# DER ZOOLOGISCHE GARTEN

# THE ZOOLOGICAL GARDEN

**Zeitschrift für die gesamte Tiergärtnerei** (Neue Folge)

Offizielles Organ des Verbandes der Zoologischen Gärten – VdZ
Organ of the World Association of Zoos and Aquariums – WAZA

ISSN 0044-5169
Zool. Garten N.F.
91 (2023) 2 · pp. 79-189

**Volume 91**
**Issue 2 · 2023**

# DER ZOOLOGISCHE GARTEN

## THE ZOOLOGICAL GARDEN

**Zeitschrift für die gesamte Tiergärtnerei (Neue Folge)**
**Offizielles Organ des Verbandes der Zoologischen Gärten – VdZ**
**Organ of the World Association of Zoos and Aquariums – WAZA**

DER ZOOLOGISCHE GARTEN ist eine internationale, wissenschaftliche, von Fachleuten begutachtete Zeitschrift, die allen die Tiergärtnerei (im weitesten Sinne) betreffenden Originalarbeiten offensteht. Neben größeren Abhandlungen werden Kurzmitteilungen und Nachrichten aus Zoologischen Gärten aufgenommen.

THE ZOOLOGICAL GARDEN is an international scientific peer-reviewd journal which is open to all original papers concerning zoo biology and related topics. In addition to larger original scientific contributions, we accept short notes and news from zoological gardens.

Founded in 1859 and continued since 1929 as "New Series" by Georg Grimpe, Karl Max Schneider, Heinrich Dathe, Hans-Günter Petzold, Wolfgang Grummt, Bernhard Blaszkiewitz and Ragnar Kühne.

**Aims and Scope**

THE ZOOLOGICAL GARDEN covers all aspects of zoological gardens, as for example

- experiences in breeding and keeping zoo animals
- management of zoological gardens
- behavioral science
- research on animals in the wild
- conservation of rare and threatened species
- reintroduction projects
- planning, building and designing at zoological gardens including horticulture
- veterinary medicine
- zoological pedagogic
- history of zoological gardens
- news from zoological gardens
- book reviews

# DER ZOOLOGISCHE GARTEN

## THE ZOOLOGICAL GARDEN

Zeitschrift für die gesamte Tiergärtnerei (Neue Folge)

Volume 91 · 2023

# DER ZOOLOGISCHE GARTEN

## THE ZOOLOGICAL GARDEN

**Zeitschrift für die gesamte Tiergärtnerei (Neue Folge)**

Volume 91 · 2023

VNW

Verlag Natur & Wissenschaft · Solingen

DER ZOOLOGISCHE GARTEN

THE ZOOLOGICAL GARDEN

doi:10.53188/zg0016

Zool. Garten N.F. 91 (2023) 79-80

# Foreword

Normally we do not start the DER ZOOLOGISCHE GARTEN, THE ZOOLOGICAL GARDEN, with a foreword, but for this special issue, the issue 2 of Volume 91, in which we show to the inside and the outside world how important modern dolphinaria are today and how we cooperate globally with other experts, I make an exception.

As Editor-in-Chief but also as Past-President of the World Association of Zoos and Aquariums (WAZA) and as Co-Chair of Reverse the Red (RtR), I am very proud that we were able to put together so many interesting, scientific articles of high ranking scientists over the globe on the topic of cetaceans, especially on their research, their management in human care, science-based conservation or conservation medicine.

And I like to congratulate all, exemplary the zoo of Nuremberg (Tiergarten Nürnberg) on the 50$^{th}$ anniversary of keeping and breeding dolphins in Germany, the first dolphin arrived in 1965. It is a good example of how keeping, breeding and animal welfare of wild animals in human care, carried out by experts, has improved especially over the last decades. You will read that the European population of the bottlenosed dolphin became self-sustaining. The life expectancy of these animals has increased and we can prove this with our own data.

The articles show how animals can benefit from our work, even ex situ but more and more mixed with in situ projects. We live the One Plan Approach of the Conservation Planning Specialist Group (CPSG).

Dr Lorenzo von Fersen initiated this special issue of our peer-reviewed magazine and I like to thank him and his team and especially Jörg Beckmann for collecting all these great articles.

And I am totally proud that no less than Prof Dr Jon Paul Rodríguez, the Chair of IUCN's Species Survival Commission (SSC), teaching at the Instituto Venezolano de Investigaciones Científicas, and head of the Non-Governmental Organization Provita, Caracas, Venezuela, has written introductory remarks for this issue. This shows also that the scientific run zoos and IUCN are partners at eye level.

Of course you know about the biodiversity loss crisis which we experience. But the zoos and aquariums of the Verband der Zoologischen Gärten (VdZ) e. V. and the World Association of Zoos and Aquariums, are fighting this crisis. That's why we are organized and run many breeding programs up to the reintroduction of animals following the IUCN Reintroduction Guidelines. We need to be inclusive, have to improve other zoos and aquariums, as we need more good, scientific run zoos to fulfill our goals: education, research and of course conservation.

Dr Rodriguez highlights the One Plan Approach and I would like to draw your attention to Reverse the Red – if you have not yet heard of it, please check our website (www.reversethered.org). We want to create a movement that makes people aware of the importance of biodiversity. And yes, we are planning to have a Species Congress next year. At this congress we want to share science but also many stories of success what we and all the other players in conservation have reached. We need to tell stories of hope and get societies involved. In addition, we are establishing more and more so called Centers for Species Survival (CSS). These are partnerships between the SSC Chair's Office and leading species conservation organizations. CSSs will closely work across NGOs, government agencies, zoos and aquariums, and among other stakeholders to understand the key networks and conservation efforts that are underway in their country or region. This will enable all involved parties to identify priority gaps and ensure that efforts, resources and experts are even more effectively connected and hopefully maximize our conservation impact.

Finally, I want to thank especially all authors not only for their articles but also for their work which made these articles possible. And a special thanks goes to all who were involved and supported these kind of important research!

Yours,

Prof Theo B. Pagel
Editor-in-Chief

DER ZOOLOGISCHE GARTEN
THE ZOOLOGICAL GARDEN

doi:10.53188/zg0016

Zool. Garten N.F. 91 (2023) 81-82

# Special Issue 50 Years Dolphin Husbandry at Nuremberg Zoo – Introductory Remarks

## Themenausgabe 50 Jahre Delfinhaltung im Zoo Nürnberg – Einführende Bemerkungen

Jon Paul Rodríguez

IUCN Species Survival Commission, Instituto Venezolano de Investigaciones Científicas, and Provita, Caracas, Venezuela

Bringing a species back from the brink of extinction is not easy, but it is certainly possible. Many examples exist, and zoos, aquariums and botanical gardens have played a key role in making this happen (CBSG 2017, Mittermeier et al. 2017). The Lord Howe Island stick insect (*Dryococelus australis*), the American burying beetle (*Nicrophorus americanus*), the Kihansi spray toad (*Nectophrynoides asperginis*), the Mauritius kestrel (*Falco punctatus*), the verticillate erica (*Erica verticillata*), the European bison (*Bison bonasus*), and the Kemp's ridley sea turtle (*Lepidochelys kempii*), among numerous others, recovered due to a combination of *in situ* and *ex situ* interventions, carefully planned and evidence-based.

That is the principle of the One Plan Approach (OPA) embraced by the IUCN Species Survival Commission (SSC) – the recognition that conservation planning and action must include all responsible stakeholders and all populations of a species, whether inside or outside their natural range (CPSG 2020), including *in situ* and *ex situ* populations. In other words, OPA provides the conceptual framework for assuring that every individual of threatened animals, fungus and plants subject to conservation interventions plays a role in the recovery of the species.

Resolution 79 (Linking *in situ* and *ex situ* efforts to save threatened species[1]), adopted the IUCN World Conservation Congress in Marseille in 2020, takes this one step further by encouraging the Union's constituents – Members, Commissions and the Secretariat – as well as Parties to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), to support application of all available tools in the design of conservation interventions. It highlights that it is never too early to explore the contribution that *ex situ* organizations may contribute, which include genetic and veterinary science, husbandry, sustainable breeding, education, and community engagement.

[1]https://portals.iucn.org/library/node/49218

*Author:
E-Mail: jonpaul.rodriguez@iucn.org (Jon Paul Rodriguez)

This special issue of *Der Zoologische Garten*, on the occasion of the 50th anniversary of dolphin husbandry at Nuremberg Zoo, brings together leading experts in the various fields of cetacean research, in the context of OPA. The backdrop is the fact that nearly half of the world's cetaceans are threatened, requiring rapid, coordinated, evidence-based action. The dramatic decline of baiji (*Lipotes vexillifer*) and vaquita (*Phocoena sinus*) serve as motivators to rapidly innovate in complementing *in situ* and *ex situ* efforts for cetacean conservation.

Von Fersen and Miller open the collection with a review of the role of modern dolphinariums in applying OPA to the conservation of threatened cetaceans. Taylor et al. summarize the recommendations of a working group on Integrated Conservation Planning for Cetaceans (part of the IUCN SSC Cetacean Specialist Group), which examined existing knowledge gaps and the potential contributions of the tools available to revert declining trends. Nachtigall & Pacini illustrate the role of dolphinariums for research, in this case the study of hearing in odontocete. Their findings provide a basis to evaluate the negative effects of noise pollution. Smith et al. focus on the body of work produced by the US Navy Marine Mammal Program, highlighting their contributions to conservation medicine of small cetaceans, especially dolphins. Baumgartner et al. bring our attention to what it means to keep dolphins from a practical point of view, by summarizing the work of Nuremberg and Duisburg Zoos leading to sustainable breeding and high life expectancy, among other achievements. Hao et al. address the urgent plight of Yangtze finless porpoises (*Neophocaena asiaorientalis*) by combining *ex situ*-population increase, natural habitat restoration and management, deepening research and knowledge generation, and further increasing engagement with the public. Secchi et al. close this special issue with a summary of 15 years of research in Brazil, Uruguay and Argentina on behalf of Lahille's bottlenose dolphin (*Tursiops truncatus gephyreus*), highlighting the key role of institutional collaboration and partnership across this subspecies' geographical range.

This special issue of *Der Zoologische Garten* is a perfect example of the implementation of OPA within SSC's Species Conservation Cycle, with its three consecutive components – assess, plan, act – and its two transversal elements – network and communicate (Rodríguez et al. 2023). More than 8,700 SSC experts in 186 countries engage in generating the scientific evidence that underlies the IUCN Red List of Threatened Species[2] and the conservation plans and proposed actions that emerged from them. As is perfectly illustrated in this special issue and the work of SSC in general, we know how to do conservation, we just need to do more of it.

## References

CBSG (2017). Second Nature: Changing the Future for Endangered Species. Conservation Breeding Specialist Group (CBSG), St. Paul, Minnesota.

CPSG (2020). Species Conservation Planning Principles & Steps, Ver. 1.0. IUCN/SSC Conservation Planning Specialist Group, Apple Valley, Minnesotta, USA.

Mittermeier, R.A., Rylands A.B., Sechrest, W., Langhammer, P.F., Mittermeier, J.C., Parr, M.J., Konstant, W.R., & Mast, R.B. (2017). Back from the Brink. CEMEX & Earth in Focus, Inc., Qualicum Beach, British Columbia, Canada.

Rodríguez, J.P., Sucre, B., Mileham, K., Sánchez-Mercado, A., de Andrade, N., & Jabado, R.W. (2023). We know how to do conservation – we just need to do more of it! Diversity 15(3): 443.

[2]https://www.iucnredlist.org/

doi:10.53188/zg0019

Zool. Garten N.F. 91 (2023) 83-100

DER ZOOLOGISCHE GARTEN

THE ZOOLOGICAL GARDEN

# Integrated Conservation Action for Small Cetaceans: A new Role for Modern Dolphinaria

## Integrierte Artenschutzmaßnahmen für Kleinwale: Ein Paradigmenwechsel für moderne Delfinarien

Lorenzo von Fersen[1*] & Philip S. Miller[2]

[1]Nuremberg Zoo and YAQU PACHA e.V., Am Tiergarten 30, D-90480 Nuremberg, Germany
[2]IUCN SSC Conservation Planning Specialist Group, 12101 Johnny Cake Ridge Road, Apple Valley, MN-55124 Minnesota, USA

## Abstract

The world is facing a biodiversity loss crisis that could be irreversible in the foreseeable future. The in situ protection of wildlife and their habitats may not be enough to stop the continued decline and extinction of some species. In these cases, new strategies for effective conservation must be employed. One such strategy is the One Plan Approach (OPA), which was launched by the Conservation Planning Specialist Group (CPSG) and later adopted by the International Union for Conservation of Nature (IUCN). Unlike conventional species conservation strategies, which primarily focus on the protection of species in their natural habitats, the OPA encompasses the broad spectrum of animal management across the in situ–ex situ spectrum, engaging all relevant stakeholders for improved collaborative decision-making. With the OPA, zoos have not only been assigned another important task but have now taken on responsibility for species conservation. While there is a consensus on the implementation of integrated conservation measures for most threatened plant and animal species, opinions differ regarding small cetaceans. This article aims to highlight this discrepancy and to show that many small cetacean species are not only calling for OPAs, but that first steps have already been taken to implement such an integrated approach. Zoological institutions that keep dolphins should be aware of the important role they now play and act responsibly.

**Keywords:** In Situ/Ex Situ Conservation, Cetaceans, Integrated Conservation, Zoos, Dolphinaria

*Corresp. author:
E-Mail: lorenzo@vonfersen.org (Lorenzo von Fersen)

## Integrated conservation in zoos

Nearly 100 years ago, zoos initiated a new era of conservation breeding when the first coordinated breeding programme was started for a species that was extinct in the wild. The European bison had disappeared from the wild by 1927, with only 54 individuals surviving in zoos. The first breeding programme was established in Bialowieza, Poland, and focused on the lowland line of this species. The descendants of just 12 animals were used for species restoration (Pucek, 1991) and were the founding animals for a zoo population that grew over the years and provided the basis for reintroducing animals into the wild. Since then, Poland has continued to lead the way in conservation breeding, with several breeding centres across the country. This programme also helped to establish new populations in other parts of Europe (Tokarska et al., 2011).

Other species then benefited from similar conservation breeding efforts, including the black-footed ferret (Jachowski & Lockhart, 2009), Arabian oryx (Spalton, 1993; Stanley Price, 2016) and Przewalski's horse (Wakefield et al., 2002). Conservation breeding programmes and habitat protection have contributed to the successful reintroduction of the California condor. In 1982, only 22 condors survived in the wild. To prevent the extinction of the species, those responsible for the project made a risky decision and that was to capture all the animals still surviving in the wild. Five years later a breeding programme to save the species was initiated. Over 500 condors are currently living in the wild again (Walters et al., 2010). Another good example of how zoos can contribute to the conservation of species is the Golden Lion Tamarin (*Leonto-*

**Fig. 1:** The golden lion tamarin: a species that has benefited from integrated conservation and is now back in its natural habitat. Photo © Andreia Martins/Associação Mico-Leão-Dourado

*pithecus rosalia*; Kierulff et al., 2012). By the early 1960s, the Golden Lion Tamarin was nearly extinct in its natural habitat (Atlantic Tropical Forest) in southern Brazil. The population living in zoos consisted of about 200 animals but was not stable due to low rates of reproduction and survival. In the 1970s, after many improvements, the captive population began to grow. At the same time, the Poço das Antas Biological Reserve was established to protect this species. The reintroduction of the Golden Lion Tamarin was a complex process involving several phases. First, captive breeding in zoos, in parallel with habitat restoration, allowed them to finally be released into the wild. Numerous zoos participated in the breeding programme, and some of them also supported additional project activities. A recent published paper estimates that in 2014, there were approximately 3700 golden lion tamarins in 41,400 hectares of the Atlantic Forest (Ruiz-Miranda et al., 2019).

