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Development of Bottlenose Dolphin (*Tursiops truncatus*) Management at the Nuremberg and Duisburg Zoo over the past 50-plus years

Entwicklung der Haltung Großer Tümmler (*Tursiops truncatus*) im Tiergarten Nürnberg und im Zoo Duisburg in den letzten 50 Jahren

Katrin Baumgartner[1], Tim Hüttner[1], & Kerstin Ternes[2]*

[1] Nuremberg Zoo, Am Tiergarten 30, 90480 Nuremberg, Germany
[2] Zoo Duisburg gGmbH, Mülheimer Str. 273, 47058 Duisburg, Germany

Abstract

The husbandry and management of bottlenose dolphins under human care has started in 1938 in Florida. In Germany the first animals arrived in 1965. Over the last decades, many studies have been conducted and advances in marine mammal medicine, breeding, husbandry, and animal welfare have been made. The European population became self-sustaining, and the life expectancy of the animals has increased continuously. Celebrating 50-plus years of the keeping of dolphins under human care in Germany, we take a look at the development of the two current German dolphinaria and how they have changed over time. With the knowledge gained during this time and through current studies, Duisburg and Nuremberg are not only contributing to the further improvement of dolphin husbandry conditions but are also helping to implement ex-situ conservation measures for endangered dolphin species.

Keywords: bottlenose dolphin, dolphin husbandry, animal, welfare, veterinary medicine, life support system, neonates

Introduction

Dolphin husbandry is – compared to other zoo animals – a very recent animal husbandry discipline. Although reports from ancient animal exhibitions including dolphins date back to

*Corresp. author:
E-Mail: ternes@zoo-duisburg.de (Kerstin Ternes)

as early as the 15th century (Couquiaud, 2005), the first modern presentation of bottlenose dolphins (*Tursiops truncatus*) started in 1938 in St. Augustine Marineland, Florida. In comparison to other animal exhibitions, this is still a recent development since many other wild animal species have been under human care for much longer. In Germany, the keeping of dolphins only began in the 1965 in Duisburg and 1971 in Nuremberg. The early dolphinaria not only led to the first experiences in terms of husbandry, training, and medical care (Defran & Pryor, 1980), but soon, scientists became interested in studying the dolphins. Initial insights into dolphin communication, behavior, and sensory ecology (see among others: Caldwell & Caldwell, 1965; 1966; 1968) led to the formation of dedicated research facilities, such as those of the US Navy (Houser et al., 2005) and the Kewalo Basin Marine Mammal Laboratory (Herman, 2012), led by Louis M. Herman who later published groundbreaking studies on the cognitive abilities of dolphins.

Today, dolphinaria continue to be important research facilities, and zoos and aquaria now focus on providing educational value through their 'animal presentations' by sharing the lessons they have learned through their scientific studies. Moreover, dolphin presentations have been shown to have a significant impact on the conservational knowledge of the visitors, sustainably raising awareness of the importance of nature and species conservation (Miller et al., 2013).

Over the years, many different dolphin species have been held under human care, most notably bottlenose dolphins, killer whales (*Orcinus orca*), pilot whales (*Globicephala macrorhynchus*), Pacific white-sided dolphins (*Lagenorhynchus obliquidens*), beluga whales (*Delphinapterus leucas*), and false killer whales (*Pseudorca crassidens*), among others. More rarely, Guiana dolphins (*Sotalia guianensis*), finless porpoises (*Neophocaena asiaeorientalis*) and harbor porpoises (*Phocoena phocoena*), and Amazon river dolphins (*Inia geoffrensis*, for an extensive review see Ternes, 2023) have also been featured in some collections.

This paper focuses on bottlenose dolphins under human care in two facilities in Germany. Thus, unless stated otherwise, the term "dolphin" is henceforth used to indicate the bottlenose dolphin.

In the early stages of dolphins under human care, there was little knowledge about their health, physiology, husbandry, or social management. However, zoos and aquaria are now committed to providing the highest level of care for their dolphins. As a result of this effort, many advances in marine mammal medicine, breeding, husbandry, and animal welfare have been made over the years. Today, largely due to the progress made in overall and especially veterinary care, as reviewed below, the populations of bottlenose dolphins held in institutions belonging to the AZA (American Association of Zoos and Aquariums) and EAZA (European Association of Zoos and Aquaria) are self-sustaining. In a recent study that investigated longevity for dolphins under human care in US zoological facilities, it was shown that survival rates and life expectancy are at least as high as those of wild populations (Jaakkola et al., 2019).

From the early years to the modern dolphinaria in Germany

Dolphin enclosures: From one-pool designs to modern enclosures using multi-pool systems

Almost all dolphinaria that opened within the US after Marineland Florida had the advantage of being close to the ocean, allowing them to make use of fresh seawater and freshly caught marine fish as well as suitable climatic conditions. It was only in 1961 that the first inland dolphinarium opened its doors in Chicago, IL, the Seven Seas Panorama at the Brookfield Zoo.

