in males and from 0,0396 Kg/day to 0,0045 Kg/day in females. Males present a higher growth rate and seem to present a less linear growth curve, so they continue to grow whereas females show a more linear growth.



Figure 8. Growth rates of the otters studied during the 500 to1500 days of life. A: general growth rate with all the individuals. B: male growth rate. C: female growth rate.

The values of the growth rates of the third phase (from 1500 to 2500 days of life) are shown in Figure 9. In this final stage, there is almost no growth of the animals, they reach the asymptote and maintain a stable weight along time. The difference with the previous stage is more remarkable in males as the growth rate drops from 0.0081 Kg/day to 0,0021 Kg/day whereas in females there is only a decrease of 0.0010 Kg/day (from 0.0045 Kg/day to 0.0035 Kg/day). In this case we suggest that males attained the asymptote at 35 Kg at age 1800 days of life.



Figure 9. Growth rates of the otters studied during the 1500 to 2500 days of life. A: general growth rate with all the individuals. B: male growth rate. C: female growth rate.

METABOLIC STUDY OF MICAS AND MARÉ

The following figures are related to the metabolic study we performed with Micas and Maré in which we studied the relationship between their weight and the percentage of the body weight they ingest during one year. These are two old females that maintain a stable

weight as both of them reached the asymptote and do not grow anymore. This study was performed for the year 2020 for which we had the data about the weight, quantity of food ingested (in kilograms), the calories and the percentage of the body weight that the food ingested represents.

Figure 10 represents the weight evolution (in kilograms), the Kcal per kilogram and the percentage of the body weight that was ingested by Maré along the year 2020.

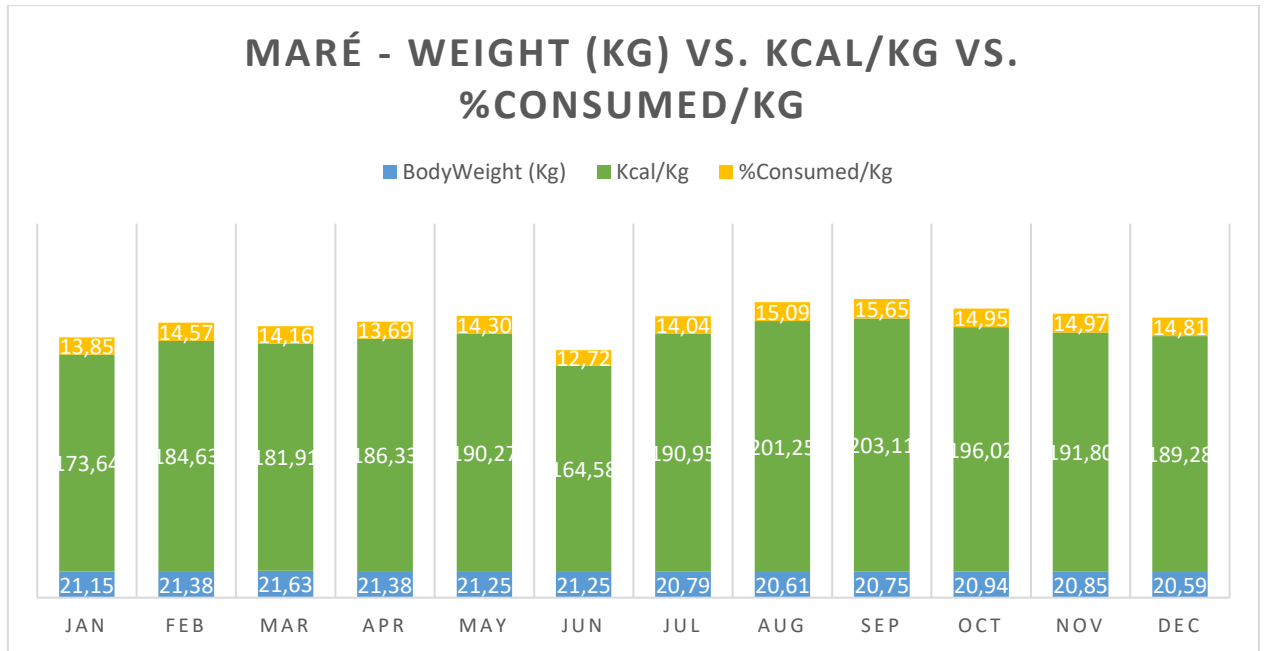


Figure 10. Maré's weight and ingestion evolution along the year 2020 (Graphic provided by the OdL).