A recent paper (Smith et al., 2023) reviewed the status of 84 species of plants and animals classified at one time as extinct in the wild (EW) on the IUCN's Red List of Threatened Species. Both extinction and recovery are possible fates for these species; given this reality, it is particularly encouraging that 12 species have regained their wild status today. Examples including the red wolf and European bison demonstrate that extinction can be reversed and that we can prevent extinction through carefully planned and executed conservation strategies. The tools to do this are available. Species that were thought to be lost could have a future again.

These and other examples share a consistent and – at the time of their application – an overdue zoo strategy: to maintain and breed species through thoughtful and dedicated ex situ management. It is no longer practical (or, for that matter, ethical) for zoos to acquire individuals from wild populations to display in their facilities. Successful ex situ breeding of many endangered species has been the result of good husbandry, improved environmental conditions and an exponential growth of knowledge in all areas of zoo biology (Kleiman et al., 2010 Irwin et al., 2013).

During these years, there has been a shift in the roles and responsibilities that zoos have set for themselves: from simply displaying wild animals to creating species conservation centres with a focus on scientific research, public education and active partnership with those engaged in species conservation in the wild (Conde et al., 2011). As a result, wildlife conservation is no longer the sole domain of wildlife biologists working to preserve populations in their natural habitats. The success of zoological institutions in maintaining a healthy breeding population for many endangered species has ultimately led to their recognition as a valuable component of a holistic species conservation strategy. The real value of zoos and aquaria for species conservation is best achieved through integrated collaboration with the wild population management community. Effective integrated conservation requires detailed planning, engaging all relevant actors or stakeholders in the planning process and optimising the use of limited resources across the ex situ-in situ management spectrum. This philosophy has been formalised through the One Plan Approach (OPA) developed by the Conservation Planning Specialist Group (CPSG) of the IUCN's Species Survival Commission (Byers et al., 2013). While a formal description of the OPA is relatively recent, it should be recognised here that the broad process undertaken by all responsible parties to jointly develop a set of management strategies and conservation measures within a comprehensive species conservation plan is not entirely a new concept. This approach has been practiced in parts – although rarely in its totality – for some decades. We have good examples of successful integrated conservation in the cases of golden lion tamarins in Brazil (Mickelberg & Ballou, 2013), Puerto Rican crested toads (Lee, 1992) in the Caribbean and Arabian, and scimitar-horned oryx in the Middle East (Stanley Price, 2016).

While conservation breeding and the release of captive-born individuals can make a key contribution in appropriate circumstances to improving the status of endangered species in the wild, it represents just one of many tools that ex situ facilities can use to participate in integrated species conservation. For example, insurance populations maintained ex situ can prevent local

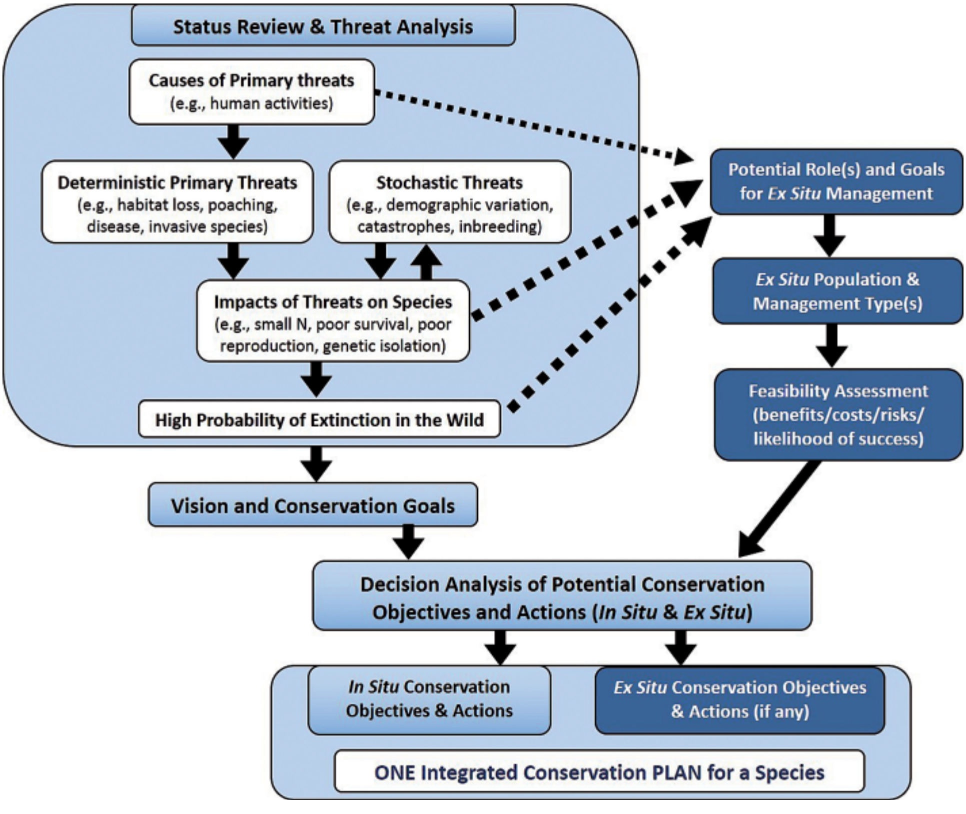


**Fig. 2:** Graphical representation of the One Plan approach, in which the decision-making steps featured in the IUCN Ex Situ Guidelines (boxes on the right side of the diagram) are incorporated into the traditional species conservation planning process. Graphic adapted from IUCN/SSC (2014).

or global species extinction; head-start programmes can remove individuals from the wild temporarily to reduce the mortality of vulnerable life stages and then can be returned to safer wild environments; and individuals can be used in research, training or public awareness programmes to improve our understanding of species biology or to educate citizens on specific threats to biodiversity. A logical decision-making process has been developed (IUCN-SSC, 2014) to assess whether ex situ management can effectively support species conservation and, if so, what form that management should take and how it can be most effectively implemented, given our current knowledge and finite resources.

Today, an integrated approach to species conservation is essential. When a species declines in abundance to a critically low number in the wild and the threats that have caused that decline cannot be controlled, the argument for ex situ management intervention is loud and clear. If an ex situ population exists and conservation breeding can be done effectively, it is possible to use that population as a source for the release of individuals to the wild. In cases where the species is not held in zoos or aquaria, an integrated approach can take the form of capturing animals from the wild and placing them temporarily in controlled conditions to avoid anthropogenic mortality. A crucial factor influencing the success of such an intervention is the timing of the action. If one waits too long, the wild population can decline to such a small number of individuals that the probability of success is reduced and cannot outweigh the risks associated with capture and handling. Another important consideration is the choice of species for which this kind of intervention is recommended. Particularly relevant in this context are the prominent objections when it comes to capturing and handling small cetaceans. Due to the special history of dolphin husbandry, there are numerous organisations that are against this kind of intervention. Also certain parts of our society, as well as some members of the scientific community, are opposed to a hands-on conservation option. Simply stated, they would rather accept the disappearance of the species than capture individuals of a rapidly declining population and transfer them to controlled areas.

## Integrated conservation of small cetaceans

In the following sections, we argue for an integrated approach to the conservation of small cetaceans and the potential for dolphinaria to play an active role in the conservation of these species. This potential has been developed by dolphinaria in a short period of time, and it is therefore important to show how this has been achieved. Therefore, the history of dolphinaria will be discussed first, but it will also be shown that in addition to this positive development, dolphins – in this case, bottlenose dolphins – have always been subjects of biological research, the results of which have been used to optimise husbandry and, above all, to identify key criteria for creating self-sustaining ex situ populations. We have learned a lot about keeping these animals in human care and it is no exaggeration to say that no other zoo animal has provided as much knowledge about species biology as the dolphin. Even if this development almost always refers to only one dolphin species, namely the bottlenose dolphin, many examples have shown that the acquired knowledge can also be transferred to other species. The bottlenose dolphin is therefore a good model for integrated species management, as it covers a broad spectrum of ex situ management and is a good example of how animal husbandry can quickly become an important source of knowledge that benefits not only this species but others as well.

## History of dolphin husbandry

To adequately evaluate the development of dolphin husbandry, it is helpful and important to describe its history. Furthermore, when dolphins are mentioned here, we refer to the bottlenose dolphin (*Tursiops truncatus*). Most dolphinaria originated from travelling circuses where these animals were shown. The first permanent facility where dolphins were kept was established in the United States (Florida) in 1938 (Defran & Pryor, 1980). Dolphins were on display in the facility known as Marine Studios, and the facility mainly served the film industry, which wanted to introduce people to marine life through film. Interestingly, this facility is also where systematic research on dolphins was first conducted. Most notable are the studies on echolocation (McBride, 1956), behaviour (McBride & Hebb, 1948) and breeding (McBride & Kritzler, 1951; Wood, 1977). Well-known American researchers took advantage of this unique opportunity to study aspects of dolphin biology under controlled conditions that may have never been studied in the field until decades later (Reeves & Mead, 1999).

However, it cannot be denied that the real reason for keeping dolphins at this time was primarily commercial. The charisma of the animals and their trainability (Pryor, 1975; Defran & Pryor, 1980) were key arguments in favour of making a profit from them. The suite of behaviours displayed in these shows made people believe that dolphins were highly intelligent. The negative thing about the dolphin show industry at that time, however, was the fact that dolphins had to be captured by the hundreds to keep the industry going. Breeding was undesirable at that time and therefore rare. However, animal husbandry was greatly improved, even in the early days of the industry, mainly because of the fact that the animals were very valuable commercially.

The passage of the United States Marine Mammal Protection Act (MMPA) in 1972 severely restricted the capture of dolphins from the wild and led to a change in thinking about the handling of these animals. For many purely commercial businesses, this law meant the end for many dolphinaria in both the US and England. This new legislation initiated a long-overdue paradigm shift in dolphin management. The main goal of the leading institutions was now breeding and thus building a self-sustaining population in human care. Although successful breeding was a rarity at first, this change in thinking led to rapid development in the husbandry and management of these animals (Schroeder, 1990; McBain, 1999). Coordinated breeding programmes, in the USA under the aegis of the American Zoo and Aquarium Association (AZA) and in Europe in the form of the conservation breeding programme EEP of the European Association for Zoos & Aquaria (EAZA), were the key to success. In just a few decades, these programmes resulted in the fourth generation of dolphins being bred in dolphinaria and, in the case of the EEP, in 81.6% of all dolphins living in Europe being born in human care (EAZA-EEP, data as of 2023).

In addition to improved breeding success, the life expectancy for dolphins is also increasing in ex situ facilities. A recent study (Jaakkola et al., 2019) clearly showed that the life expectancy of dolphins in US zoos and aquaria has more than tripled over recent decades and is now at least as high as in some wild populations for which comparable data are available. A similar development can also be observed in Germany (see Baumgartner, et al in this volume).

Although the previous sections refer to only one dolphin species – the bottlenose dolphin – it is important to emphasise that other dolphin species have also been kept in zoos and dolphinaria. The challenges in creating a self-sustaining cetacean population, as demonstrated by the bottlenose dolphin, can have many reasons. As Curry et al. (2013) rightly pointed out, there are still many information gaps that need to be addressed before ex situ strategies are adopted as ubiquitous tools to conserve species. Many species, such as the vaquita, are not suitable for human care due to their vulnerability to capture/transport mortality (Rojas-Bracho et al., 2019). However, many species have already been kept and partly bred under controlled conditions and have tolerated acclimation, including the Amazon River dolphin (*Inia geoffrensis*; Boede et al., 2018; Ternes, 2022), the tucuxi (*Sotalia guianensis*; Bossenecker, 1978), the Commerson dolphin (*Cephalorhynchus commersonii*), the harbour porpoise (*Phocoena phocoena*) and the beluga (*Delphinapterus leucas*). The lack of results comparable to those from bottlenose dolphins is not necessarily related to the inability of these species to adapt to ex situ conditions. Above all, the lack of foresight in terms of long-term husbandry and science-based management led to failure. This includes the capture methods, the sex ratio of the captured animals, the lack of planning for new animal husbandry and the lack of a breeding programme involving experts and institutions that are devoted to species conservation.

## The need for an integrated conservation approach for small cetaceans

According to the latest report of the IUCN SSC Cetacean Specialist Group, 46% of all cetacean species, subspecies and subpopulations are threatened (IUCN-CSG, 2022). In the last 20 years, we witnessed the functional extinction of the baiji (*Lipotes vexillifer*) in 2007 (Turvey et al., 2007). This river dolphin became extinct just over a decade ago because the management tools available at that time were not used effectively or in a timely manner. Today, we are witnessing the next cetacean extinction. According to recent counts, there are only eight vaquitas left in the Upper Gulf of California (Rojas-Bracho et al., 2021). Mexico's vaquita is thus about to follow the baiji's fate because fishery practices that are inadvertently causing their demise cannot be changed quickly enough. A field programme launched in 2017 to catch the last vaquitas and transfer them into a protected ex situ environment had to be stopped after two unsuccessful capture attempts (Rojas-Bracho et al., 2019). Both cases clearly show that efforts made thus far to save dolphin species from extinction have had only a limited effect.

These two examples illustrate the problems faced by many cetacean species. Many of the threatened species and populations most vulnerable to extinction or extirpation have shallow water distributions that entirely overlap areas used intensively by people. Most of them are declining, at least in part, due to unsustainable bycatch mortality in fishing nets (Brownell et al., 2019), and extinction for some species is imminent unless concerted action is taken to save them. One thing is certain: to prevent further species extinctions, the range of tools available for conservation should be expanded. It is no longer enough to understand the causes of population decline; aggressive action must now be taken to reduce their impacts on population and/or species persistence. Consequently, all conservation options, including ex situ measures, should be evaluated to ensure the survival of a species.

The "Ex situ Options for Cetacean Conservation" (ESOCC) workshop, held in Nuremberg, Germany, in December 2018, was designed to address this critical need (Taylor et al., 2020). This includes preparations to lay the political, cultural, scientific and logistical foundations necessary for success. Discussions at the ESOCC workshop focused on seven small cetacean species (with an additional species, the Lahille's bottlenose dolphin, added later) that are on the IUCN Red List as Critically Endangered (CR), Endangered (EN) or Vulnerable (VU). The participants recognised the value of the OPA for each of the focal species. The current trend of declining population abundance for each of the eight species could lead to some of them becoming extinct within a short period of time – much faster than the time typically required to develop and implement a successful ex situ action plan. To make matters worse, there are significant gaps in our knowledge of the biology and management of many of these species. Consequently, there is an urgent need to fill these information gaps long before the implementation of ex situ management to prevent extinction can be seriously undertaken. Early preparation means that an action plan can be developed with greater confidence in success, and the expertise will be ready if or when the need arises. Early preparation would also mean knowing how a particular species would react to processes such as capture, transport, captivity or semi-captivity, and medication. In addition, research is needed to better understand individual animal responses to capture and how managers might neutralise problems resulting from confinement. These findings and experiences underline the role that zoos and aquaria play in effective conservation.