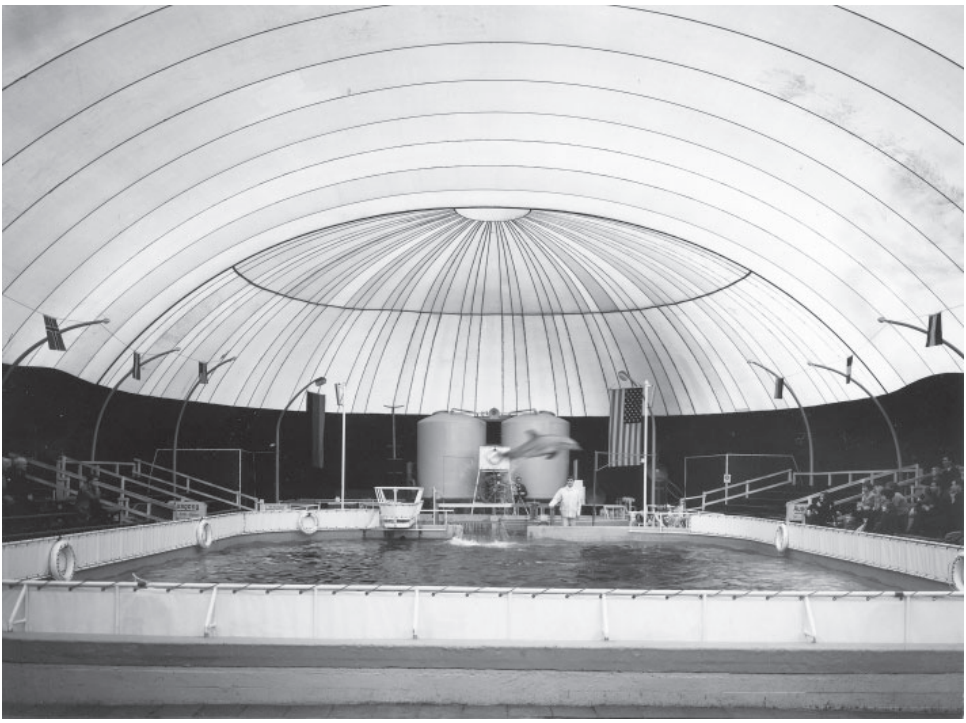

Fig. 1: The first dolphinarium in Germany opened 1965 in Duisburg (Photo by Zoo Duisburg).

In 1965, the first German dolphinarium opened at the Duisburg Zoo. Still being a provisional facility called "Versuchsanlage für Delphine" (i.e., "experimental exhibit for dolphins"), the basin (15 x 12 m, 3.50 m deep) had no solid roof and only an air-inflated tent (see Fig. 1).

Providing artificial seawater and sufficient high-quality nutrition as well as the long and strenuous transportation for the dolphins were the main challenges that had to be faced. Four bottlenose dolphins then arrived from Miami Seaquarium on July 4th in 1965 and set the foundation for holding dolphins in Germany.

While the first dolphin facilities only had small single pools with no extra holding possibilities for the dolphins, the state-of-the-art facilities of the 1960s and 1970s all were designed similarly and almost always consisted of one main pool, used for the presentation of the animals to the public, and two or three smaller holding pools for separation purposes. Over time, the round tanks became bigger and deeper, as seen in the two German facilities opened at that time. In 1968, the provisional arrangement in Duisburg was replaced by the first permanent dolphinarium, which became an example for many others in Europe. The main pool (160 m^2, 4 m deep) was connected to four holding pools that were not visible to the visitors (72 m^2, 3 m deep) and provided a total water volume of 0.86 million liters.

The second German dolphinarium opened in 1971 at Nuremberg Zoo with five bottlenose dolphins. Planned by the same architect and following the Duisburg model, it also consisted of a main pool (176 m^2, 4.4 m deep) and some smaller holding pools backstage (64 m^2 and depths between 1.55 and 4.4 m) with a total volume of 0.88 million liters. The holding areas were just used at night and the animals only had access to the main pool during the majority of the day.

Bottlenose dolphins live in so-called fission-fusion societies (Connor et al., 2000), characterized by ever changing associations among individuals. In order to accommodate this type of social organization, it was soon realized that several inter-connected pools were needed to provide adequate housing conditions, but also to improve animal husbandry measures. By giving the animals the freedom of choice of which pools to use, they could choose where and with whom to spend their time and were able to avoid social tensions. Animal husbandry is facilitated by having the ability to separate animals for short-term purposes (e.g., diseased ones, mother-calf pairs, or for research purposes).

In 1995, a new pool complex was built in Duisburg and connected to the dolphinarium, leaving the older part as a quarantine and breeding area. When this is not needed, the dolphins can access all pools (3.5 million liters of water) 24 h per day.

In Nuremberg, the first step towards a multi-pool system was the construction of a new pool in 1991. It was added to the main one, resulting in a total of 1.3 million liters of water. Then in 2009, the foundation stone was laid for a new outdoor facility, the so-called *dolphin lagoon*. This took several years of planning and was conceived to connect the new outdoor pools to the already existing indoor dolphinarium. Completed in 2011, the new lagoon offers the animals five outdoor and two indoor pools (in the old dolphinarium), with a total of 8 million liters of salt water (see Fig. 2). There are shallow-water and beaching areas, as well as graduated pools with depths up to 7 meters. Each pool has at least two accesses, so that circular swimming is possible in the entire area. Two of the outdoor pools can be covered by an air dome during the winter.