In Figure 11 we represent the same information for the other female, Micas. It is evident that this last one is heavier than Maré as she maintains a weight between 25 Kg and 30 Kg along the months with a mean of 27,26 Kg. On the other hand, Maré present a weight always close to 20 Kg, with a mean for the year of 21,02 Kg. We can also observe that Maré ingests a higher quantity of food than Micas, even if there are some periods in which she presents a decrease and Micas an increase in the food ingested.

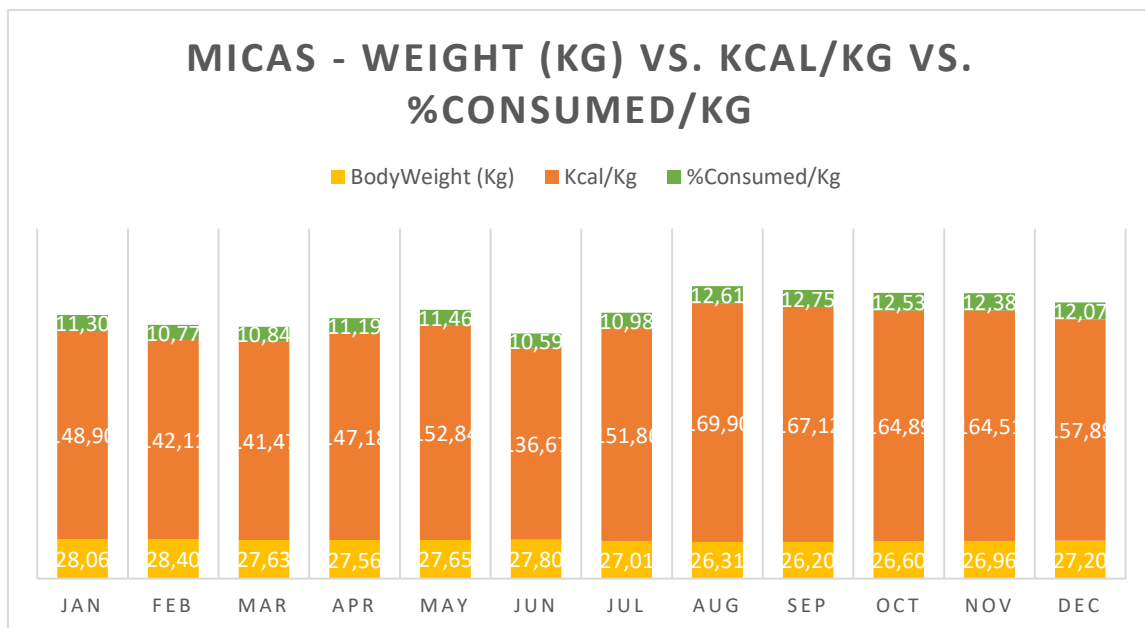


Figure 11. Mica’s weight and ingestion evolution along the year 2020 (Graphic provided by the OdL).

STATISTIC ANALYSIS

GROWTH RATES

Table 5 summarizes the statistical information of the data studied: sample size; mean of each group; deviation and error of the deviation. For female we had 1768 values with a mean of 20,44 Kg and for male, 1973 values with a mean of 24,56 Kg.

Table 5. Summary statistic for the t-Student test performed to compare the female and male weight.

Estatísticas de grupo					
	GENDER	N	Média	Desvio Padrão	Erro Padrão da Média
WEIGHT	Female	1768	20,43812	5,122409	,121824
	Male	1973	24,55705	7,931862	,178571

If we assumed that the variances were equal, we obtained a p-value lower than 0,001 (Table 6 in red) so it was not possible to accept the null hypothesis. For this reason, we had to assume that the variances were unequal. In this case, we obtained a p-value less than 0,001 (Table 6 in blue) indicating that the means for the weight of male and female are statistically different.

Table 6. Statistical results of the t-Student test performed to compare the means of male and female growth.

		Teste de amostras independentes								
		Teste de Levene para igualdade de variâncias		teste-t para Igualdade de Médias					95% Intervalo de Confiança da Diferença	
		F	Sig.	t	gl	Sig. (bilateral)	Diferença média	Erro padrão da diferença	Inferior	Superior
WEIGHT	Variâncias iguais assumidas	407,693	,000	-18,629	3739	,000	-4,118928	,221099	-4,552414	-3,685441
	Variâncias iguais não assumidas			-19,054	3410,340	,000	-4,118928	,216168	-4,542761	-3,695095

Figure 12 represents the mean of weight for female and male sea otters indicating the non-overlap of the respective error bars as female present a mean of 20.44 Kg and male of 24.56 Kg.