In this article, we want to address ex situ measures that are tailored for dolphinaria within the OPA framework and that can be practically applied to small cetacean management. There has never been a greater need for these institutions to become active in species conservation, whether through support for in situ measures, research and education within their own institution, or ex situ individual/population management. Only if they manage to carry out these activities in a thoughtful way will they be perceived as active partners in species conservation. Many examples described in the following sections testify to the feasibility of these tasks.

## Ex situ management/conservation breeding

Dolphins have been kept in human care for over 80 years. In all these years, keepers, zoo veterinarians and biologists have learned a vast amount about the animals and have acquired management knowledge that not only benefits the animals kept but can also help wild populations. The term zoo management covers a variety of measures that have been carefully developed to ensure safety for animals and the humans who care for them. In recent years, it has been recognised that this knowledge can also be applied to wild populations. This includes, for example, the responsible handling of animals, which is one of the most important tools that zoos / dolphinaria have to manage their animals. Many measures that have been increasingly used in the wild in recent years, such as translocation and transport of animals or health assessments, require the capture and handling of animals (Barratclough et al., 2019). In most cases, this knowledge comes from dolphinaria or zoos that have experience with these animals and conduct and support research.

The need to manage animals intensively has grown due to increasing threats to species in the wild. In some cases – such as the baiji (Turvey et al., 2007) or vaquita (Rojas-Bracho et al., 2019) – the last option to preserve the species was to remove animals from their natural habitat and transfer them to a safe environment. Efforts to save the baiji were unsuccessful because no more animals were sighted, even after several weeks of searching. Attempts to rescue vaquita from immediate environmental threats were similarly unsuccessful after one individual had to be released due to significant stress following capture and the other animal died of capture myopathy. There is an important lesson to be learned from both cases. If measures such as capturing individuals from an endangered population are the last option to conserve the species, then one should not wait too long before intervening. Managing individuals in an ex situ environment is certainly challenging and the learning curve is steep. It is necessary to understand the behavioural and physiological responses of a species to the actions required to build an ex situ population before it reaches a critically low level. There will always be a risk that animals will be lost during these periods of adaptation to ex situ conditions and the special needs of the animals, but it is important to analyse and evaluate these findings to gain important insights into how to keep them alive and healthy. In general, important aspects that need to be addressed are how the animal reacts to capture, transport and confinement. It is also important to address key husbandry questions, such as the quality of the facilities housing the animals and the quality of individual animal care (food/veterinary medicine). These considerations are particularly important given that such long-lived animals could remain in ex situ facilities for extended periods of time. In many of these areas, zoos/dolphinaria can make important contributions, as they have the necessary expertise and trained staff to carry out such measures effectively. As these conservation measures will likely increase in scope and intensity in the near future, it is important to be aware of the important roles and responsibilities these facilities will take on.

One dolphin species that is considered vulnerable (Vermeulen et al., 2019) according to the IUCN but is under increasing pressure in its natural habitat is the Lahille bottlenose dolphin (*Tursiops gephyreus*). A maximum of 360 mature individuals remain in the South Atlantic, where this subspecies is endemic (Fruet et al., 2015; Secchi et al., in this volume). Conservation efforts are rare and where management has been implemented, as in Brazil through enacting a new fishing law, the effects of the actions are questionable. In other words, without much-needed protection, this species will suffer a fate similar to that of baiji and vaquita. Unlike the vaquita, there is an ex situ population in Mundo Marino, Argentina, a dolphinarium that has kept and successfully bred this species for decades (Loureiro et al., 2021). This means that this species is well suited for ex situ holding and an insurance population can therefore be created. Continued breeding success and the establishment of a self-sustaining ex situ population depend on factors such as individual demographic characteristics and adult sex ratio. In the case of Mundo Marino, this is not optimal, as there is a surplus of males and only two females. The fate of Lahille's bottlenose dolphin also prompted the EAZA to establish an ExSitu Programme (EEP) in 2022, with the aim of supporting conservation efforts for the species (EAZA Regional Collection Plan, 2022). Unlike the usual EEPs, it is not intended to keep the species in European zoos. A new campaign by the European Association for Aquatic Mammals (EAAM) will also be dedicated to the conservation of this species, providing expertise and funding to support in situ conservation projects. These examples clearly show the immense potential for zoos and dolphinaria to be active members of the conservation community.

**Fig. 3:** The Lahille Bottlenosed Dolphin in Southern Brazil. Photo © Rodrigo Genoves, KAOSA

A very important tool in zoo population management is the Zoological Information Management System (ZIMS) software package. This database houses records on more than 10 million individuals of more than 22,000 species, including medical histories and genetic tools for population analysis. The global web-based application is structured to facilitate cooperative animal management to achieve ex situ conservation goals. ZIMS will soon be used for the first time for a threatened dolphin population: a Lahille's dolphin population inhabiting the Lagoa dos Patos in Southern Brazil. A special feature of ZIMS is its application to analyse the demographic and genetic status of populations with a small number of individuals. It also enables the linking of data management processes for animals that spend part of their lives in human care and part of their natural environment and has great potential for use in managed wild populations (Schwartz et al., 2017). This first application of ZIMS to a threatened dolphin population will surely provide important information to better manage the species across the *in situ-ex situ* spectrum.

Perhaps the best example of how conservation breeding can contribute to the survival of a cetacean species is the case of the Yangtze finless porpoise or YFP (*Neophocaena asiaeorientalis* ssp. *asiaeorientalis*). When the steadily declining wild population reached a critical number of individuals, it was decided to capture animals and transfer them to remote riverine areas called oxbows. The first *ex situ* YFP population was established in 1990 in Tian-E-Zhou Oxbow in Hubei Province. The breeding programme that subsequently came into effect has resulted in the ex situ population now numbering more than 160 individuals (Wang, 2009; Hao et al., this volume). This population also provides research and training opportunities for local and regional scientists and is the subject of many regional education and public awareness programmes.

In summary, across the management continuum – from natural habitats in the wild to controlled environments in the dolphinarium or zoo – well-grounded practical knowledge has been instrumental in achieving success. The expertise in cetacean management acquired in the ex situ community – mostly based on accumulated experience with just one species – has led to the development of effective management technique measures that can be applied to other species in need. This flow of knowledge will no doubt become even more relevant in the coming years due to the perilous conservation status of many species.

## Research in support of conservation

There are few animal species of which we know as much about their general biology – from the performance of the sensory organs to cognition and behaviour – as we do about the bottlenose dolphin. It is particularly striking to appreciate the wealth of knowledge that ex situ-based research on these animals has provided. In particular, research on echolocation, which began in the 1950s, has provided many insights into the way dolphins perceive their environment (Au, 1993). Scientists working with animals in dolphinaria have also proven what dolphins perceive in terms of hearing (Ridgway & Au, 2009), communication (Caldwell & Caldwell, 1968; Janik & Sayigh, 2013) and other senses (Hüttner et al., 2022).

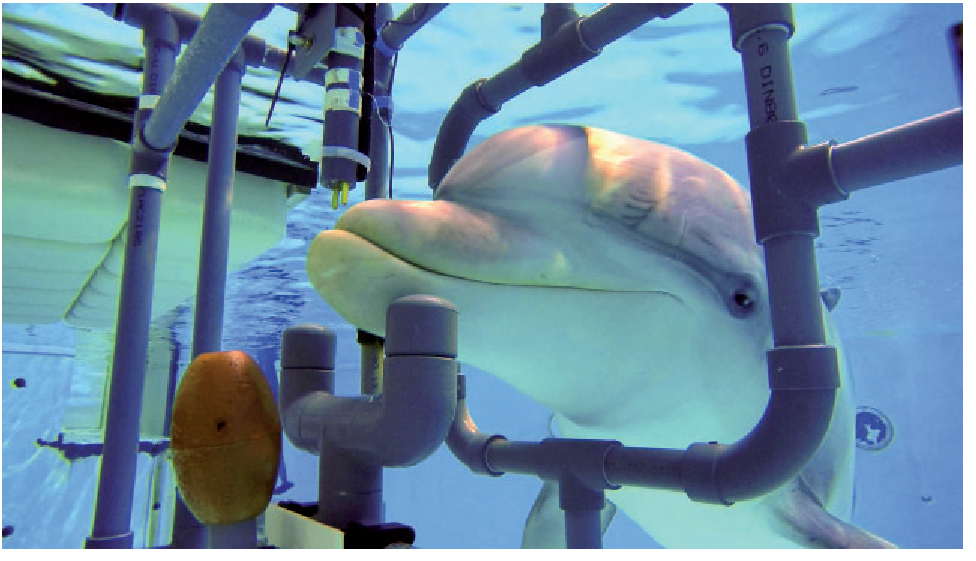

**Fig. 4:** Special electroreception test apparatus developed for dolphins. The dolphin touches the target with its rostrum. The electrodes are located approximately 10 cm directly above the dolphin's vibrissal crypts on the upper rostrum. After an electric signal was presented, the dolphin learned to leave the apparatus and return to its trainer. Each correct response was reinforced by the experimenter with a short continuous whistle sound and a food reward from the trainer. During stimulus-absent trials, the dolphin learned to stay in station for at least 12 s. Photo © Tim Hüttner, Nuremberg Zoo

The US Navy has conducted important research in Hawaii over the years in the area of dolphin echolocation (Au, 1993; Nachtigall & Pacini, in this volume). This work is now being continued and complemented by other topics in San Diego by the National Marine Mammal Foundation (NMMF). Hundreds of publications focusing on physiology, acoustics and advanced diagnostic methods have been produced over the past decades thanks to the dolphins housed there (Houser et al., 2010). Overall, understanding the sensory systems of dolphins can help conservationists to better understand these animals in the first place, as well as to better assess the effects of different stressors, such as noise. Understanding how echolocation works may be important for developing bycatch mitigation methods.

Controlled conditions, such as those found in dolphinaria, are also critical environments for exploring other research fields that are becoming increasingly relevant. With the rapid development of new technologies in the field of biologging (animal-attached logging of biological variables with small electronic devices) and the increased demand for their use in the field, it is particularly important to conduct preliminary experiments with animals where detailed monitoring is possible (Tyack, 1985). Such non-invasive bio-logging tags, used in hundreds of studies ranging from basic ecology to the effects of human disturbance, are constantly being improved in ex situ facilities, while novel methods for sampling DNA (Frere et al., 2017) and hormones (Richard et al., 2017) from exhaled breath are being developed for health and genetic studies. Many of these studies have been designed to document the physiological and behavioural responses of dolphins to environmental stressors, such as sound and pollutants. The results of these studies help managers and scientists understand, for example, how entanglement and noise (e.g. from man-made sonar, oil and gas exploration) affect individual behaviour and survival (Houser et al., 2010).

Despite the intellectual advances summarised above, there are still many open questions about cetacean biology that dolphinaria can contribute to solving. The development of fishery gear deterrent devices is particularly urgent. Bycatch is and will certainly remain the greatest threat to the survival of many small cetaceans in the coming years. Pingers (active or passive) are seen as a solution, but there is still a lot of research to be done in this area, and answers to some of these questions can certainly be provided by projects with dolphins in human care. Another area relates to developing solutions using artificial intelligence. Be it behaviour or acoustics, animals from dolphinaria serve as good models to test a wide range of hypotheses.

In summary, close access to animals in human care has allowed scientists to study many aspects of cetacean biology and to gather information that would otherwise be inaccessible. This basic information from studies in facilities serves as a direct basis for scientists to interpret data from studies in the wild.

## Veterinary medicine

Zoo veterinary medicine is certainly one of the fields that has developed most rapidly, and it has ultimately contributed greatly to the good health of bottlenose dolphins in ex situ facilities. This is echoed not only in breeding success and life expectancy but also in evidence of good animal welfare (Baumgartner et al. in this volume). In the meantime, the field of zoo veterinary medicine has now expanded to include the study of wild populations. One product of this work that reflects the exponential growth of knowledge is The Handbook of Marine Mammal Medicine. While the first editions focus mainly on diagnosis and treatment methods, the content in the last edition looks at the bigger picture by adding animal welfare, tagging and tracking rehabilitated animals, and a holistic concept of health, now known as One Health (Dierauf & Gulland, 2001). The term conservation medicine (Aguirre et al., 2002 and Smith et al., in this volume) covers this new field of veterinary medicine, addressing inter alia species conservation issues. Conservation medicine plays a vital role in preserving biodiversity by promoting the health of wildlife populations and their ecosystems. It incorporates the One Health Approach, which recognises the strong connections between the health of humans, animals and the environment. Conservation medicine takes a one-health approach to promoting health and well-being across all three domains. By monitoring the health of animal populations, conservation medicine can help prevent the spread of these diseases and protect public and environmental health. By investigating the impact of environmental factors on health, conservation medicine can help promote a healthy environment for all.

A particularly striking phenomenon that has recently increased among dolphins is strandings (Alvarado-Rybak et al., 2020). In the case of dead animals, a well-considered and conducted necropsy is crucial for determining the cause of death. Good protocols, such as those designed and applied in zoological institutions, often serve as models and are the basis for scientific work. A good example of how zoo-acquired marine mammal medicine can be directly and effectively implemented in the field is given with live strandings. Starting with the transport to the Rehabilitation Centre, the initial care and the entire rehabilitation process up to the release, all depends on veterinary knowledge from zoological institutions. For live strandings, zoo veterinarians' participation is of great importance due to their long experience with these animals. Dolphinaria as institutions play a crucial role here as they provide staff, first aid, logistics, space, medicine and professional care. An excellent example of this type of collaboration is the Alliance for Franciscana-Dolphin Conservation, Research, Rescue and Rehabilitation (AFCR3), composed of veterinarians, biologists, animal managers and rehabilitation experts from different countries. The aim of this alliance is to help protect the endangered Franciscana dolphin by not only better understanding the phenomenon of live strandings but also identifying ways to keep these animals alive. For that purpose, the Alliance has developed rehabilitation protocols that are not only based on scientifically valid findings but also consider the specific circumstances of the places/countries (Meegan et al., 2022).

Conservation translocation, the deliberate movement of organisms from one site for release to another, is also a phenomenon that is becoming more and more common. River dolphins in particular are more frequently affected (Aliaga-Rossel & Escobar, 2020). Habitat changes result in the animals' habitat becoming restricted and often requiring the translocation of single individuals. Again, zoo veterinarians, as well as trained staff (i.e. keepers) who are familiar with the handling of these animals, can be extremely important for ensuring successful translocation.

Another important achievement of dolphinaria relates to artificial insemination (AI). AI is considered a very important tool in species conservation. Assisted reproductive technologies (ART) are a critical component of management tools and include semen cryopreservation, AI and sex pre-selection using sperm sorting. Some dolphinaria have already had some success with the application of ART tools and techniques (O'Brien & Robeck, 2006). AI with sex-selected sperm is a potentially effective tool for restoring small animal populations, as it shifts the sex ratio in favour of females and ultimately increases recruitment rates (Robeck et al., 2013). Although the applicability of bottlenose dolphin successes to other species has been debated (Curry et al., 2013), it is undeniable that many of the fundamentals that have been created here facilitate the application of AI to a host of endangered cetacean species. Finally, it is important to emphasise that AI can help maintain genetic diversity in endangered species by allowing the mixing of genetic material between individuals that are geographically separated, have a low reproductive rate or have difficulty reproducing in controlled environments.