Medical pools with lifting platforms

Since in the early days, when animals were still caught from the wild, individuals were formerly selected on their outer appearance alone and no pre-transfer checkup could be performed, it was only possible to see and address health issues after arrival (e.g., parasitic infection, fungal

Fig. 2: Aerial view of the dolphin lagoon at Nuremberg Zoo. The lagoon consists of five connected outdoor pools of different sizes and with different depths. The indoor dolphinarium (right) is also part of the dolphin enclosure and consists of another 2 pools. (Photo by Hajo Dietz)

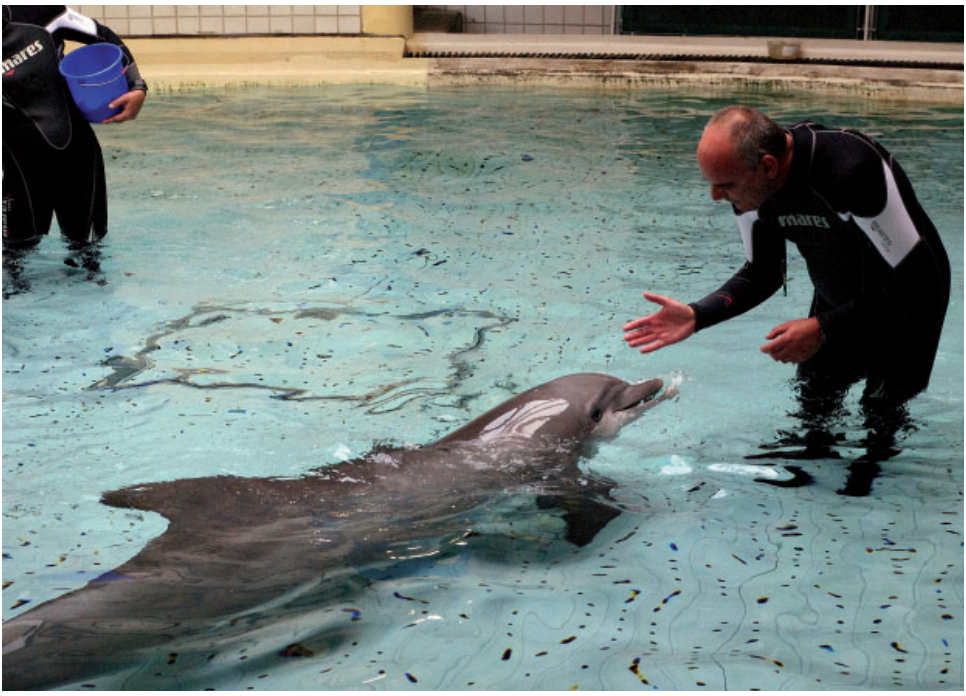

Fig. 3: Lifting platforms allow trainers to directly approach the dolphins in shallow water and thus facilitate, among other things, medical training, or interventions on newborn animals. In the photo shown here, the lifting platform was raised to a water depth of approx. 60 cm in an otherwise 4 m deep pool. (Photo by Nuremberg Zoo)

infections). Immediate access to the animals was often necessary and therefore small lifting platforms were installed at the beginning. These were positioned in the gate areas and usually designed for one animal only.

Nowadays there are highly technical platforms large enough to allow lifting several animals at the same time. In Nuremberg, such a lifting platform was installed in a round indoor pool with a diameter of 12 meters and a depth of 3.5 meters (see Fig. 3). The lifting floor can be brought to the desired level within a few minutes. Through regular training sessions, dolphins become well accustomed to the lifting procedure. This management tool greatly improves animal husbandry, since it allows better access to the animals. This is not only helpful in breeding situations, but also for diagnostics, treatments, and transport preparations.

Life Support Systems (LSS)

The early stages required also the development of LSS, which are essential for good water quality. The first hurdle in the early days was the creation of an artificial saltwater environment. Dolphins are dependent on salt water, as it helps with buoyancy and reduces their energy expenditure. The next step was to add a filter to the closed-circuit system. Apart from mechanical filtration, the number of bacteria and algae had to be constantly limited.

In Duisburg, the water filtration system based on chlorination was changed to biological filtration. In addition to the mechanical filters, protein skimmers and ozonation were used. While

Figure 4: Typical life support systems of modern dolphinariums include drum filters (A), protein skimmers (B), and ultrafiltration systems (C). (Photos by Nuremberg Zoo)

this increased the workload, in the form of manual pool scrubbing by divers, it provided a more natural experience for the zoo visitors.

In Nuremberg, as well, disinfection was initially based mainly on chlorination. In the new lagoon, a modern, automated life-support system was installed, with drum filters for the mechanical filtration (see Fig. 4A), protein skimmers (see Fig. 4B) and sand filters covered by hydro anthracite, using ozone as the main disinfectant and chlorine as the secondary one. An ultrafiltration system (see Fig. 4C) and UV-disinfection were also put in place.

Mixed species exhibit

A special feature of the dolphin husbandry in Nuremberg is that bottlenose dolphins have been kept in mixed exhibits with different pinniped species since 1971, first with South American fur seals (*Arctocephalus australis),* then with California sea lions (*Zalophus californianus*). Since then, the breeding of California sea lions has been very successful and offspring from Nuremberg can be found all over the world and seventh generation cubs have already been raised. To accommodate the needs of all species, some pools in the lagoon were designed to be suitable for young sea lions that include shallow water areas as well as separate pens for simultaneous births. The multi-pool system allows them to be separated during birth and then slowly be introduced into the rest of the group as well as the dolphins. The sea lions can also use the islands between the pools and the terrestrial part of the enclosure. This animal constellation allows a great deal of interaction among the individuals and is seen as an enrichment for both species (Fig. 5).