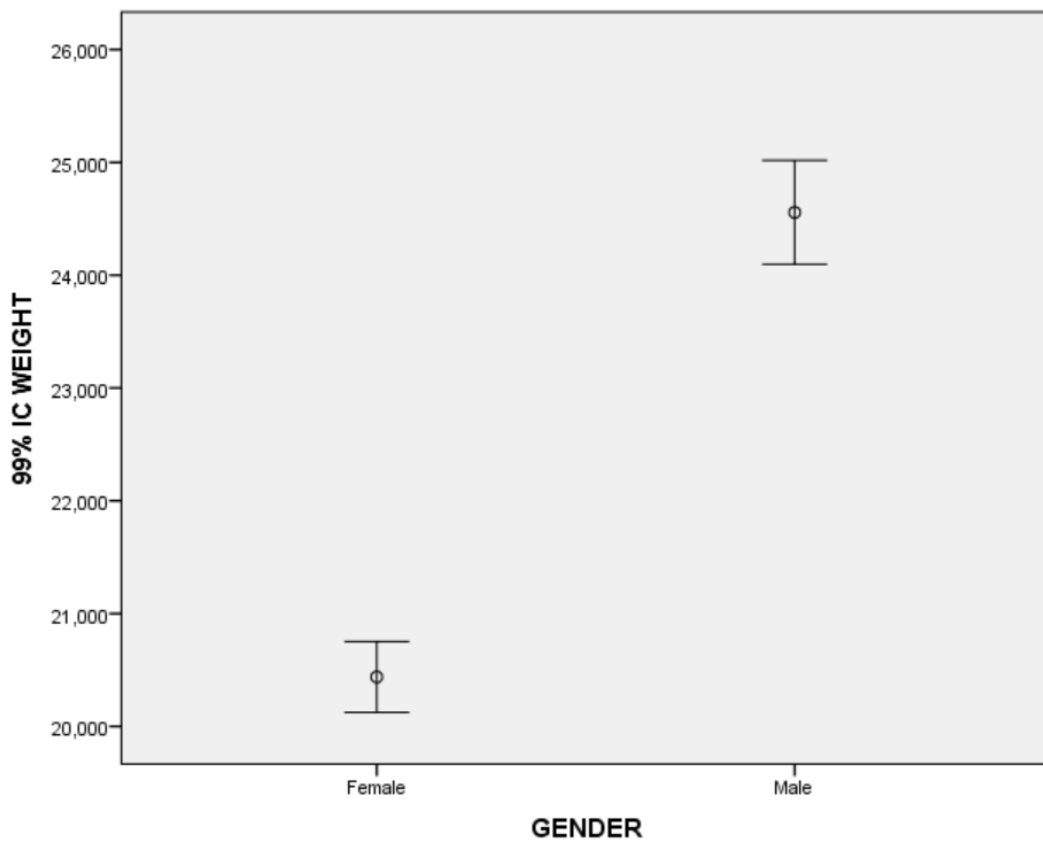


Figure 12. Mean weight of male and female sea otters at 99% degree of confidence with a t-Student test of independent variables.

METABOLIC STUDY

Table 7 shows the statistical information of the data studied for the metabolic study of Micas and Maré. We have 162 values of percentage of body weight for Maré and 147 for Micas with a mean of 14,33% and 11,58% respectively.

Table 7. Group statistics for the t-Student test performed to compare the percentage of body weight consumed by Maré and Micas during the year 2020.

	Otter	N	Média	Desvio Padrão	Erro Padrão da Média
Percentage_bodyweight	Maré	162	14,3343	1,36295	,10708
	Micas	147	11,5801	1,03499	,08536

For this second t-Student test, we obtained a value higher than 0,001 assuming that the variances were equal (Table 8 in red) so we could not assume the inequality of the variances. Assuming so, that the variances were equal, we obtained a p-value lower than 0,001 (Table 8 in blue) and we were able to affirm that the means percentage of body weight ingested by Micas and Maré along the year 2020 are statistically different.

Table 8. Results for the 99% confidence t-Student test to compare the mean percentage of body weight consumed by Micas and Maré during the year 2020.