## Capacity building

Much of the collective knowledge regarding animal husbandry in ex situ facilities is scientifically valid and published, but much of it is based on many years of experience and is referred to as management-based expertise (MBE). The Animal Care Manuals (ACMs) of the Association of Zoos and Aquariums (AZA), the EAAM Standard and Guidelines, and the EAZA Best Practice Guidelines (BPG) are certainly very valuable sources of knowledge, as they contain practical information relevant to the management of animals. This knowledge is not only used for the continuous improvement of their animal management efforts but also serves as a good foundation for the management of wild populations. In this context, capacity building in wildlife management means applying and transferring the knowledge, skills and resources learned in an ex situ-facility to effectively manage wildlife populations, protect habitats and address the challenges facing wildlife in different contexts.

Training is an important activity for capacity building in wildlife management. Providing targeted training for wildlife veterinarians, biologists, conservationists and community members can help build their knowledge and skills in different areas of husbandry, capture, veterinary care and animal handling. Another important capacity-building area is research and monitoring. Many dolphinaria/zoos have in-house scientists who work with animals to answer different research questions. Capacity building can involve developing the skills and resources needed to carry out research in the wild as well as the ability to analyse and interpret the resulting data.

Engaging local communities in wildlife management can also build capacity by empowering them to take an active role in conservation efforts, fostering a sense of ownership and stewardship and building local capacity to manage wildlife resources sustainably. Methods for this can be partly derived from the work that zoos/dolphinaria do in environmental education and training.

Overall, capacity building requires, above all, knowledge and this is abundant in zoos/dolphinaria. It is rooted in a multi-layered approach that includes expertise and knowledge but also education, research, training, collaboration, innovation and community engagement. By building capacity, we can improve the living conditions of kept animals, and we can better protect and conserve wildlife populations and their habitats for future generations.

## Networking

An important prerequisite for maximising the chances of success in species conservation is networking. Building partnerships and collaboration between scientists, wildlife managers, government agencies, NGOs, community organisations and other stakeholders can help build capacity by pooling resources, expertise and knowledge. This can involve sharing best practices, coordinating efforts and leveraging each other's strengths.

Zoos and aquaria are often members of many professional organisations (IUCN, WAZA, EAZA, EAAM), enjoy partnerships with universities and other research institutions, and develop contacts with local political institutions. As a result, these institutions are well suited to building effective conservation networks. These networks should serve to highlight the relevance of zoos/dolphinaria to ultimately be recognised as active and serious partners in species conservation. The efforts of the European Association for Aquatic Mammals as the umbrella organisation of European dolphinaria are worth mentioning in this respect. In particular, the political work done in France and other European countries to consolidate the status of dolphinaria as research and educational institutions was important in preventing further closures. Additionally, initiatives such as the ESOCC workshop described previously can be good examples of these networks. The ESOCC enabled the ex situ community to prove how deeply integrated species conservation is in its activities. The task is to continue this work.

## Awareness and conservation education

Visiting a zoo/dolphinarium and seeing a live animal are probably the most effective ways to communicate animal-related content in an effective and sustainable way. These institutions use this phenomenon to make visitors aware of important issues. Through careful planning and implementation, these encounters and associated educational programmes can be powerful sources of information for the public.

Building awareness of wildlife in a zoo/dolphinarium is an important task that requires a multi-faceted approach and can take place in different ways. Many institutions offer educational programmes for visitors, especially children, to learn about animals and their habitats. These programmes can include guided tours, interactive exhibits and hands-on activities.

Especially in the case of dolphinaria, animal presentations can be a great way to showcase the magnificence and diversity of wildlife. These presentations are also used to communicate content, for example, from scientific research or species conservation. Some institutions show pure research presentations, which again shows that visitors can be attracted to these topics. At the same time, these research presentations are also a good opportunity to collect data for science.

Another important source of information for visitors are signs, posters and monitors. If well designed, they can hold other important content about the animals, their behaviours and the importance of conservation complementary to the presentations. Overall, building awareness of wildlife requires a holistic approach that prioritises education, animal welfare and conservation efforts. By engaging visitors and partnering with organisations, zoos/dolphinaria can play an important role in protecting and preserving wildlife. For example, in the Nuremberg Zoo, the zoo-based conservation organisation YAQU PACHA has conducted numerous campaigns to draw the attention of visitors to the conservation problems of small cetaceans and to raise awareness of them.

At this point, it should be mentioned that the reach of zoos/dolphinaria is immense. Each year, over 700 million people visit these institutions (WAZA, 2022). This figure illustrates the enormous potential as an awareness-raising and educational institution. Through the presentation of live animals, zoos/dolphinaria have a unique platform to direct the visitors' attention to biological topics but also to point out environmental problems.

## Fundraising

If everything that was mentioned before is fulfilled – successful population management, animal welfare, expansion of knowledge through research, public awareness and education – then the conditions are given for visitors to donate money for conservation projects. Zoos/dolphinaria can generate revenue through a variety of fundraising opportunities. The best known are membership programmes, corporate partnerships, individual donations, special events, animal adoptions, merchandise sales and grant funding.

Overall, zoos/dolphinaria have many opportunities for fundraising, and these initiatives can help support important conservation efforts (in situ/ex situ), education programmes and research projects. Collectively, the global zoo/aquarium community invests more than US$ 350 million in in situ wildlife conservation, representing the third largest conservation organisation contributor globally (Gusset & Dick, 2011; EAZA Conservation Database). These in situ conservation activities are primarily funded by paying visitors and other sources, such as donations.

Without having exact figures, one has the impression that active participation in species conservation through financial support for projects in dolphinaria is unfortunately not yet as advanced as zoos. There is often a lack of creativity and ideas on how to get visitors to participate financially in species conservation. It should be clear to everyone that species protection is not just a word but that it is about taking responsibility and setting a good example to ensure the survival of animal species. Thus, dolphinaria should take this task seriously and act accordingly.

## Conclusions

The OPA is now a central paradigm within the IUCN's Species Survival Commission for the integrated conservation of endangered species. We argue here that this approach should become a similar organising principle for the cetacean conservation community. In adopting this principle for the conservation of a species group to which humans have such a deep emotional connection, it is crucial to understand that integrated conservation does not equate only with keeping animals in tanks for display and entertainment. As explained in the IUCN's Guidelines for the Use of Ex Situ Management for Species Conservation, dolphinaria can engage in a host of activities that can make meaningful contributions to the conservation of small cetacean species in their natural habitats. Where appropriate, maintaining healthy animals in ex situ environments comes with difficult scientific challenges. It is the responsibility of the ex situ community to accept this challenge and help create conditions in which ex situ management can ultimately play a key role in saving cetacean species from extinction.

Dolphinaria are a significant and largely untapped resource in the global cetacean conservation community. In this article, the term dolphinaria consistently refers to facilities that keep dolphins in their care. These institutions have proven to be successful over many years and have been markedly successful in raising people's awareness of dolphins and their role in nature. There have been institutions that, in parallel with their traditional focus on animal display, have also conducted biological research, developed educational programmes and supported species conservation. In this article, however, we want to clarify that the traditional vision of a dolphinarium is no longer sufficient if the goal is to be an active player in the protection of endangered species. In view of the catastrophic situation of many dolphin species, but also in view of current developments in species conservation, such as the OPA and IUCN Motion 079, there is a call for a new evaluation of these facilities. In this article, we have highlighted numerous opportunities for involvement in the broad conservation movement, and it would be negligent, at best, for dolphinaria to ignore this invitation. We would like to see dolphinaria follow the same path taken by zoos and aquaria over the past few decades, moving from mere exhibit institutions to active participants in global species conservation. With this in mind, we envision a future for dolphin facilities in which their primary goal is to educate and empower their visitors to appreciate the value of species conservation, to enable research and to actively participate in in situ species conservation. Without the active participation of our community, the likelihood of improving the conservation status of these animals decreases.

## Zusammenfassung

Die Welt befindet sich in einer Phase des Verlusts der biologischen Vielfalt, die in absehbarer Zeit nicht aufzuhalten ist. In-situ-Artenschutz/Habitatschutz reichen nicht aus, um den weiteren Verlust von Arten zu stoppen. Daher ist der Ruf nach neuen Strategien unausweichlich. Eine dieser Strategien ist der One Plan Approach (OPA), der von der Conservation Planning Specialist Group (CPSG) ins Leben gerufen und später von der International Union for Conservation of Nature (IUCN) übernommen wurde. Im Gegen-

satz zu herkömmlichen Artenschutzstrategien, die sich in erster Linie auf den Schutz von Arten in ihrem natürlichen Lebensraum konzentrieren, umfasst OPA das gesamte Spektrum des Tiermanagements (von intensiv in zoologischen Einrichtungen bis zur weniger intensiven im Freiland). Mit OPA wurde den Zoos nicht nur eine weitere wichtige Aufgabe übertragen, sondern sie haben nun auch Verantwortung für den Erhalt der Artenvielfalt übernommen. Während bei den meisten bedrohten Pflanzen- und Tierarten ein Konsens über die Umsetzung integrierter Schutzmaßnahmen besteht, gehen die Meinungen bei den Kleinwalen auseinander. Dieser Artikel soll diese Diskrepanz aufzeigen und zeigen, dass für viele Kleinwalarten integrierte Artenschutzstrategien nicht nur dringend erforderlich sind, sondern dass bereits erste Schritte zur Umsetzung eines solchen integrierten Ansatzes unternommen wurden. Zoologische Einrichtungen, die Delfine halten, sollten sich der wichtigen Rolle, die sie jetzt spielen, bewusst sein und verantwortungsbewusst handeln.

## References


Aguirre, A.A., Ostfeld, R.S., Tabor, G.M., House, C., & Pearl, M.C. (2002). Conservation Medicine: Ecological Health in Practice. New York, NY: Oxford University Press.

Aliaga-Rossel, E., & Escobar, M. (2020). Translocation of trapped Bolivian river dolphins (*Inia boliviensis*). IWC Report, 21(1), 17-23. https://journal.iwc.int/index.php/jcrm/article/view/96

Alvarado-Rybak, M., Toro, F., Escobar-Dodero, J., Kinsley, A.C., Sepúlveda, M.A., Capella, J., Azat, C., Cortés-Hinojosa, G., Zimin-Veselkoff, N., & Mardones, F.O. (2020). 50 years of cetacean strandings reveal a concerning rise in Chilean Patagonia. Sci Rep**,** 10, 9511.

Au, W.L. (1993). The Sonar of Dolphins. New York: Springer-Verlag.

Barratclough, A., Wells, R.S., Schwacke, L.H., Rowles, T.K., Gomez, F.M., Fauquier, D., Sweeney, J., Townsend, F.I., Hansen, L., Zolman, E.S., Balmer, B.C., & Smith, C.R. (2019). Health assessments of common bottlenose dolphins (*Tursiops truncatus*): past, present, and potential conservation applications. Frontiers in Veterinary Science, 6, 444.

Boede, E.O., Mujica Jorquera, E., Boede, F., & Varela, C. (2018). Reproductive management of the Orinoco river dolphin *Inia geoffrensis humboldtiana* in Venezuela. International Zoo Yearbook, 52, 1-13. https://doi.org/10.1111/izy.12195

Bossenecker, P.G. (1978). The capture and care of *Sotalia guianensis*. Aquatic Mammals, 6, 13-17.

Brownell, R.L., Reeves, R.R., Read, A.J., Smith, B.D., Thomas, P.O., Ralls, K., Amano, M., Berggren, P., Chit, A.M., Collins, T., Currey, R., Dolar, M.L.M., Genov, T., Hobbs, R.C., Kreb, D., Marsh, H., Zhigang, M., William F. Perrin12, Somany Phay18, Rojas-Bracho, L., Ryan, G.E., Shelden, K.E.W., Slooten, E., Taylor, B.L., Vidal, O., Ding, W., Whitty, T.S., & Wang, J.Y. (2019). Bycatch in gillnet fisheries threatens critically endangered small cetaceans and other aquatic megafauna. Endangered Species Research, 40, 285-296. https://doi.org/10.3354/esr00994

Byers, O., Lees, C., Wilcken, J., & Schwitzer, C. (2013). The One Plan Approach: the philosophy and implementation of CBSG's approach to integrated species conservation planning. WAZA Mag, 14, 2-5.

Caldwell, M.C., & Caldwell, D.K. (1968). Vocalization of naive captive dolphins in small groups. Science 159, 1121-1123.

Conde, D.A., Flesness, N.R., Colchero, F., Jones, O.R., & Scheuerlein, A. (2011). An emerging role of zoos to conserve biodiversity. Science, 331, 1390-1391. doi: 10.1126/science.1200674

Curry, B.E., Ralls, K., & Brownell Jr., R.L. (2013). Prospects for captive breeding of poorly known small cetacean species. Endangered Species Research, 19, 223-243. https://doi.org/10.3354/esr00461

Defran, R.H., & Pryor, K. (1980). The behavior and training of cetaceans in captivity. In L.M. Herman (Ed.), Cetacean Behavior: Mechanisms and Functions (pp. 319-362). New York: John Wiley & Sons.

Dierauf, L., Gulland, F.M.D. (2001). CRC Handbook of Marine Mammal Medicine. Boca Raton, Florida: CRC Press.

European Association for Zoo and Aquaria – Marine Mammal TAG. (2022). Regional Collection Plan.

Frère, C.H., Krzyszczyk, E., Patterson, E.M., Hunter, S., Ginsburg, A., & Mann, J. (2010). Thar she blows! A novel method for DNA collection from cetacean blow. PloSone, 5(8), e12299.

Fruet, P.F., Daura-Jorge, F.G., Möller, L.M.L.M., Genoves, R.C., & Secchi, E.R.E.R. (2015). Abundance and demography of bottlenose dolphins inhabiting a subtropical estuary in the Southwestern Atlantic Ocean. Journal of Mammalogy, 96(2), 332-343. https://doi.org/10.1093/jmammal/gyv035

Gusset, M., & Dick, G. (2011). The global reach of zoos and aquariums in visitor numbers and conservation expenditures. Zoo Biol, 30, 566-569.

Houser, D.S., Finneran, J.J., & Ridgway, S.H. (2010). Research with Navy marine mammals benefits animal care, conservation and biology. International Journal of Comparative Psychology, 23(3), 249-268.

Hüttner, T., von Fersen, L., Miersch, L., Czech, N.U., & Dehnhardt, G. (2022). Behavioral and anatomical evidence for electroreception in the bottlenose dolphin (*Tursiops truncatus*). The Anatomical Record, 305(3), 592-608. https://doi.org/10.1002/ar.24773

IUCN-CSG (2022). https://iucn-csg.org/update-on-cetacean-red-list-assessments-published-in-2022.

IUCN-SSC (2014). https://www.eaza.net/assets/Uploads/Position-statements/IUCN-Guidelines-on-the-Use-of-ex-situ-management-for-species.pdf

Irwin, M.D., Stoner, J.B., & Cobaugh, A.M. (eds) (2013). Zookeeping. Chicago: The University of Chicago Press.

Jachowski, D.S., & Lockhart, J.M. (2009). Reintroducing the Black-footed Ferret *Mustela nigripes* to the Great Plains of North America.