Fig. 5: Dolphin and California sea lion interaction at Nuremberg Zoo (Photo by Nuremberg Zoo)

Dolphin Management

When the zoological management of cetaceans began, almost everything one knew was either related to observations in the wild or necropsies on carcasses of stranded animals or those caught and killed industrially. More and more experience was gained by keeping the animals under human care.

Nutrition

A well-balanced diet of high-quality food is of utmost importance for any animal. The food must be carefully selected, palatable, of good nutritive value and free from contamination. It is also important to ensure that the thawing method prevents the loss of ingredients and guarantees good quality (Gimmel et al., 2022). Each animal receives an individually prepared diet, based on its age, condition and reproductive state (e.g., pregnant, nursing, growing, etc.). To meet these requirements each food item, fish, or squid, is evaluated every day before feeding and certain quality parameters and caloric and fat content are analyzed on a regular basis. This also facilitates a calculation of food energy requirements, based on the weight and condition of the animal (Rosen & Worthy, 2018). The dolphins are offered a variety of fish and receive vitamin and mineral supplements based on the results of blood tests.

Especially bottlenose dolphins, who range at the upper end of the food chain, need to be protected from the highly polluted fish species found along the world's coastlines. Dolphins can store pollutants, such as heavy metals, in their blubber layer, resulting in various organic consequences on a long-term basis. These pollutants can be measured by blubber biopsies, a method performed yearly on wild populations to follow-up on the situations at the coastlines (Kucklick et al., 2011).

Based on present knowledge, we can provide food items from less-polluted waters. In addition, some animals with a higher need for hydration receive freshwater with their daily diet.

Improvements in veterinary medicine and medical training

In the beginning, diagnostic methods for dolphins had to be developed by modifying certain tools that had been created for terrestrial animals and extrapolating medications.

Now we have profound knowledge of physiological data, such as blood reference values and scientific data about prophylaxis and therapy for bottlenose dolphins, and hardly any limitations for diagnostic and therapeutic options for dolphins. Even computer tomography and magnetic resonance imaging can be carried out.

Medical training plays an important role in keeping dolphins. The principle of positive reinforcement was developed right from the start (Pryor, 2002). Comparable to the clicker training in dogs, for example, the trainer looks for a certain behavior and reinforces it. This reinforcement needs to be precisely timed. Therefore, a so-called "bridge" is introduced. The bridge, in our case, a whistle, reinforces the behavior instantly and a reward can then be given. An animal's participation is completely voluntary.

Many different procedures can be carried out through medical training, allowing important improvements in a preventative medical program. Physical exams can be performed, including weighing the animals, auscultation, and palpation as well as eye, teeth, and skin checks (for further review, see Brando, 2010).

Various samples can be taken including blood that has been proven most valuable, as they provide reference values for healthy as well as for certain disease conditions. Saliva and skin samples can give information on the health status as well as hormone and cortisol levels. Gastric, blowhole and fecal samples provide current information on microbiological flora and are also important for cytology and the detection of certain diseases. Urinary samples can be important for both health assessment and hormonal analysis.

Other valuable diagnostic methods can be applied on a voluntary basis such as radiographic imaging that might be important for health assessments and in cases of suspected diseases. Electrocardiography or encephalography can also be carried out by asking the animal to "beach", a trained behavior where it lies on land for a short amount of time. Ultrasonography is one of the

most important tools, as it can be carried out as an in-water procedure during voluntary medical training. Since dolphins have no fur, and water being an excellent coupling media, one can obtain images of multiple organs, follow-up diseases and healing processes, as well as general organ functioning, including the hormonal status (e.g., testicular, or ovarian ultrasound) or fetal development in pregnant animals (see Fig. 6). Gastroscopies can be carried out without the necessity of restraining the animal and can provide information not only about the digestive tract, but also on the animal's hormonal and welfare status. Moreover, therapeutic measures can also be carried out, including injections, the administration of fluids, wound treatment, the treatment of eye or dental diseases, etc.

Research in veterinary medicine

Medical training is not only important for prophylaxis, diagnostics, and therapy, but also crucial for conducting research, as is shown by the following projects. Many dolphinaria around the world conduct veterinary research, leading to improved knowledge about the physiology of dolphins and thus can lead to more targeted procedures.

In recent years, the focus in Duisburg and Nuremberg has been on the following topics, some of which have already been published, while for others the research is still in progress.

Vitamin supplementation

This study evaluated fish-handling techniques and vitamin supplementation. Blood samples from 57 bottlenose dolphins living in 10 European facilities were analyzed in a reference laboratory for retinol, thiamine pyrophosphate, cobalamin, calcidiol, and tocopherol. Blood concentrations were then correlated to the fish preparation procedures and compared to the blood concentrations of free-ranging dolphins, resulting in a proposal for future fish handling and vitamin supplementation (Gimmel et al., 2016).