Teste de amostras independentes										
		Teste de Levene para igualdade de variâncias		teste-t para Igualdade de Médias						
		F	Sig.	t	gl	Sig. (bilateral)	Diferença média	Erro padrão da diferença	99% Intervalo de Confiança da Diferença	
								Inferior		Superior
Percentage_bodyweight	Variâncias iguais assumidas	6,457	,012	19,850	307	,000	2,75412	,13875	2,39450	3,11375
	Variâncias iguais não assumidas			20,111	297,956	,000	2,75412	,13695	2,39910	3,10914

Figure 13 represents the graphic representation of the statistical analysis presented previously. Micas ingested a mean of 11,58% of her body weight and Maré a mean of 14,33% over the year 2020.

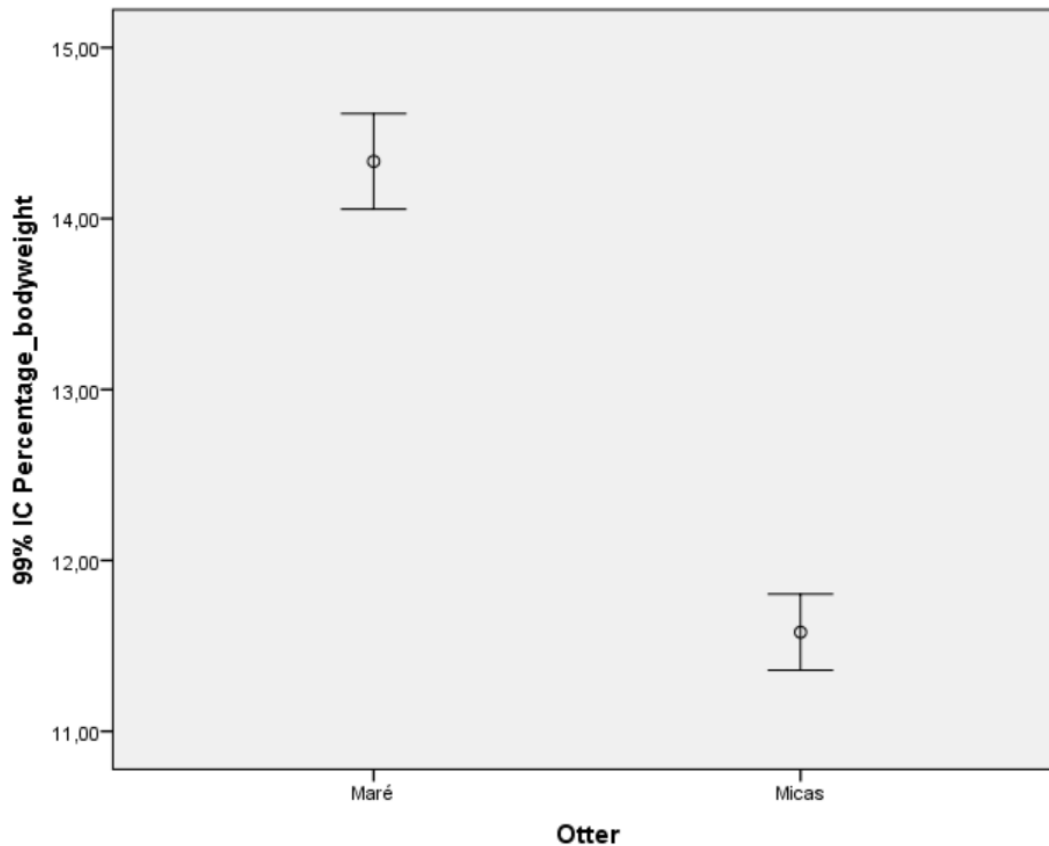


Figure 13. Mean percentage of body weight ingested by Maré and Micas following the t-Student test.

Discussion

Northern Sea otters (*Enhydra lutris lutris* and *Enhydra lutris kenyoni*) need to ingest very high caloric meals to prevent heat loss. Nevertheless, the quantity of calories needed can be conditioned by the age, sex and conditions of each individual.

As mentioned previously in this work, there are three subspecies of *Enhydra lutris*: *E. l. lutris*; *E. l. kenyoni* (that together are known as the Northern sea otter) and *E. l. nereis* (the Southern sea otter). Nevertheless, we only studied individuals of Northern sea otter based on the premise that *E. l. nereis* is the most different of the three subspecies as they present monophyletic haplotypes contrary to the subspecies *lutris* and *kenyoni* (Cronin *et al.*, 1996). Cheney (1995) points out that the two populations are different in morphology, social and reproductive behavior.