Jaakkola, K., & Willis, K. (2019). How long do dolphins live? Survival rates and life expectancies for bottlenose dolphins in zoological facilities vs. wild populations. Mar Mam Sci, 35:1418–1437. https://doi.org/10.1111/mms.12601

Janik, V.M., & Sayigh, L.S. (2013). Communication in bottlenose dolphins: 50 years of signature whistle research. Journal of Comparative Physiology A, 199, 479-489. https://doi.org/10.1007/s00359-013-0817-7

Kierulff, M.C.M., Ruiz-Miranda, C.R., Oliveira, P.P., Beck, B.B., Martins, A., & Dietz, J.M. (2012). The Golden lion tamarin *Leontopithecus rosalia*: a conservation success story. International Zoo Yearbook, 46:36–45. https://doi.org/10.1111/j.1748-1090.2012.00170.x

Kleiman, D.G., Thompson, K.V., & Baer, C.K. (2010). Wild Mammals in Captivity. Principles and Techniques for Zoo Management. 2nd edition. Chicago: The University of Chicago Press.

Lee, G. (1992). Recovery Plan for the Puerto Rican Crested Toad (*Peltophryne lemur*). Boqueron, Puerto Rico: USDI, Fish and Wildlife Service, Caribbean Field Office.

Loureiro, J.D., Migliorisi, A.L., Loureiro, J.P., Rodríguez Heredia, S., Rebollo, J., Álvarez, K.C., Morón, S., & Nuñez Favre, R. (2021). Breeding program in rehabilitated bottlenose dolphins (*Tursiops truncatus gephyreus*) from the Southwestern Atlantic Ocean. Zoo Biology, 40(3), 208-217. doi: 10.1002/zoo.21592. Epub 2021 Feb 19. PMID: 33606298.

McBain, J. (1999). Captive breeding of marine mammals: feasibility and success. Report of the Workshop Marine Mammal Reproduction: Morphology & Physiology. P. 417 in: European Research on Cetaceans Vol. 12 (P.G.H. Evans & E.C.M. Parsons, eds). Liége, Belgium: European Cetacean Society.

McBride, A.F., & Hebb, D.O. (1948). Behavior of the captive bottle-nose dolphin, *Tursiops truncatus*. Journal of Comparative Physiology and Psychology, 41, 111-123.

McBride, A.F., & Kritzler, H. (1951). Observations on pregnancy, parturition, and post-natal behavior in the bottlenose dolphin. Journal of Mammalogy, 32, 251-266.

McBride, A.F. (1956). Evidence for echolocation by cetaceans. Deep Sea Research, 3, 153-154.

Meegan, J., Gomez, F., Barratclough, A., Smith, C., Sweeney, J., Ruoppolo, V., Kolesnikovas, C., Pinho da Silva Filho, R., Lima Canabarro, P., Laporta, P., Loureiro, J.P., Alvarez, K., Rodriguez Heredia, S.A., Cabrera, A., Faiella, A., Saubidet, A., & von Fersen, L. (2022). Rescue and rehabilitation of neonatal Franciscana dolphins, care and hand-rearing protocol, AFCR3 – Publication Nr. 01 – 2022.

Mickelberg, J., & Balou, J. (2013). The Golden Lion tamarin conservation programme's One Plan Approach. WAZA Magazine, 14, 24-27.

O'Brien, J.K., & Robeck, T.R. (2006). Development of sperm sexing and associated assisted reproductive technology for sex pre-selection of captive bottlenose dolphins (*Tursiops truncatus*). Reproduction Fertility and Development, 18, 319-329.

Pryor, K. (1975). Lads Before the Wind: Adventures in Porpoise Training. New York: Harper & Row.

Pucek, Z. (1991). History of the European bison and problems of its protection and management. Global Trends in Wildlife Management, 39, 19.

Reeves, R.R., & Mead, J.M. (1999). Marine mammals in captivity. In J.R. Twiss, & R.R. Reeves (Eds), Conservation and Management of Marine Mammals (pp. 412-436). Washington, D.C.: Smithsonian Institute Press.

Richard, J.T., Robeck, T.R., Osborn, S.D., Naples, L., McDermott, A., LaForge, R., Romano, T. & Sartini, B.L. (2017). Testosterone and progesterone concentrations in blow samples are biologically relevant in belugas (*Delphinapterus leucas*). General and Comparative Endocrinology, 246, 183-193.

Ridgway, S.H., & Au, W.W.L. (2009). Hearing and echolocation in dolphins. Encyclopedia of Neuroscience, 4, 1031-1039. https://doi.org/10.1016/B978-008045046-9.00263-1

Robeck, T., Montano, G., Steinman, K, Smolensky, P., Sweeney, J., Osborn, S., & O'Brien, J. (2013). Development and evaluation of deep intra-uterine artificial insemination using cryopreserved sexed spermatozoa in bottlenose dolphins (*Tursiops truncatus*). Animal Reproduction Science, 139(1-4), 168-181. https://doi.org/10.1016/j.anireprosci.2013.04.004

Rojas-Bracho, L., Gulland, F.M.D., Smith, C.R., Taylor, B., Wells, R.S., Thomas, P.O. Bauer, B., Heide-Jørgensen, M.P., Teilmann, J., Dietz, R., Balle, J.D., Jensen, M.V., Sinding, M.H.S., Jaramillo-Legorreta, A., Abel, G., Read, A.J., Westgate, A.J., Colegrove, K., Gomez, F., Martz, K., Rebolledo, R., Ridgway, S., Rowles, T., van Elk, C.E., Boehm, J., Cardenas-Hinojosa, G., Constandse, R., Nieto-Garcia, E., Phillips, W., Sabio, D, Sanchez, R., Sweeney, J., Townsend, F., Vivanco, J., Vivanco, J.C., & Walker, S. (2019). A field effort to capture critically endangered vaquitas *Phocoena sinus* for protection from entanglement in illegal gillnets. Endangered Species Research 38, 11-27. https://doi.org/10.3354/esr00931

Rojas-Bracho, L., Booth, C., Taylor, B., Thomas, L., Jaramillo-Legorreta, A., Mesnick, S., Gerrodette, T., & Henry, H. (2021). Report using expert elicitation to estimate total unique vaquitas and calves seen in the Zero Tolerance Area during the 2021 survey. Paper submitted to the IWC.

Ruiz-Miranda, C.R., de Morais Jr., M.M., Dietz, L.A., Rocha Alexandre, B., Martins, A.F., & Ferraz, L.P. (2019). Estimating population sizes to evaluate progress in conservation of endangered golden lion tamarins (*Leontopithecus rosalia*). PLoS ONE, 14(6), e0216664. https://doi.org/10.1371/journal.pone.0216664

Schroeder, J.P. (1990). Breeding bottlenose dolphins in captivity. In S. Leatherwood, & R.R. Reeves (Eds), The Bottlenose Dolphin (pp. 435-460). San Diego, California: Academic Press.

Schwartz, K.R., Christien, E., Rockwood, L., Wood, T.C. (2017). Integrating in-situ and ex-situ data management processes for biodiversity conservation. Front Ecol Evol, 5. https://doi.org/10.3389/fevo.2017.00120

Smith, D., Abeli, T., Bruns, E.B., Dalrymple, S.E., Foster, J., Gilbert, T.C., Hogg, C.J., Lloyd, N.A., Meyer, A., Moehrenschlager, A., Murrell, O., Rodriguez, J.P., Smith, P.P., Terry, A., & Ewen, J.G. (2023). Extinct in the wild: the precarious state of Earth's most threatened group of species. Science, 379, eadd2889. https://doi.org/10.1126/science.add2889

Spalton, A. (1993). A brief history of the reintroduction of the Arabian oryx *Oryx leucoryx* into Oman 1980–1992. Int Zoo Yearb, 32, 81-90. https://doi.org/10.1111/j.1748-1090.1993.tb03519.x

Stanley-Price, M. (2016). Reintroduction as an antelope conservation solution. In J.B. Jørgensen, & D. Mallon (Eds), Antelope Conservation: From Diagnosis to Action, First Edition (pp. 125-132). New York: John Wiley & Sons.

Taylor, B.L., Abel, G., Miller, P., Gomez, F., von Fersen, L., DeMaster, D.P., Reeves, R.R., Rojas Bracho, L., Wang, D., & Cipriano, F. (eds) (2020). Ex situ Options for Cetacean Conservation: December 2018 workshop. Nuremberg, Germany: IUCN. Gland, Switzerland. https://doi.org/10.2305/IUCN.CH.2020.SSC-OP.66.en

Ternes, K. (2022). Ex situ management of the Amazon River dolphin (*Inia geoffrensis humboldtiana*): previous experiences, successes, and constraints. Der Zoologische Garten Neue Folge, 90, 183-218 .

Tokarska, M., Pertoldi, C., Kowalczyk, R., & Perzanowski, K. (2011). Genetic status of the European bison *Bison bonasus* after extinction in the wild and subsequent recovery. Mammal Review, 41, 151-162. https://doi.org/10.1111/j.1365-2907.2010.00178.x

Turvey, S.T., Pitman, R.L., Taylor, B.L., Barlow, J., Akamatsu, T., Barrett, L.A., Zhao, X., Reeves, R.R., Stewart, B.S., Wang, K., Wei, Z., Zhang, X., Pusser, L.T., Richlen, M., Brandon, J.R., & Wang, D. (2007). First human-caused extinction of a cetacean species? Biology Letters, 3, 537-540. https://doi.org/10.1098/rsbl.2007.0292

Tyack, P. (1985). An optical telemetry device to identify which dolphin produces a sound. Journal of the Acoustic Society of America, 1892-1895.

Vermeulen, E., Fruet, P., Costa, A., Coscarella, M., & Laporta, P. (2019). *Tursiops truncatus* ssp. *gephyreus*. The IUCN Red List of Threatened Species, 2019, e.T134822416A135190824. https://doi.org/10.2305/IUCN.UK.2019-3.RLTS.T134822416A135190824.en

Wakefield, S., Knowles, J., Zimmermann, W., & van Dierendonck, M. (2002). Status and Action Plan for the Przewalski's Horse (*Equus ferus przewalskii*). In P. Moehlmann (Ed.), Equids: Zebras, Asses and Horses (pp. 82-92). Cambridge, UK: IUNC/SSC Equid Specialist Group, IUCN Publications Services Unit.

Walters, J.R., Derrickson, S.R., Fry, D.M.D., Haig, S.M., Marzluff, J.M., & Wunderle Jr., J.M. (2010). Status of the California condor (*Gymnogyps californianus*) and efforts to achieve its recovery. Auk, 127, 969-1001. https://doi.org/10.1525/auk.2010.127.4.969

Wang, D. (2009). Population status, threats and conservation of the Yangtze finless porpoise. Chinese Science Bulletin 54, 3473–3484. https://doi.org/10.1007/s11434-009-0522-7

Wood, F.G., Jr. (1977). Births of porpoises at Marineland, Florida, 1939 to 1969, and comments on problems involved in captive breeding of small cetacea. In S.H. Ridgway, & K. Benirschke, K. (Eds), Breeding Dolphins: Present Status, Suggestions for the Future (pp. 47-69). Washington, DC: Marine Mammal Commission.

DER ZOOLOGISCHE GARTEN
THE ZOOLOGICAL GARDEN

doi:10.53188/zg0017

Zool. Garten N.F. 91 (2023) 101-112

# Integrated Conservation Planning for Cetaceans

## Planung integrierten Artenschutzes für Cetaceen

Barbara L. Taylor [1], Grant Abel [2], David Bader [3], Jay Barlow [1], Gill Braulik [4], Frank Cipriano [5], Tim Collins [6], Douglas DeMaster [7], Lorenzo von Fersen [8], Forrest Gomez [9], Yujiang Hao [10], Philip S. Miller [11], Gianna Minton[12], Randall R. Reeves [13], Lorenzo Rojas-Bracho [14], Eduardo R. Secchi [15], Cynthia R. Smith [9], Robert Suydam [16], Ding Wang [10], Randall S. Wells [17], & Alexandre Zerbini [18]

[1] Southwest Fisheries Science Center, NMFS, NOAA, 8901 La Jolla Shores Drive, La Jolla, CA 92037 USA
[2] Seattle Aquarium, 1483 Alaskan Way, Pier 59, Seattle, WA 98101-2051 USA
[3] 1324 W 26th Place, San Pedro, CA 90732 USA
[4] Sea Mammal Research Unit, University of St. Andrews, UK
[5] California Academy of Sciences, 55 Music Concourse Drive, San Francisco CA 94118 USA
[6] Wildlife Conservation Society, Bronx, New York, USA
[7] National Marine Fisheries Service, NOAA, USA (retired)
[8] Tiergarten Nürnberg and YAQU PACHA e.V., Am Tiergarten 30, 90480 Nürnberg, Germany
[9] National Marine Mammal Foundation, 2240 Shelter Island Drive Suite 200, San Diego, CA 92106, USA.
[10] Institute of Hydrobiology, Chinese Academy of Sciences, No. 7, South Rd. of East Lake, Wuhan 430072 China
[11] IUCN-SSC Conservation Planning Specialist Group, 12101 Johnny Cake Ridge Road Apple Valley. Minneapolis, MN, 55124-8151 USA
[12] Megaptera Marine Conservation, Wassenaar, South Holland, Netherlands
[13] Okapi Wildlife Associates, 27 Chandler, Hudson, Quebec J0P 1H0, Canada
[14] Ocean Wise, 101-440 Cambie St, Vancouver, BC, V6B 2N5, Canada
[15] Instituto de Oceanografia, Universidade Federal do Rio Grande-FURG, Rio Grande do Sul, Brazil
[16] Department of Wildlife Management, North Slope Borough, Box 69, Utqiaġvik, AK 99723 USA
[17] Chicago Zoological Society's Sarasota Dolphin Research Program, c/o Mote Marine Laboratory, 1600 Ken Thompson Pkwy, Sarasota, FL 34236 USA
[18] Marine Mammal Laboratory, Alaska Fisheries Science Center, NOAA Fisheries, 7600 Sand Point Way NE, Seattle, WA, 98115-6349, USA

*Corresp. author:
E-Mail: subspecies.def@gmail.com (Barbara S. Taylor)

## Abstract

The Integrated Conservation Planning for Cetaceans team, a sub-group of the IUCN SSC's Cetacean Specialist Group, was formed in response to the desperate situation of increasing numbers of endangered riverine and coastal dolphin and porpoise species and populations in the world today. The extinction of the baiji and the catastrophic decline to the edge of extinction of the vaquita are both examples of conservation actions being too late and not having all the necessary tools ready for dealing with those emergencies. Integrated conservation action plans actively fill-in knowledge gaps and explicitly consider all tools that may be needed to save a species or population.


## Introduction

This paper is intended to familiarize readers with the goals and objectives of the Integrated Conservation Planning for Cetaceans (ICPC) team. Furthermore, it is intended to encourage discussion about how accredited zoos, aquariums, cetacean biologists, and NGO's can foster collaboration and avoid unnecessary duplication or contradictions. ICPC is a sub-group, nested within the International Union for Conservation of Nature Species Survival Commission's Cetacean Specialist Group (CSG). ICPC members are biologists, veterinarians, and individuals with other relevant expertise. Integrated conservation planning involves various stakeholders working across disciplinary groups and is actively promoted by the IUCN. Motion 079 (IUCN, 2020), recently adopted by the IUCN, "1. URGES the Secretariat and professional societies to promote integration of *in situ* and *ex situ* conservation interventions by applying the One Plan Approach, to ensure effective use of all available conservation tools.". This motion "3. ALSO CALLS ON all Members to ensure that 11th hour, last ditch *ex situ* conservation efforts are prevented by proactive and timely application of planning methods, such as the One Plan Approach, and informed by the Guidelines on the Use of *Ex situ* Management for Species Conservation.