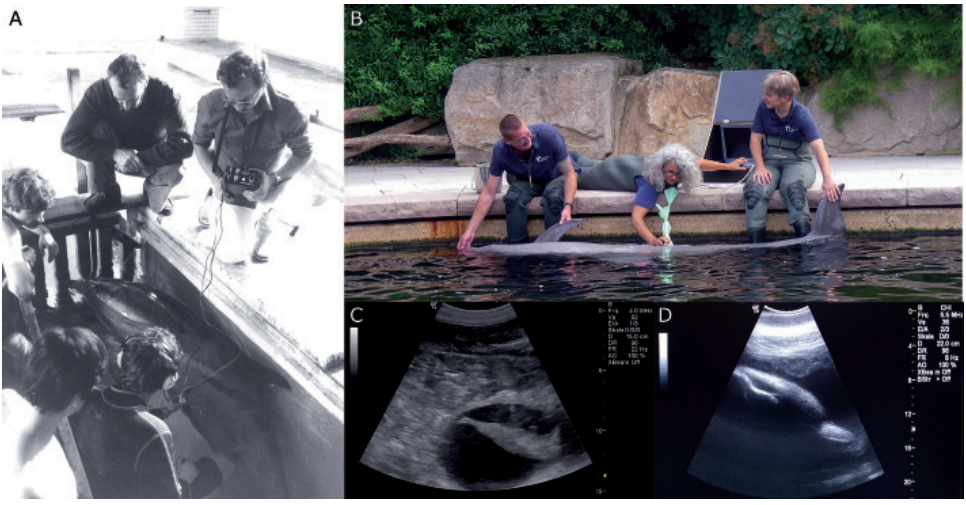

Fig. 6: Ultrasound examinations. While in the early days ultrasound examinations often included a restriction of the animal (A), today's progress in medical training allows veterinarians to conduct a sonogram to monitor the status of a pregnant female (B) as well as the unborn calf (C, D) on a voluntary basis. (Photos by Zoo Duisburg (A, C) & Nuremberg Zoo (B, D))

Salivary and blood cortisol measurement in bottlenose dolphins

At both zoos, blood cortisol levels are routinely analyzed. Cortisol levels are one of the most commonly used biomarkers to measure the level of stress in many zoo animals (Whitham et al., 2020), including bottlenose dolphins (Galligan et al., 2018; Romano et al., 2004; Suzuki et al., 1998; Suzuki et al., 2002; Suzuki et al., 2003).

One of the main findings from the long-running cortisol monitoring at both, Duisburg and Nuremberg Zoo, was that the blood cortisol content of bottlenose dolphins was shown to depend on the sampling procedure used. Cortisol levels were significantly lower when blood samples were taken during voluntary medical training (see Fig. 7), as compared to when dolphins are sampled on a lifting platform. New approaches to measure cortisol non-invasively have become more and more popular. Collecting saliva has been shown to be most feasible to track cortisol levels in many terrestrial mammal species (great apes, jaguars, elephants, spider monkeys, rhinoceros, tamarins etc.). In dolphins, reliable measurement of salivary cortisol is more challenging due to different circumstances, such as sample dilution with pool water and only few studies exist (Monreal-Pawlowsky et al., 2017; Pedernera-Romano et al., 2006; Ugaz et al., 2013). While it has been shown in several mammal species that blood cortisol levels correlate with the cortisol levels measured in saliva samples, the study conducted at Nuremberg Zoo by Rickert et al. (2021) did not find a correlation between salivary cortisol and blood cortisol values. Moreover, it was very interesting to find that salivary samples can also be contaminated by fodder fish, which may exhibit high cortisol values. It is thus important to be very careful when sampling saliva and to interpret salivary cortisol values with caution (Rickert et al., 2021).

Fig. 7: Trained voluntary blood sampling at Zoo Duisburg (Photo by Zoo Duisburg)

Heart ultrasound

Transthoracic cardiac ultrasound examination of bottlenose dolphins was first established by Stefan Miedler at Nuremberg Zoo in 2001 and has become a valuable diagnostic tool in recent years. It can be used in different situations, be it in older animals in the form of a checkup, in animals with a known cardiac, lung or kidney problem or in pre-transport examinations. If performed on a regular basis, small cardiac abnormalities can also be detected early to allow treatment to be initiated (Miedler et al, 2008; Miedler et al, 2015).

Ocular health

A dissertation study started at the Duisburg Zoo was carried out in many different zoos to complement dolphin welfare assessment. Ocular health is also of outmost importance, as any disease can be quite compromising to an animal's welfare. Within the framework of the research project, the physiological anatomy, and pathological findings of the eye of bottlenose dolphins were determined by ultrasound examination (see Fig. 8). Ophthalmological sonography was supplemented by a physical examination and general ophthalmologic examination adapted to the bottlenose dolphin species.

This study provides a non-invasive approach achieved through medical training that will hopefully enable veterinarians and trainers to detect ocular abnormalities and pathologies at an early stage.

Fig. 8: Ophthalmological sonography performed on a dolphin at Zoo Duisburg. (Photo by Zoo Duisburg)

Animal welfare assessment

The need for research on how to assess, monitor and improve the welfare of their animals became a central issue for zoos and aquaria. In response to this demand the welfare committee of the European Association for Aquatic Mammals (EAAM) brought together a heterogeneous group of experts on welfare science, cetacean biology and/or zoo medicine across Europe, aimed at developing the so-called "Dolphin Welfare Evaluation Tool" (Dolphin WET), a protocol for evaluating the welfare of bottlenose dolphins. The integration of the multidimensional aspects of welfare was inspired by Mellor's "Five Domains" model (Mellor et al., 2020) and the protocol's hierarchical structure of the Welfare Quality®, consisting of overall welfare assessment > principles > criteria > sub-criteria > welfare indicators. Importantly, the present protocol highly prioritizes animal-based indicators and does not allow compensating between principles or between criteria or sub-criteria of the same principle. Moreover, the protocol is intended to assess the welfare status of the dolphins over a three-month period, by combining animal-based indicators and the information provided by records (see Fig. 9). The aim of the protocol is to provide a science-based tool for the evaluation, protection, and improvement of the welfare of dolphins under human care, which could be used mainly for internal purposes as routine welfare monitoring, including identification of welfare concerns and daily welfare management. The protocol is currently being applied in various European institutions.