In this work we studied sea otters from different institutions, ages and sexes. Females show a higher growth rate in the first stage of 500 days of life but reach the asymptote

with 1000 days of life at a mean body weight of 25 Kg. Males present a slower growth rate in the first one and a half year and does not reach the asymptote until 1800 days of life with 30 Kg of body weight. The statistical study demonstrated a significant difference in the mean weight of female and male as the error bars did not overlap. Cortez *et al.* (2016) described the growth of the Northern sea otters similar to that of fur seals and sea lions. Until weaning, wild males present a growth rate of 95 g/day and wild females of 83 g/day. Under controlled conditions, during the first 500 days of life, the animals studied showed a growth rate of 37 g/ days for males and 39,6 for females. Under controlled conditions, different factors can influence the sea otter's growth. Some of these are stress, the conditions in which they live, the number of individuals or the male/female ratio. It was surprising to find a higher growth rate in females, as normally, this should be seen in males. The result obtained can be due to the number of individuals that was used for the study. The less linear growth of male individuals can be explained as we obtained a low R^2 in the graphic representations. For this reason, the extrapolations here made are not a 100% reliable and a deeper study with more individuals would give clearer and better results. Nevertheless, it is difficult to obtain all the information about the otters as not so many aquariums have Northern sea otters and they may not agree to share their data.

When comparing to wild animals, we notice a lower food ingest in the sea otters. These can be explained as in wild conditions, these animals present high foraging costs due to swimming, floating, thermoregulation and the metabolic effects of food processing. When raised in aquariums, all these effects are annulled, sea otters present lower energetic costs and so, need less quantity of food to maintain their body temperature (Yeates *et al.*, 2007). In a similar work to ours about sea otters raised in aquariums, the previous authors concluded that it is important to maintain the water temperature between 13°C and 17°C in order to prevent heat loss as in these conditions, the resting metabolism is not affected.

In the metabolic study performed with Micas and Maré, we observed statistical differences between the two animals. However, these two sea otters are females, with a similar age (19 and 22 years old respectively) and were raised in the same conditions since they were born at the OdL, but they present different metabolism rates. Maré eats a higher percentage of food to maintain a lower body weight compared to Micas. This can be explained because Maré presents a high metabolism and needs a larger quantity of food to maintain her body temperature. Thometz *et al.* (2014), explained in their study

about the energetic demands of the sea otters, that the mass-specific metabolic rate shows a decrease with the age. At the OdL, the trainers observed with their older otters, that metabolic rate and weight decrease with age and so, the feeding parameters must be readjusted. It would be, for this reason, interesting to elaborate a study with “senior” otters of other institutions to verify and obtain more data on this subject.

Laidre *et al.* in 2006 performed a study on the growth and body condition patterns of sea otters. They obtained the growth curves for females and males in two different periods (Figure 14): 1967-1971 (solid line) and 1992-1997 (dashed line). When compared to our study we can observe that the results are similar. Females reach the asymptote sooner than males and reach a body weight of 25 Kg maximum whereas males can attain body weights up to more than 30 Kg. The results obtained by Laidre *et al.* correspond to wild otters. As both studies present similar results, we can suggest that the otters studied in the present work, are maintained in good conditions, that are similar to those of wild life.