The ICPC team was formed in response to the desperate situation of increasing numbers of endangered riverine and coastal dolphin and porpoise species and populations in the world today. The report of the *Ex Situ* Options for Cetacean Conservation (ESOCC) workshop held at Nuremberg in 2018 recommended *inter alia*, that "marine mammal conservationists around the world work together and act with urgency to consider critically needed conservation measures both in wild environments within the species' geographic range (*in situ*) and in protected or modified environments within or outside that range (*ex situ*)" (Taylor et al., 2020). Many of the threatened species and populations most vulnerable to extinction or extirpation have shallow-water distributions that entirely overlap areas used intensively by people. Most are declining due, at least in part, to bycatch mortality in fishing nets (e.g., Brownell et al., 2019) and for some, we already know extinction is imminent without concerted action to save them. Many species experiencing serious conservation issues are in countries with poor governance coupled with corruption and impunity, which makes it difficult to implement timely solutions to reduce or eliminate bycatch. Some of these extreme cases may require *ex situ* interventions to bridge the time-gap between when the species could become extinct in the wild and when meaningful management actions allowing recovery are taken. The extinction of the baiji (Turvey et al., 2007) and the catastrophic decline to the edge of extinction of the vaquita (Jaramillo-Legorreta et al., 2019) are both examples of conservation actions being insufficient, ineffective, coming too late, and of not having all the necessary tools ready for dealing with those emergencies. Integrated conservation action plans explicitly consider from the outset all tools that may be needed to save a species or population and to actively fill-in knowledge gaps.

The need for integrated planning for the most at-risk species and populations is especially urgent as knowledge gaps for many small cetaceans are complex and may take decades to fill. Field biologists are often focused on addressing questions of abundance and decline and therefore gaps relating to basic biology and health may seem less important. The consequences are epitomized by the dilemma of the vaquita, where a lack of knowledge about the species' response to capture and handling (i.e., stress response) proved detrimental to efforts to save the species with the attempted *ex situ* measures.

## Integrated conservation plans and the One Plan Approach

Integrated conservation plans are action plans with specific goals and deadlines, including for monitoring and assessment. Those plans are developed by individuals with a variety of backgrounds and expertise, working together to identify and evaluate needed conservation measures. This may include both *in situ* and *ex situ* measures. If after careful consideration of all risks and available options it is determined that no *ex situ* conservation measures are justified or necessary, the end-product is still considered an integrated conservation plan.

This holistic framework for species conservation planning, known as the "One Plan Approach", was developed by the IUCN Species Survival Commission's Conservation Planning Specialist Group (CPSG). The approach seeks to engage all relevant stakeholders, consider all available resources from the start, and combine science-based decision making to create the species or population conservation action plan (Byers et al., 2013).

### The IUCN *ex situ* guidelines and the full range of *ex situ* approaches

The IUCN Species Survival Commission "Guidelines on the Use of *Ex situ* Management for Species Conservation" (IUCN 2014) provide guidance on how to determine if, when, and how to employ *ex situ* measures in a species conservation plan, the precise role(s) that *ex situ* measures could play, and how to thoroughly integrate those activities into the overall conservation plan for the species.

The term *in situ* is typically used to describe animals living in their natural habitat. The IUCN *Ex situ* Guidelines describe *ex situ* as: "conditions under which individuals are spatially restricted with respect to their natural spatial patterns or those of their progeny, are removed from many of their natural ecological processes, and are managed on some level by humans."

And notes that: *"Ex situ* management may take place either within or outside the species' geographic range but is in a controlled or modified environment."

In practice, the range of *ex situ* measures includes actions such as safeguarding animals in protected environments, for example in semi-natural reserves and netted or fenced enclosures, as well as the recovery, rehabilitation, and release of stranded, bycaught or otherwise incapacitated individuals. The practice of e*x situ* management also applies to other actions, such as capture and removal of animals from imminent threats such as a disease outbreak or a climate catastrophe, drought that dries up river channels leaving animals stranded or in fragmented groups, or a hurricane that causes animals to become beach-cast or stranded in unsuitable habitats.

An integrated conservation action plan explicitly considers all populations of a species, whether inside or outside of the species' natural range, and all management options, including *ex situ* approaches, as potential contributors to the successful conservation of that species or population in the wild. The social conditions and culture of both the stakeholders and the species concerned are critical factors to be considered (e.g., Venter et al., 2008; Whitehead and Rendell, 2015; Brakes et al., 2019). In this way, integrated conservation planning encourages the formation of new partnerships, increases communication, trust and understanding among conservation practitioners and stakeholders across multiple management contexts, and expands and enhances the range and quality of the tools available for science-based conservation action. In general, advantages of an integrated conservation plan include:

Having *in situ* and *ex situ* experts working together to fill critical knowledge gaps.

Having field biologists and veterinarians working together to improve overall understanding of the species and individual animal responses to various situations.

Having social scientists and others engaging stakeholder communities in the development of an integrated conservation action plan, including alternative livelihood options, thereby enhancing support for the plan, and increasing the likelihood of success.

*Ex situ* measures have already been used for marine mammal populations. Notably, self-sustaining *ex situ* populations of Yangtze finless porpoises (*Neophocaena asiaeorientalis* ssp. *asiaeorientalis*) have been established in oxbow lakes contiguous with the current natural habitat of the species, as insurance populations (Wang, 2009). They also provide research and training opportunities for local and regional scientists and are used to benefit conservation directly as well as contribute to public awareness and education. The rescue, rehabilitation, and translocation of young Hawaiian monk seals (*Neomonachus schauinslandi*) that otherwise would have died is another example of successful *ex situ* conservation action (Baker et al. 2011). In total, 32% of the Hawaiian monk seals alive in 2012 were either directly involved in survival-enhancing interventions or are descendants of seals that had benefited from dehooking, disentanglement, removal from high predation zones, vaccination and other medical interventions (Harting et al. 2014).

Another outcome of the ESOCC workshop was the recognition that many knowledge gaps remain for most of the 'at risk' species reviewed during the workshop. For example, almost every year some Indus dolphins are trapped in irrigation canals and need to be translocated to the mainstem of the river. Providing experienced veterinary expertise to improve local skills to care for those animals while at the same time learning about the species' stress response has multiple benefits: directly to the *in situ* population in the short term, and improved prospects for success should longer translocations to safe habitats become necessary in the long term.

## Integrated conservation planning workshops and the ICPC priority projects

ICPC and associated collaborators are directly involved in seven priority projects that were identified during the 2018 ESOCC workshop and focused workshops on the franciscana (Argentina, 2019), Yangtze finless porpoise (China, 2019), tucuxi (Florida, 2022), and on applying tools, methods, and approaches from social science disciplines to the development of integrated conservation plans (Nuremberg WS, 2022). The projects have been advanced by ICPC members working with individual project leads and are listed below (see Appendix 1 for points of contact, Appendix 2, and the ICPC projects webpage for further descriptions of each project):

Yangtze finless porpoise (*Neophocaena asiaeorientalis asiaeorientalis*) – Initial workshop (November 2019) and continued planning for a population viability analysis

Atlantic humpback dolphin (*Sousa teuszii*) – Short- and medium-term priority actions to conserve the Atlantic humpback dolphin were drafted in 2020 (Weir et al 2020), and these led to the formation of an international consortium

Ganges & Indus river dolphin (*Platanista* spp.) – rescue/translocation assistance and local capacity building

Franciscana (*Pontoporia blainvillei*) – Initial workshop (October 2019) and continued planning for franciscana

1. Health assessment added to catch/release/satellite-linked tagging study
2. Enhancement of stranding response and neonate, juvenile and adult rehabilitation protocols

Lahille's bottlenose dolphin (*Tursiops truncatus gephyreus*) – Initial planning occurred at the franciscana workshop in 2019

Development of health assessment methods for stranded and incidentally captured dolphins

Enhanced methods of aging individual animals for population assessment

Tucuxi (*Sotalia fluviatilis*) – Initial workshop (July 2020) included a review of the distribution, movements, and genetic distinctiveness of tucuxi, analysis of critical data gaps for enhancing tucuxi conservation, and planning to develop a better understanding of genetically distinct populations in relation to localized threats.

Analysis of capture myopathy in small cetaceans - to develop a better understanding of capture myopathy, which is an essential veterinary consideration for hands-on conservation work with small cetaceans.

ICPC's goal is the eventual development of integrated conservation plans for some of the most endangered small cetacean species, i.e., those with freshwater or very coastal distributions and other challenges, prioritized by their conservation status, the imminence of catastrophic decline or extinction, and the potential for effective mitigation. As a group within the Cetacean Specialist Group, ICPC will build upon efforts to assess the threat levels of subspecies and subpopulations and prioritize which groups are likely to benefit most from the One Plan Approach.

## Examples of integrated conservation plans

There are numerous examples of successful integrated conservation plans based on the One Plan Approach (e.g., Pramuk et al., 2013; Delphey et al., 2016; Miller, 2017; Traylor-Holzer et al., 2018) showing how those action plans helped to prevent species extinction. Many of those plans led to the re-establishment of wild, viable, self-sustaining populations of threatened species of mammals, birds, reptiles, amphibians, and various flora (IUCN, 2013). It must be stressed, however, that effective use of *ex situ* conservation measures requires extensive information, intensive preparation, adequate long-term funding and – crucially – it becomes less and less likely to succeed once the wild populations have been reduced to near extinction (Rojas-Bracho et al., 2019). As such, thorough preparatory research, outreach, and planning are required before any decisions can be made (McGowen et al., 2016). It is for this reason that the time-consuming process of addressing key knowledge gaps concerning a species' biology and developing an understanding of the risks and benefits of potential *ex situ* actions for an integrated conservation action plan should begin well before the species or population in question is nearing extinction. Understanding of the risks and potential benefits of appropriate *ex situ* measures takes time and is best done when a small cetacean species numbers in the thousands, or more.

### Yangtze finless porpoise

During the 1990s, researchers began bringing wild Yangtze finless porpoises from the main river and lakes into smaller oxbow lakes, which are now referred to in China as *natural ex situ reserves*. As the wild population continued to decline, this subspecies was listed as Critically Endangered in the IUCN Red List of Threatened Species™ (Red List), and the program to establish insurance populations in these reserves became a major component of the government's conservation action plan (Mei et al., 2021; Wang, 2009; Wang et al., 2015). Although not formally developed as an integrated conservation plan following IUCN guidelines, the Chinese Government's Action Plan for Saving the Yangtze Finless Porpoise 2016-2025 (referred to below as the YFP Action Plan) stands as a unique example of applying a conservation management strategy for small cetaceans that integrates both *in situ* and *ex situ* conservation measures. The current *ex situ* population in the Tian-e Zhou *ex situ* reserve is now considered to be reaching the capacity of that reserve, and six porpoises have recently been translocated to other *ex situ* reserves. The potential to return some individuals from the reserves back to the Yangtze River and adjoining lakes is also being considered. Based on the results of a 2017 survey, the decline of the wild population in the mainstem of the river and adjoining lakes appears to have slowed (Huang et al., 2020). Future range-wide surveys will confirm this trend. In addition, the government banned all commercial fishing for ten-years from 2021 and is actively working to restore the health of the Yangtze River.

An international symposium on Yangtze finless porpoise conservation and an associated workshop were held in November 2019 at the Institute of Hydrobiology of the Chinese Academy of Sciences (IHB) in Wuhan, China. The aims of the symposium and workshop were to (a) review the status of the Yangtze finless porpoise, (b) provide participants with an overview of the efforts to maintain the population of wild porpoises living in the Yangtze River and the series of natural *ex situ* reserves, and (c) initiate a review of the YFP Action Plan.

Overall, the *ex situ* program is impressive, with more than 130 porpoises living nearly natural lives within four protected reserves (Mei et al., 2021). Every five years these porpoises are herded into shallow-water areas and caught, where they can be identified from pit-tags, or if born since the last health examination, have a pit-tag inserted and a genetic sample taken to determine parentage. The first 5 animals were introduced into the Tian-e Zhou oxbow in 1990 before the reserve was formally established in 1992. The capture and physical examination of the porpoises in the Tian-e Zhou reserve was first conducted in 2002. There were a few porpoise deaths during the early years of the capture program, but the methods have been improved over the years and the risk of injury or death has been largely reduced. Further understanding of the porpoises' physiological response to capture and the procedures developed to mitigate fatalities from capture myopathy and other causes, could be advantageous for advancing capture methods for other porpoises.

Although not yet finalized, the general conclusion of the ongoing review is that the laudable goals and strategies described in the YFP Action Plan should be augmented with additional explicit information to support all its stated objectives. The review has already resulted in a series of recommendations for advancing the goals of the YFP Action Plan including short-, medium-, and long-term goals for operationalizing the objectives of the Plan and provides quantitative targets for needed actions (Appendix 3). Some of the recommendations are already being implemented in collaboration with ICPC members, including development of a strategy to both maintain genetic diversity within the *ex situ* population and begin the learning process for reintroduction into the wild population when that is deemed safe.

## Concluding thoughts

With this article, we intend to provide context for the formation and objectives of the ICPC team, and as a further step towards the development of improved coordination and collaboration between various stakeholders with the aim of protecting small cetaceans. The adoption of Motion 079 at the last IUCN Congress represents an important milestone by highlighting the potential role of zoos and aquariums in the ICPC framework. Combined with a declaration of commitment by zoos and aquariums to both *in situ* and *ex situ* conservation, this motion provides the basis for their work in species conservation. It is therefore important that the technical groups of the IUCN Species Survival Commission and the zoo and aquarium associations (WAZA, EAZA, AZA to name just a few) strive to establish or strengthen relationships. This is exemplified by IUCN's "Reverse the Red" campaign, in which zoos play an important role by supporting efforts to protect endangered species and their habitats. Zoos and aquariums can host and support both *ex-situ* and *in-situ* research and provide technical expertise to better understand the biology and threats to dolphin and porpoises. In addition, zoos and aquariums have the potential to increase public engagement, stewardship, and importantly, raise funds for the conservation of species and populations in the wild. Co-operation and collaboration between industry peers and non-governmental organizations will harmonize efforts, improve the chances of success and avoid unnecessary duplication. The coming decades will be crucial for many small cetaceans, and it will take the efforts of many dedicated people from a wide range of sectors to prevent further extinctions.

## Zusammenfassung

Die Arbeitsgruppe Integrierte Erhaltungsplanung für Wale und Delfine (ICPC), eine Untergruppe der Wal- und Delfin-Spezialistengruppe der IUCN SSC, wurde als Reaktion auf die dramatische Situation ei-

ner wachsenden Zahl gefährdeter Fluss- und Küstendelfinarten und -populationen gegründet. Das Aussterben des Baiji und der katastrophale Rückgang der Vaquita-Populationen bis an den Rand des Aussterbens sind beides Beispiele dafür, dass Schutzmaßnahmen zu spät ergriffen wurden und nicht alle notwendigen Instrumente zur Verfügung standen, um diese Notfälle zu bewältigen. Integrierte Erhaltungsaktionspläne schließen aktiv Wissenslücken und berücksichtigen ausdrücklich alle Instrumente, die zur Rettung einer Art oder Population erforderlich sein könnten.