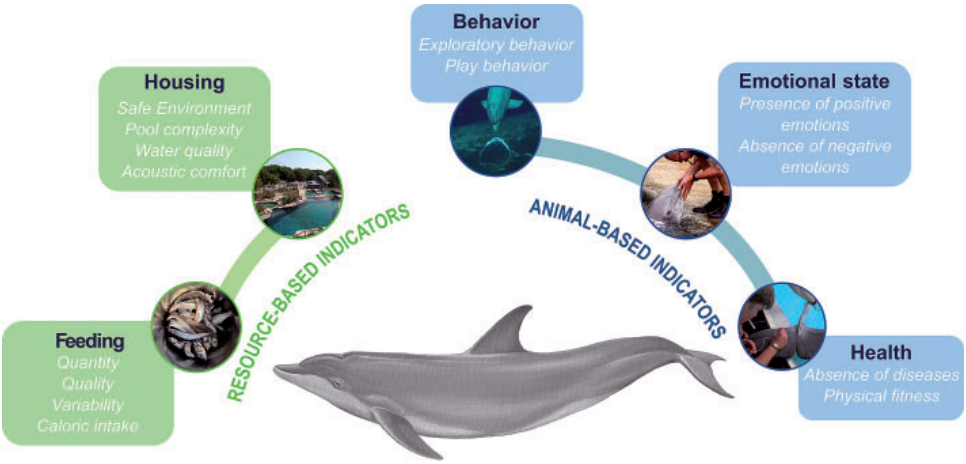

Fig. 9: The main structure of the Dolphin Welfare Evaluation Tool (Dolphin WET) includes the five principles following the Five Domains model (Mellor et al., 2020; Rogers Brambell, 1965) and prioritizes animal-based indicators. (Dolphin by J. Mazur)

Life expectancy

An often-discussed topic regarding animals under human care is the life expectancy. Since this is often seen as an indicator of overall health and well-being, the question of how it compares to the wild is also interesting (Jaakkola et al., 2019). However, it is challenging to compare data from animals under human care to that of wild animals because neither are single populations, there being many different wild populations and the animals kept in zoos and dolphinar-

iums live under different circumstances. The mathematic calculations used also differ from one another (Jaakkola et al., 2019).

Jaakkola et al. (2019) compared life expectancy and survival rate for dolphins in zoological facilities in the US and were able to show that life expectancy and annual survival rate of dolphins kept in American marine mammal facilities have increased significantly over the years. Compared to those wild population with comparable data, e.g., the well-studied Sarasota population, life expectancy of dolphins in US zoological facilities is at least as high as the one of wild animals.

Calculating Life Expectancy (LE) and Annual Survival Rate (ASR) for all dolphins older than 90 days of age across the two German dolphinariums across two time periods (1980-1999; 2000-2023) results show that for both parameters a similar pattern can be observed (Tab. 1). We can note that LE and ASR, overall and facility-wise, increases between 1980-1999 and 2000-2023 (see Tab. 1). With a calculated life expectancy of >40 years since 2000 the medium lifespan of bottlenose dolphins living in German facilities are higher as those of dolphins living within US zoological facilities or in the wild (Jaakkola et al., 2019). However, given the very small sample size for these kinds of calculations, these data must be interpreted very cautiously.

Tab. 1: Annual Survival Rate (ASR) and corresponding Life Expectancy (LE) calculated for both German dolphinaria since the start (all time) and for two periods (1980-1999; 2000-2023).

	Nuremberg		Duisburg		both	
Period	**ASR**	**LE**	**ASR**	**LE**	**ASR**	**LE**
all time	0.9571	22.7892	0.9525	20.5343	0.9546	21.5007
1980-1999	0.9633	26.7392	0.9648	27.9017	0.9675	30.2248
2000-2023	0.9773	43.5051	0.9766	42.3030	0.9770	42.9899

If we look at the European population over decades, a similar development can be seen, and life expectancy increased continuously over the last 40-plus years (see Tab. 2) up to an average life-expectancy of approx. 33.1 years (2010-2019). At the same time, the number of zoo born animals has also increased from to 9% between 1980-1990 to over 70% between 2010-2019 (Fig. 9).

Tab. 2: Development of the mean life expectancy within the EEP (EAZA Ex-situ Programme) population of bottlenose dolphins over each decade since 1980.

	Time period			
EEP Population	**1980-1989**	**1990-1999**	**2000-2009**	**2010-2019**
Males	23.4	23.7	30.0	33.8
Females	17.7	20.0	23.7	32.5
Average	20.5	21.8	26.8	33.1

Breeding and early intervention

The breeding of bottlenose dolphins has been important from the beginning, not only to establish a self-sustaining population, but also to allow animals under human care to experience natural behavior and live in social groups. Another aspect of reproduction is its important role in the well-being of the animals, as parturition and nursing are essential needs and activities to keep the animals stimulated and active.

In the early years, breeding dolphins was not difficult, but a high neonatal mortality was the main worrying factor. Bottlenose dolphins have a diffuse, epitheliochorial placenta, similar to horses. This means that there is no transfer of antibodies from dam to calf before birth. Only the colostral milk does provide the antibodies to cope with pathogens in the environment until the immune system takes over. If colostrum uptake is insufficient or too late, the offspring will be more prone to infections.