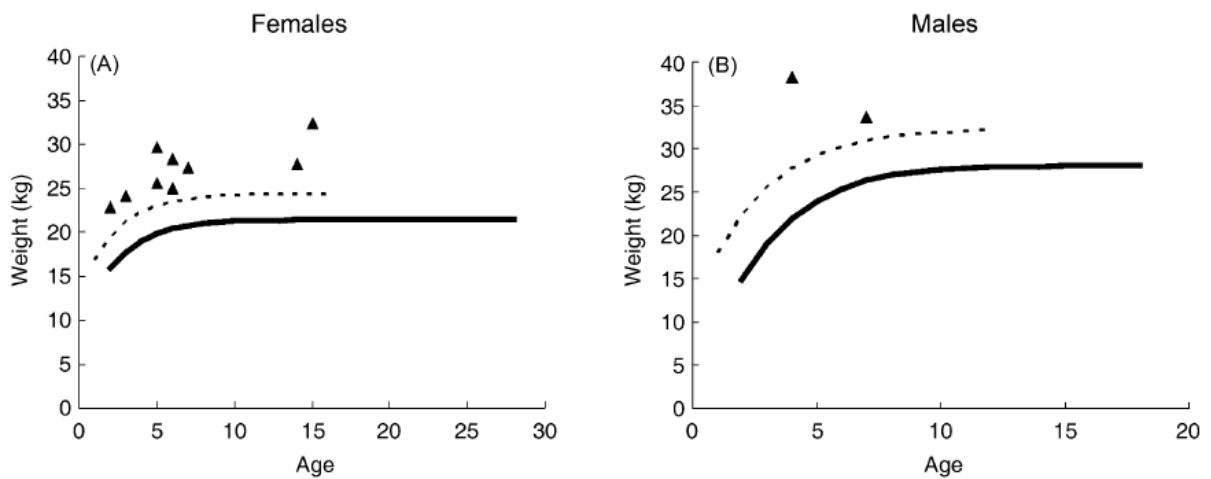


Figure 14. From Laidre *et al.* (2006). Females (A) and males (B) body weight from 1967 to 1971 (solid line) and from 1992 to 1997 (dashed line).

Mal’kovich (1937) studied some sea otters in semi-controlled conditions and concluded that these are social animals that get used to human presence quite fast and that it is possible to raise sea otter pups in captivity. This was only the first approach of Northern sea otter studies under controlled conditions. With the study here performed, we demonstrated that it is possible to raise Northern sea otters in controlled conditions and

good health, whenever we assure that enough calories and circa 25% of their body weight in food (per day) is consumed.

Due to the sanitary situation that we are living nowadays, the initial project that was planned for this investigation suffered some modifications. I was supposed to spend five months at the Oceanário de Lisboa in order to collect my own data, learn the procedures of the feedings, trainings and cares of the four otters owned by the aquarium. During this period, I was going to digitalize the old data available at the OdL, start to collect data of Micas; Maré; Odi and Kasi, participate at the trainings and feedings and learn to prepare the meals. Finally, it was only possible for me to stay the first month at the oceanarium since this one was closed at the beginning of March and I was forced to return to Madrid. For this reason, I was just able to learn how to prepare the meals, see the trainings from the outside and start to digitalize data from when the OdL opened. Due to the actual situation, I made this work from home with the help of the workers of the oceanarium that sent me the data (diet and weight) of all the otters. It would have been much easier to work on the data directly at the OdL and knowing where the data came from exactly. Also, the oceanarium stay closed for a long period and it was not possible for my colleagues to send me the information I needed to continue my work. For these reasons, it took me more time than expected to finish the analysis and writing of this paper.

Conclusions

The present study demonstrated that sea otters can be elevated in aquariums assuring their good health. Some papers even consider that it is necessary in order to obtain precious information about the biology and conservation of these mammals.

Nevertheless, not enough information is yet available on different aspects of how Northern sea otters grow under controlled conditions. It would be interesting, for example, to study the influence that lactation in females and castration in males have on the diet and growth of these marine mammals. Another interesting study would be about all the different phases and details to take into account when a sea otter pup is born at the aquarium.

Apart of scientific studies, it is important for the conservation to maintain the species under the protection of the IUCN in order to avoid hunting of the otters for their fur and to take them in count in fisheries and conservation plans.

As we have mentioned all over this work, the alimentation of these mammals is a very significant part of their ecology. For this reason, a deep investigation on how to optimize the diet of the sea otters (items, brands, storage, feeding procedures, Kcal) could be carried out to offer as much information as possible to the institutions that would like to raise sea otters in the future.

With the research performed in this work, we concluded that some aspects should be guaranteed for the wellness of the Northern sea otters raised in aquariums. The otters need to have enough water to swim but also dry areas where the trainings are made every day and where the animals can play, eat and groom their fur. The water conditions must be similar to those of their natural habitat (the North Pacific Ocean) with temperatures around 13°C and never higher than 17°C. Four to six feedings must be given in the dry areas during the training sessions and inside the tank during the rest of the day. The items and quantity of food given to each animal must be calculated and controlled to ensure the good alimentation of the animals. Also, periodic weight measurements are essential for the control of the metabolism and growth of the otters. If all these guidelines are followed all over the life of the sea otters raised in aquariums, we can expect the good physical and mental health of these animals.

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