## References


Baker, J.D., Becker, B.L., Wurth, T.A., Johanos, T.C., Littnan, C.L., & Henderson, J.R. (2011). Translocation as a tool for conservation of the Hawaiian monk seal. Biological Conservation 144, 2692-2701. https://doi.org/10.1016/j.biocon.2011.07.030

Barham, P. J., Underhill, L. G., Crawford, R. J. M., Altwegg, R., Leshoro, T. M., Bolton, D. A, Dyer, B. M., & Upfold, L. (2008). The efficacy of hand rearing penguin chicks: evidence from African penguins (*Spheniscus demersus*) orphaned in the Treasure oil spill in 2000. Bird Conservation International 18, 144-152. DOI: 10.1017/S0959270908000142

Brakes, P., Dall, S.R.X., Aplin, L.M., Bearhop, S., Carroll, E.L., Ciucci, P., Fishlock, V., Ford, J.K.B., Garland, E.C., Keith, S.A., McGregor, P.K., Mesnick, S.L., Noad, M.J., di Sciara, G.N., Robbins, M.M., Simmonds, M.P., Spina, F., Thornton, A., Wade, P.R., Whiting, M.J., Williams, J., Rendell, L., Whitehead, H., Whiten, A., & Rutz, C. (2019). Animal cultures matter for conservation: understanding the rich social lives of animals benefits international conservation efforts. Science 363:1032-1034. http://science. sciencemag.org/content/363/6431/1032

Brownell Jr., R.L., Reeves, R.R., Read, A.J., Smith, B.D., Thomas, P.O., Ralls, K., Amano, M., Berggren, P., Chit, A.M., Collins, T., Currey, R., Dolar, M.L.L., Genov, T., Hobbs, R.C., Kreb, D., Marsh, H., Zhigang, M., Perrin, W.F., Phay, S., Rojas-Bracho, L., Ryan, G.E., Shelden, K.E.W., Slooten, E., Taylor, B.L., Vidal, O., Ding, W., Whitty, T.S., & Wang, J.Y. (2019). Bycatch in gillnet fisheries threatens Critically endangered small cetaceans and other aquatic megafauna. Endangered Species Research 40, 285-296. DOI: 10.3354/esr00994

Byers, O., Lees, C., Wilcken, J., & Schwitzer, C. (2013). The One Plan approach: the philosophy and implementation of CBSG's approach to integrated species conservation planning. WAZA Magazine 14, 2-5.

Delphey, P., Runquist, E., Harris, T., Nordmeyer, C., Smith, T., Traylor-Holzer, K., & Miller, P.S. (eds). (2016). Poweshiek Skipperling and Dakota Skipper: Ex Situ Feasibility Assessment and Planning Workshop. Apple Valley, MN: IUCN/SSC Conservation Breeding Specialist Group. Rep. 2016-004.pdf

Harting, A.L., Johanos, T.C., & Littnan, C.L. (2014). Benefits derived from opportunistic survival-enhancing interventions for the Hawaiian monk seal: the silver BB paradigm. Endangered Species Research 25, 89-96. DOI: https://doi.org/10.3354/esr00612

Huang, J., Mei, Z., Chen, M., Han, Y., Zhang, X., Moore, J.E., Zhao, X., Hao, Y., Wang, K., & Wang, D. (2020). Population survey showing hope for population recovery of the critically endangered Yangtze finless porpoise. Biological Conservation, 241, 108315. https://doi.org/10.1016/j.biocon.2019.108315

International Union for Conservation of Nature Species Survival Commission (2013). Guidelines for Reintroductions and Other Conservation Translocations. Version 1.0. Gland, Switzerland: IUCN Species Survival Commission, viiii + 57 pp.

International Union for Conservation of Nature Species Survival Commission. (2014). Guidelines on the Use of *Ex Situ* Management for Species Conservation. Version 2.0. Gland, Switzerland: IUCN SSC. IUCN-2014-064 (Accessed Feb. 23, 2020).

International Union for Conservation of Nature (2020). Linking in situ and ex situ efforts to save threatened species (WCC-2020-Res-079-EN). https://portals.iucn.org/library/sites/library/files/resrecfiles/WCC_2020_RES_079_EN.pdf

Jaramillo-Legorreta, A.M., Cardenas-Hinojosa, G., Nieto-Garcia, E., Rojas-Bracho, L., Thomas, L., Ver Hoef, J.M., Moore, J., Taylor, B., Barlow, J., & Tregenza, N. 2019. Decline towards extinction of Mexico's vaquita porpoise (*Phocoena sinus*). Royal Society Open Science 6, 190598. DOI: 10.1098/rsos.190598

MacCracken, J.G., Lemons, P.R., Garlich-Miller, J.L., & Snyder, J.A. An index of optimal sustainable population for the Pacific Walrus. Ecological Indicators 43, 36-43.

McGowan, P.J.K., Traylor-Holzer, K., & Leus, K. (2016). IUCN guidelines for determining when and how *ex situ* management should be used in species conservation. Conservation Letters 10, 361-366. DOI:/10.1111/conl.12285

Mei, Z., Chen, M., Han, Y., Hao, Y., Zheng, J., Wang, K., & Wang, D. 2021. Thresholds of population persistence for the Yangtze finless porpoise: implications for conservation managements. Integrative Zoology DOI: 10.1111/1749-4877.12523. Online ahead of print.

Miller, P.S. (2017). Population viability analysis for the Mexican wolf (*Canis lupus baileyi*): Integrating wild and captive populations in a metapopulation risk assessment model for recovery planning. Report prepared for U.S. Fish and Wildlife Service, Albuquerque NM. https://mexicanwolves.org/uploads/RP02-03-2017_FWS-PopulationViabilityAnalysis.pdf

Pramuk, J., Koontz, F., Tirhi,M., Zeigler, S., Schwartz, K., & Miller, P. (eds). (2013). The Western Pond Turtle in Washington: A Population and Habitat Viability Assessment. IUCN/SSC Conservation Breeding Specialist Group, Apple Valley, MN. http://www.cbsg.org/sites/cbsg.org/files/documents/WPT_PHVA_FINAL_26Sept2013_0.pdf

Rojas-Bracho, L., Gulland, F.M.D., Smith, C.R., Taylor, B., Wells, R.S., Thomas, P.O., Bauer, B., Heide-Jørgensen, M.P., Teilmann, J., Dietz, R., Balle, J.D., Jensen, M.V., Sinding, M.H.S., Jaramillo-Legorreta, A., Abel, G., Read, A.J., Westgate, A.J., Colegrove, K., Gomez, F., Martz, K., Rebolledo, R., Ridgway, S., Rowles, T., van Elk, C.E., Boehm, J., Cardenas-Hinojosa, G., Constandse, R., Nieto-Garcia, E., Phillips, W., Sabio, D, Sanchez, R., Sweeney, J., Townsend, F., Vivanco, J., Vivanco, J.C., & Walker, S. 2019. A field effort to capture critically endangered vaquitas *Phocoena sinus* for protection from entanglement in illegal gillnets. Endangered Species Research 38, 11-27. https://doi.org/10.3354/esr00931

Taylor, B.L., Abel, G., Miller, P., Gomez, F., von Fersen, L., DeMaster, D.P., Reeves, R.R., Rojas-Bracho, L., Wang, D., & Cipriano, F. (eds). (2020). *Ex situ* options for cetacean conservation: December 2018 workshop, Nuremberg, Germany. IUCN. Gland, Switzerland. https://doi.org/10.2305/IUCN.CH.2020.SSC-OP.66.en

Traylor-Holzer, K., Leus, K., & Bauman, K. (eds). (2018). Global Integrated Collection Assessment and Planning Workshop for Canids and Hyaenids: Final Report. IUCN SSC Conservation Planning Specialist Group, Apple Valley, MN. https://doi.org/10.2305/IUCN.CH.2020.SSC-OP.66.en

Turvey, S.T., Pitman, R.L., Taylor, B.L., Barlow, J., Akamatsu, T., Barrett, L.A., Zhao, X., Reeves, R.R., Stewart, B.S., Wang, K., Wei, Z., Zhang, X., Pusser, L.T, Richlen, M., Brandon, J.R., & Wang, D. (2007). First human-caused extinction of a cetacean species? Biology Letters 3: 537-540. https://doi.org/10.1098/rsbl.2007.0292

Venter, F.J., Naiman, R.J., Biggs, H.C., & Pienaar, D.J. (2008). The evolution of conservation management philosophy: Science, environmental change and social adjustments in Kruger National Park. Ecosystems 11:173-192. https://doi.org/10.1007/s10021-007-9116-x

Wang, D. (2009). Population status, threats and conservation of the Yangtze finless porpoise. Chinese Science Bulletin 54, 3473-3484. https://doi.org/10.1007/s11434-009-0522-7

Wang, D., Wang, K., Hao, Y., & Zheng, J. (2015). Review of population status and conservation measures for Baiji and Yangtze finless porpoise. American Fisheries Society Symposium. https://doi.org/10.47886/9781934874448.ch7.

Weir, C., Leeney, R.H., & Collins, T. 2020. Reinvigorating conservation efforts for the Atlantic humpback dolphin (*Sousa teuszii*): A brief progress report. Document presented to the Scientific Committee of the International Whaling Commission SC/68B/SM/07: 1-20.

Wells, R.S., Cremer, M.J., Berninsone, L.G., Albareda, D., Wilkinson, K.A., Stamper, M.A., Paitach, R.L., & Bordino. P. (2022). Tagging, ranging patterns and behavior of franciscana dolphins (*Pontoporia blainvillei*) off Argentina and Brazil: Considerations for conservation. Marine Mammal Science, 38(2): 571-605. https://doi.org/10.1111/mms.12879

Whitehead, H., & Rendell, L. 2015. The cultural lives of whales and dolphins. University of Chicago Press, Chicago, IL. USA. ISBN: 9780226325927

## Appendix 1. Contact details for ICPC and related projects

ICPC CO-CHAIRS
Barbara L. Taylor
Southwest Fisheries Science Center, NMFS, NOAA
8901 La Jolla Shores Drive
La Jolla, CA 92037 USA
barbara.taylor@noaa.gov

Grant Abel
Seattle Aquarium
1483 Alaskan Way, Pier 59
Seattle, WA 98101-2051 USA
g.abel@seattleaquarium.org

IUCN SSC Cetacean specialist group chair
Randall R. Reeves
Okapi Wildlife Associates
27 Chandler, Hudson, Quebec J0P 1H0, Canada
rrreeves@okapis.ca

IUCN SSC CPSG REPRESENTATIVE
Philip S. Miller
IUCN SSC Conservation Planning Specialist Group
12101 Johnny Cake Ridge Road Apple Valley
Minneapolis, MN, USA 55124-8151
pmiller@cpsg.org

MEDIA CONTACT
David Bader
Marine Mammal Care Center
3601 S Gaffey St. #8
San Pedro, CA 90731 USA
dbader@marinemammalcare.org

CONSERVATION MEDICINE SPECIALISTS
Cynthia Smith DVM
Forrest Gomez DVM
National Marine Mammal Foundation
2240 Shelter Island Drive Suite 200
San Diego, California 92106 USA
forrest.gomez@nmmpfoundation.org

RAPPORTEUR
Frank Cipriano
California Academy of Sciences
55 Music Concourse Drive
San Francisco CA 94118 USA
frankwcipriano@gmail.com

PRIORITY PROJECTS POINT-OF-CONTACT
Atlantic humpback dolphin
Tim Collins
Wildlife Conservation Society
tcollins@wcs.org

Gianna Minton
Megaptera Marine Conservation
gianna.minton@gmail.com

Information available on: sousateuszii.org

Yangtze finless porpoise
Ding Wang,
Institute of Hydrobiology
Chinese Academy of Sciences. China
wangd@ihb.ac.cn

Yujiang Hao,
Institute of Hydrobiology
Chinese Academy of Sciences. China
hao.yj@ihb.ac.cn

Indus and Ganges River dolphins
Gill Braulik
University of St Andrews, Scotland
gillbraulik@gmail.com

Capture myopathy
Cynthia Smith DVM
National Marine Mammal Foundation
2240 Shelter Island Drive Suite 200
San Diego, California 92106 USA
cynthia.smith@nmmpfoundation.org

Franciscana dolphin
Lorenzo von Fersen,
Nuremberg zoo, YAQU PACHA e.V. Germany
Lorenzo@vonfersen.org

Lahille's dolphin
Eduardo Secchi
Instituto de Oceanografia, Universidade Federal do Rio Grande/FURG,
Rio Grande, RS, Brazil, 96203-900
edu.secchi@furg.br

Tucuxi dolphin
Susana Caballero
Universidad de los Andes
Carrera 1 No. 18A-10, Bogota, Colombia
sj.caballero26@uniandes.edu.co

# Appendix 2. Short descriptions of current ICPC-related initiatives

## Atlantic humpback dolphins (*Sousa teuszii*) – Conservation Action Plan Project

With fewer than 3000 individuals estimated to remain throughout the species' entire range along the Atlantic coast of Africa, international conservation organizations, including the International Union for the Conservation of Nature (IUCN), the Convention on Migratory Species (CMS) and the International Whaling Commission (IWC) have expressed grave concerns about the species' future. Restricted to shallow-water habitats that overlap with human activities, including fishing and coastal development, Atlantic humpback dolphins are thought to be in decline throughout their range. In 2020 scientists involved with the ICPC, as well as the IWC and CMS collaborated to form the Consortium for the Conservation of the Atlantic Humpback Dolphin (CCAHD). This consortium now involves over 90 partners, including an increasing number of scientists and conservation organizations from 15 of the 19 AHD range states, who collaborate to undertake fund-raising and implementation of research and conservation projects. For more information see https://www.sousateuszii.org/, and the CCAHD's recent report on conservation priorities for the species.

## Indus (*Platanista minor*) and Ganges River dolphins (*Platanista gangetica*) – Capacity Building Project

The entrapment of Indus and Ganges dolphins in irrigation canals is a regular conservation challenge in Pakistan and India, requiring annual translocation of dolphins from the canals back to the mainstream river. While rescue operations for canal-entrapped dolphins occur, they lack scientific data collection, formal veterinary assessments, and trained personnel, resulting in individual animal loss and lack of data acquisition. Current resource gaps limit the scope of the ongoing rescue efforts, as well as the ability to fill critical species-specific data gaps needed to help conserve these poorly known species. The National Marine Mammal Foundation and St. Andrews University have formed collaborations with the organizations currently overseeing local rescue operations, WWF Pakistan and Turtle Survival Alliance India. The aim of these new alliances is to build urgently needed infrastructure through the training of local first responders and the organization of data collection in order to improve long-term conservation efforts. Funding is currently being sought in support of these developing projects.

## Franciscana dolphins (*Pontoporia blainvillei*) – Tagging and Health Assessment Project

Plans are in place for a project off the coast of Argentina in October 2023, to catch, tag, and release up to four franciscanas to learn about movement patterns relative to coastal fisheries, extending research conducted since 2005 in Argentina and Brazil (Wells et al. 2022). The project, sponsored by Disney Conservation Funds and conducted by the Chicago Zoological Society's Sarasota Dolphin Research Program and AquaMarina, will attempt to deploy satellite-linked tags in a region of coastal artisanal fishery activity. During the process of handling for tagging, efforts will be made to carefully incorporate health assessment protocols by experienced veterinarians from AquaMarina, the National Marine Mammal Foundation, and Disney, and document responses.