A comparison to the situation in the wild is hardly possible. Abortions, stillbirths, and predation would never be detected and sometimes even in the best-monitored populations, e.g., the one in Sarasota, Florida, calves that only live for a few days could be missed due to bad weather conditions.

The first birth in Duisburg took place in 1978. The dolphinarium was opened to the public immediately and everybody was invited to see the first dolphin offspring. Unfortunately, the animal died of pneumonia on day 13. In the years that followed, 26 more animals were born alive in Duisburg, five fetuses were aborted. 12 of the 26 animals survived their first year of life.

In Nuremberg, the first bottlenose dolphin was born in 1986, followed by another in 1990, two in 1993 and one in 1998. All five animals grew up healthy. Then followed years with calf losses. The reasons were various: in one case of attempted hand rearing (2004), the animal died of an aspergillosis after 30 days, two calves failed to thrive with primiparous mothers, others did not survive due to traumatic events, or an aspiration pneumonia, and also one female had a stillbirth. After this accumulation of juvenile losses, the Nuremberg Zoo commissioned the Leibniz Institute for Zoo and Wildlife Research to investigate the causes. The result was that no clear pattern for the deaths could be identified and, more importantly, that pathogens did not play a predominant role.

Before the installation of modern lifting platforms, all interventions concerning mother and calf were difficult and dangerous. The necessary net capture was stressful, and the small plat-

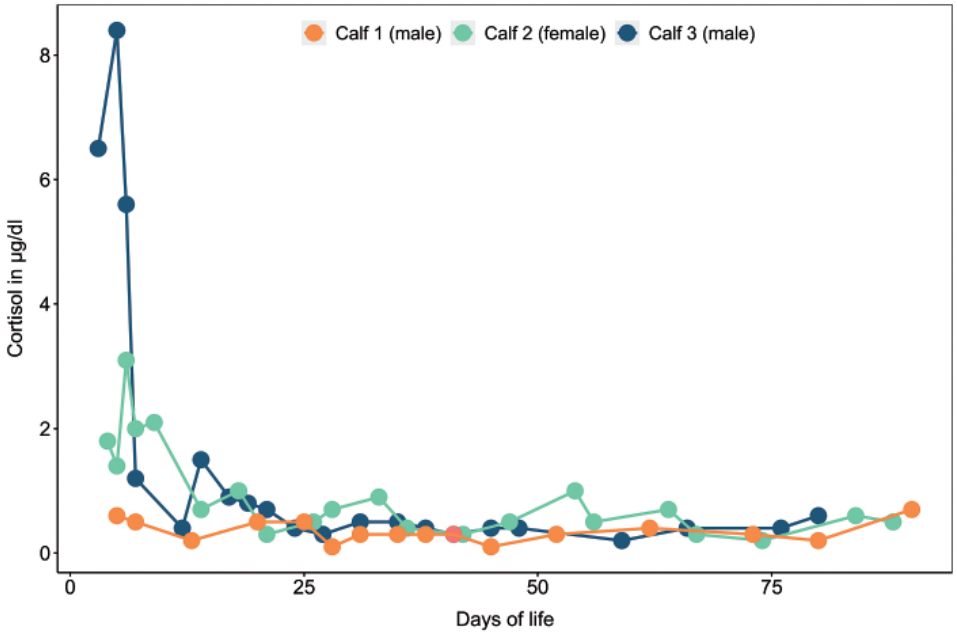

Fig. 10: Cortisol levels of three calves born at Zoo Duisburg in 2011 over the first 90 days of life decrease to baseline levels within days after birth. Cortisol measurements were carried out each time blood samples were taken.

forms were not suitable for animal fixation purposes. This led to a situation where there often was no possibility of intervening and breeding management was limited to observation.

Today's lifting platforms (see Fig. 3) simplify the hands-on procedures on newborn animals. The size of the platform allows regular training, and mothers and calves can be examined there together without being separated which reduces stress for both animals. The use of lifting platforms made it possible to stop the wait-and-see-tactic and apply a more proactive approach, so-called early intervention (Sweeney et al., 2010). Dolphin calves are not as sensitive as they were thought to be. Getting hands on them from an early age makes intervention possible and has already helped many animals to survive the first critical month of life and built up a properly functioning immune system. Calves are weighed, samples taken, and treatment initiated when necessary. The dam is able to remain in contact during the whole procedure, making it as stressless as possible. Measuring the blood cortisol levels over the first 90 days, a study conducted at Duisburg Zoo showed that, even in inexperienced first-time mothers, cortisol levels of the newborns dropped to baseline levels within days after birth (Fig. 10).

A birth protocol, established to help prepare for births (Baumgartner et al., 2018), resulted from years of experience in managing bottlenose dolphins, scientific research, and the advances in marine mammal medical knowledge. It includes all steps of parturition, birth, and the mother-calf relationship, and it is a very useful tool in the preparation of breeding dolphins. It is divided into the following sections: preparation, female pre-partum, female intra-partum, female post-partum, and calf post-partum. The observation and monitoring of mother and calf through all stages not only enables an intervention as soon as necessary, but also creates opportunities for international scientists to study maternal behavior, as well as the anatomy, physiology, and pathologies of the offspring. The protocol was published in 2018 and has proven to be highly effective in decision making and could help enhance dolphin reproduction in similar situations at other facilities.

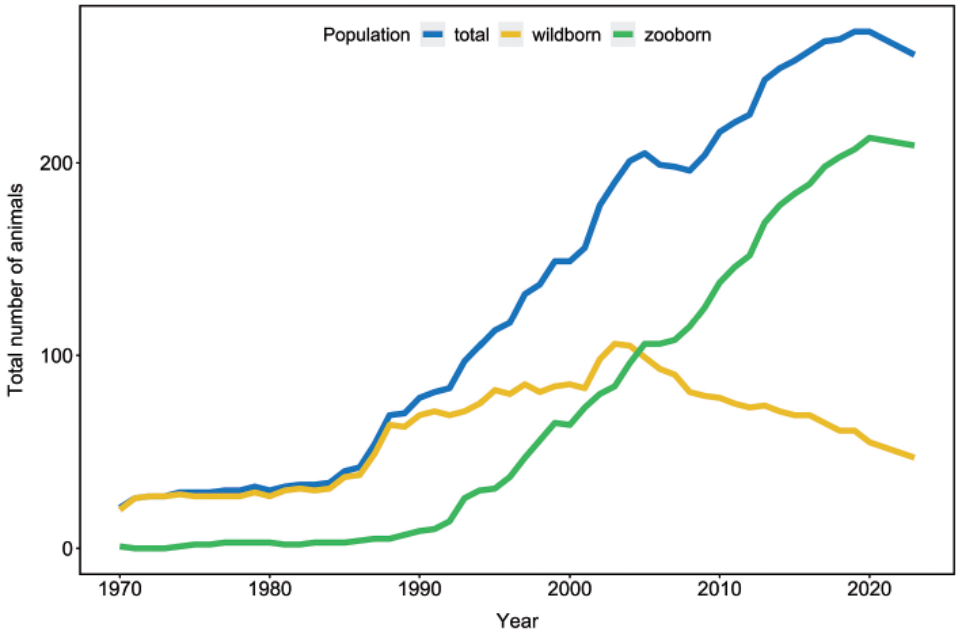

Fig. 11: Development of the EEP population since 1970 comparing the percentage of wild born versus zoo born animals across all EEP facilities.

In Duisburg and Nuremberg this proactive approach led to an increased survival rate of newborn dolphins. In the last 15 years, 17 calves were born in Duisburg and Nuremberg, of which 10 survived, resulting in a survival rate of 58.8 %.

Thanks to the early intervention protocol and with the knowledge that social learning is important for successful rearing, reproduction has become very successful during the last two decades in the United States and in Europe, creating a self-sustaining population (van Elk & Hartmann, 2013). Since 2003, the *bottlenose dolphin* EEP (EAZA Ex-situ Programme) has been fully self-sustaining and since then is based only on their own offspring. By 2007, almost all scientifically managed dolphinaria in Europe had joined the EEP for bottlenose dolphins and of the almost 260 animals currently in the program, 20% are founder animals and 80% percent are zoo-born (see Fig. 11).

Conclusions

The husbandry and management of bottlenose dolphins under human care has not only improved greatly but rapidly in recent decades. Zoo Duisburg and the Nuremberg Zoo are two examples of the development of dolphin husbandry worldwide. Whereas in the beginning hardly anything was known about bottlenose dolphins, and most conclusions about their anatomy, physiology or biology were only drawn from necropsies of stranded animals, they are now among the most and best researched cetacean and zoo species worldwide. Even today, new findings are being made, such as establishment of passive electroreception in bottlenose dolphins by a study conducted to Nuremberg Zoo (Hüttner et al., 2022).

Only by keeping dolphins under managed-care, it was possible to find out more about their behavior, communication, and sensory abilities, and the advances in veterinary medicine and animal welfare have made the population under human care a healthy and self-sustaining one. In the course of the One-Plan-Approach (Byers et al., 2013) or the One-Health-Approach (Adisasmito et al., 2022), it is exactly this knowledge which makes an indispensable contribution instead of in the field of Conservation medicine (see Smith et al., this special issue). More and more, especially small cetaceans become endangered, and the advances made in the management of species such as the bottlenose dolphin can be of enormous importance when it comes to the treatment and rehabilitation of stranded animals (Meegan et al., 2022) or, if necessary, in the implementation of ex-situ conservation measures.

Zusammenfassung

Die Haltung von Großen Tümmlern in menschlicher Obhut begann 1938 in Florida. 1965 kamen die ersten Tiere nach Deutschland. Seitdem wurden viele Studien durchgeführt und wichtige Erkenntnisse in der Meeressäugermedizin, Zucht, Haltung und im Tierschutz gewonnen. Dies führte zu einer heute sich selbst erhaltenden Population innerhalb Europas, in der die Lebenserwartung der Tiere kontinuierlich steigt. Anlässlich des mehr als 50-jährigen Bestehens der Delfinhaltung in Deutschland werfen wir einen Blick auf die Entwicklung der beiden heutigen deutschen Delfinarien und wie sie sich im Laufe der Zeit verändert haben. Mit den in dieser Zeit gewonnenen Erkenntnissen und durch aktuelle wissenschaftlichen Studien tragen Duisburg und Nürnberg nicht nur zur

weiteren Verbesserung der Haltungsbedingungen von Delfinen bei, sondern helfen auch bei Umsetzung von Ex-situ-Schutzmaßnahmen bedrohter Delfinarten.

Fig. 12: Underwater view of the dolphinarium at Zoo Duisburg. (Photo by Zoo Duisburg)

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