## Franciscana dolphins (*Pontoporia blainvillei*) – Neonate Rehabilitation Project

The franciscana dolphin is distributed along shallow coastal waters and estuaries in Brazil, Uruguay, and Argentina, increasing their vulnerability to anthropogenic activities, mainly gillnet entanglement. Due to high bycatch rates, the species is considered the most endangered dolphin in the South Atlantic Ocean. Live stranded franciscana dolphins require rapid response, especially neonates that typically die within hours of stranding. To date, rehabilitation success of orphaned neonates is minimal and there is a critical need for enhancement of current conventions. To answer this urgent call, Yaqu Pacha (YP), the National Marine Mammal Foundation (NMMF), and Zoo Nuremberg (ZN) formed a consortium with local and international experts to improve existing rehabilitation protocols for franciscana dolphins. A neonate protocol has been completed and is being translated into multiple languages. Improvement of adult franciscana procedures and the development of mobile animal care units are also underway. This collaborative project aims to: (1) increase individual animal survival and subsequent release, (2) aid in the acquisition of critical species-specific data, (3) expand the body of knowledge on species biology and medicine, and (4) inform future conservation actions. The project is currently supported with funds from YP, the NMMF Board of Directors Grants Program, and ZN. Additional funding is being sought for international training and capacity building.

## Lahille's bottlenose dolphins (*Tursiops truncatus gephyreus*) – Understanding Knowledge Gaps Project

The Lahille's bottlenose dolphin (*Tg*) occurs only in southern Brazil, Uruguay, and Argentina. Abundance estimates suggest a maximum total population size of 600 dolphins, with an estimated 360 mature individuals. *Tg* are listed as vulnerable on the IUCN Red List and endangered on the respective National Red Lists of Brazil and Argentina. Improved knowledge of age structure, population demographics, and health status could provide further basis for classification and protections. The National Marine Mammal Foundation (NMMF) and Universidade Federal do Rio Grande (FURG) are developing a skin-based, epigenetic aging technique to estimate the age of *Tg*. Establishing an epigenetic aging technique will directly address IWC health assessment priorities by creating a foundation to establish population demographics and age-related context for individual health status of *Tg*. The project builds on the emerging epigenetic aging techniques developed for common bottlenose dolphins. The research team aims to apply this technique to *Tg* and establish the ages of previously sampled animals through population surveys conducted by FURG. If successful, this project will help fill critical data gaps regarding population demographics. Additionally, the resulting technique and data will provide a foundation on which to study biological aging of *Tg*. Research is underway with funds from the NMMF Board of Directors Grants Program. Additional funds are being sought for data analysis, interpretation, and international capacity building.

## Capture myopathy analysis – Understanding Knowledge Gaps Project

NOAA's Marine Mammal Health & Stranding Response Program held a virtual capture myopathy workshop in February 2021, co-chaired by the University of California at Davis, in collaboration with the Smithsonian Institute, University of Illinois, and National Marine Mammal Foundation. The primary goal was to develop a better understanding of capture myopathy, which is an essential veterinary consideration for hands-on conservation work with small cetaceans. The workshop brought together marine mammal and terrestrial wildlife veterinarians and biologists to discuss risk factors, diagnostic techniques, treatment options, and prevention strategies for capture myopathy. Spin-off projects currently being discussed include the development of field-ready diagnostics and prognostic indicators for small cetaceans, as well as the continued collaboration needed to advance these tools and techniques.

## Tucuxi – Elucidating Population Structure from Environmental DNA (eDNA) Analysis

Tucuxi (*Sotalia fluviatilis*) is an endemic freshwater dolphin species inhabiting the Amazon basin. Tucuxi are found throughout the Amazon, occurring in all types of water, but there are no estimates of population size for most parts of the tucuxi's range. In some areas observed rates of declines are consistent with a 'critically endangered' status. Threats include accidental entanglement in fishing nets, habitat fragmentation due to dam building and associated decreases in food supply, and the effects of pollutants and continued habitat destruction. Genetic evidence suggests two distinct subpopulations of *Sotalia fluviatilis*: one in the upper Amazon of Colombia and Peru and the other in the middle and lower Amazon in Brazil, while the genetic distinctiveness of the isolated Ecuador subpopulation still needs to be evaluated. Researchers studying the distribution, movements, and genetic distinctiveness of tucuxi in Colombia and Ecuador are now using eDNA analysis to develop a better understanding of population differences in relation to localized threats across their range.

DER ZOOLOGISCHE GARTEN

doi:10.53188/zg0020 Zool. Garten N.F. 91 (2023) 113-121 THE ZOOLOGICAL GARDEN

# Measuring Hearing in Odontocete Cetaceans

## Messung des Hörvermögens bei Zahnwalen

Paul E. Nachtigall* & Aude Pacini

Marine Mammal Research Program, Hawaii Institute of Marine Biology, University of Hawaii at Manoa, 46-007 Lilipuna Road, Kaneohe, HI 96744, USA

## Abstract

The initial measurements of odontocete hearing were obtained using captive trained animals and established psychophysical procedures that revealed very sensitive hearing at very high frequencies. However, these procedures tend to take a long time and require dedicated animals. New procedures using brain wave auditory evoked potential measurements in response to sound allowed for faster hearing tests and quick measurement of the hearing of untrained animals, including animals that stranded on beaches. As a result, knowledge of hearing in odontocetes rapidly expanded. The development of new procedures continued, including the possible inclusion of hearing measurements gathered via startle responses and via Evoked Auditory Potentials gathered from free-swimming wild animals with temporary tags attached with suction cups. Understanding hearing in marine mammals remains a priority to ensure that proper management decisions are made to minimize the impact of man-made underwater noise on these species

**Keywords:** Hearing, dolphins, whales, AEP

C. Scott Johnson's (1966) measurement of the original audiogram of the bottlenose dolphin (*Tursiops truncatus*, Montague) was the first true measurement of hearing in a whale or dolphin. However, it took over two years to complete, and he used young trained animals and developed the psychophysical method and training as he went along. The animals were trained in the laboratory with the help of professional animal trainers who learned their craft based on the principles devised with pigeons by B.F. Skinner and techniques used by dolphin trainers in oceanaria. Johnson's techniques were logical and produced outstanding data, demonstrating very high frequency underwater hearing with relatively good detection of sounds with frequencies up to 150 kHz. The techniques that Johnson developed became the 'gold standard' for measuring ma-

*Corresp. author:
E-Mail: nachtiga@hawaii.edu (Paul E. Nachtigall)

rine mammal hearing. If one followed his methods, a researcher was assured of administering accurate hearing tests. Most psychophysical behavioral tests of hearing have taken a long time to complete, but true measures of hearing, which require an animal to report the presence and absence of sound, require that the animal be trained. Once a baseline for a species is established with multiple animals, Auditory Evoked Potential (AEP) measures, which are much quicker, can be used to measure the hearing of individuals (Yuen et al., 2005). AEP measurements of hearing are not based on the animal's reports of experiencing sound, but on measurements of brainwave patterns produced in response to sound. Suction cups containing passive electrode sensors are normally placed on the whale or dolphin's skin (see Fig. 1). Typically, sounds to be measured are presented in patterns that are replicated in the brain so that they can be easily distinguished. This hearing measurement technique is now used for most human babies born in hospitals during their first couple of days of life. The technique applied to whales and dolphins was developed within the laboratory and in marine zoological parks. Animal hearing had to be tested using both behavioral psychophysical and evoked auditory potential testing procedures,

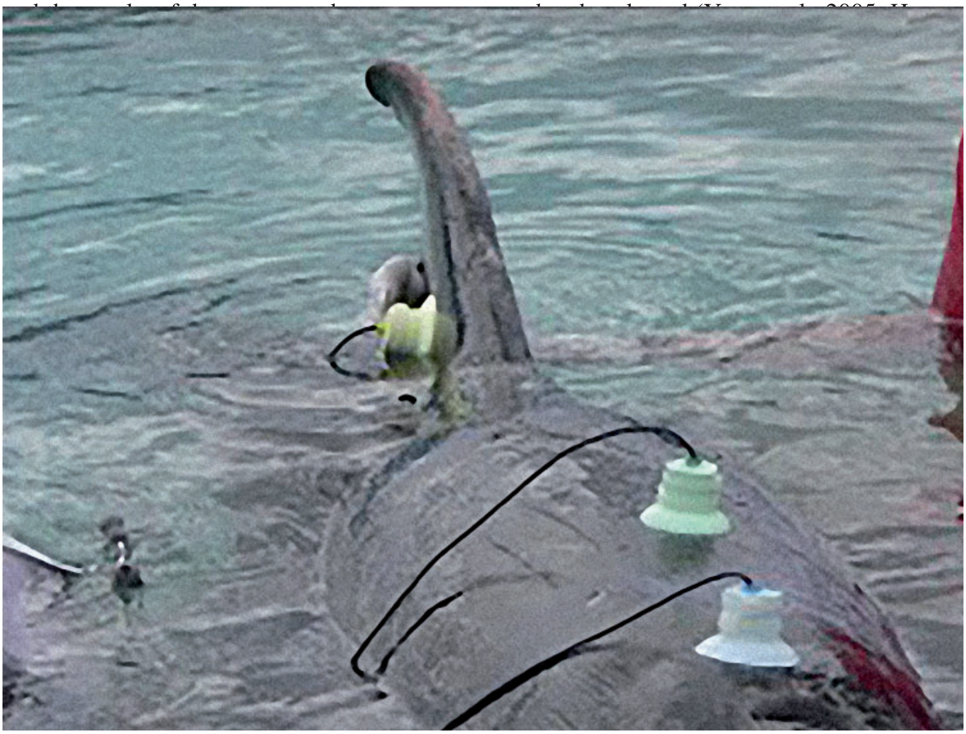

**Fig. 1:** Suction cups containing surface electrodes attached to a beached cetacean. Photo: Marine Mammal Research Program, University of Hawaii

Establishing a baseline for a species requires measuring the hearing of multiple animals within that species. If the hearing of only one individual is tested, the resulting audiogram should be interpreted with caution as hearing abilities can vary among individuals of the same species. The initial hearing measurements published by Hall & Johnson (1972) for killer whales (*Orcinus orca*) were very different from those of bottlenose dolphins, not due to a species difference, but due to intraspecific variations. The early studies showed an upper frequency cutoff at 30 kHz, which was much lower than the 150 kHz frequency cutoff measured by Johnson for bottlenose dolphins (*Tursiops truncatus*). Because of the amount of time required for behavioral tests and the scarcity of available subjects, the 30 kHz upper frequency cutoff for *O. orca* remained the only representative data for this species for over 25 years. However, when Szymanski et al. (1999) tested the hearing of two killer whales at the Marine World Park in California, they found that the high-frequency hearing cutoff was closer to 100 kHz, which more closely resembles the higher thresholds found in other odontocete cetaceans. These thresholds were further confirmed with „gold standard" psychophysical behavioral measures conducted by Branstetter et al. (2017) on eight different killer whales from two different marine parks within the last five years.

The development of rapid hearing testing procedures and their validation with psychophysical behavioral measures has provided valuable scientific information about dolphin and small whale hearing. It has also laid the foundation for evaluating the effects of loud sounds on cetaceans and for conserving groups and individual animals exposed to excessive anthropogenic noise. Early measures of auditory brain responses primarily relied on responses to clicks and showed promise for measuring audiograms but were not refined for precise hearing measurements to specific frequencies (Bullock & Ridgway, 1972; Ridgway et al., 1981). Shortly after the development of the Auditory Evoked Potential envelope following response procedure for measuring cetacean hearing (Supin & Popov, 1995; Dolphin et al., 1995), conservationists and animal welfare advocates began seeking ways to rapidly assess cetacean hearing.

When a group of Risso's dolphins (*Grampus griseus*) stranded on a beach in Southern Portugal,

**Fig. 2:** Stranded neonate Risso's dolphin (*Grampus griseus*) at Mundo Aquatico Rehabilitation Facility of ZooMarine in Guia. Photo: Marine Mammal Research Program, University of Hawaii

a neonate *G. griseus*, so young that it still had fetal fold creases visible on its side, was rescued and taken to the rehabilitation facility at the ZooMarine marine park in Guia, Albufeira, Portugal (see Fig. 2). During the rehabilitation, the staff and veterinarians observed that the animal had difficulty maintaining horizontal stability and suspected that the ears and vestibular system (responsible for balance) may have been damaged by overexposure to anthropogenic noise. A behavioral psychophysical audiogram had been previously measured for one adult *G. griseus* (Nachtigall, Au, Pawloski & Moore, 1995). The management at ZooMarine Park in Portugal‘s Algarve requested that the hearing of the stranded calf be quickly tested. The stranded infant‘s hearing was tested at night when veterinarians were not administering medical care. The data showed (Nachtigall, Yuen, Mooney & Taylor, 2005) that compared to the audiogram obtained using behavioral methods for the older Risso‘s dolphin, the hearing threshold values at upper frequencies were much lower (i.e., better sensitivity) for this neonate animal. This means that this neonate whale heard well at much higher frequencies. The results redefined hearing sensitivity for the *G. griseus* species, with peak sensitivity near 100 kHz and the ability to hear sounds above 150 kHz. The experiment also demonstrated that, like human infants in hospitals, infant cetacean hearing could be rapidly assessed for diagnostic purposes and assistance in medical care.

The method of rapidly testing hearing through AEP analysis, which was developed within the laboratory and then used as a diagnostic tool during the rehabilitation of animals, has other distinct values. It can quickly test hearing during temporary threshold shift (TTS) experiments and analyze the hearing of dolphins and small whales that have recently stranded on the beach. Cetacean stranding has been demonstrated to be caused by overexposure to anthropogenic noise (Frantzis, 1998; Evans & England, 2001), and determining regulatory sound limits is crucial. Sound limits for humans have been established by the determination of TTS, which determines sound levels that temporarily reduce hearing or cause an upward shift in hearing threshold. Similar levels were sought for cetaceans (Nachtigall et al., 2003; Weilgart, 2007), but reliable TTS measurements could not be obtained without quick measures of hearing. AEP provide quick hearing measurements (Nachtigall et al., 2004), allowing regulatory levels to be established to protect wild animals from overexposure to noise and potential subsequent stranding (National Marine Fisheries Service, 2018).

New and faster behavioral methods were developed by scientists at the Navy Lab in San Diego to measure the recovery of hearing in TTS experiments by training dolphins and beluga whales to whistle immediately when they hear a sound (Schlundt et al., 2000). Although this training procedure works well for threshold shift experiments (Finneran, 2015), the behavioral training method still requires that the animal is adapted to an enclosed environment and receives extensive training (Schlundt et al., 2000), limiting the number of animals that can be tested. On the other hand, AEP measurements of cetacean hearing are less time-consuming and can be conducted without adaptation or any animal training (Supin et al., 2001; Houser & Finneran, 2006; Andre & Nachtigall, 2007). While true hearing tests still rely on behavioral measures of animal reports of hearing, AEP measures can be used in various situations where animals are available for only short periods of time.

Because AEP hearing tests can be done quickly and are part of the veterinary diagnostic routine for stranded animals, their use has allowed for much-needed expansion of the study of hearing in small whales and dolphins. They can now measure the hearing of interesting deep-diving small whales that are rarely held in research facilities or animal display facilities and have stranded on beaches (Pacini et al., 2010). At times this may require taking the animal back to an animal care facility for rehabilitation, but hearing tests can also be conducted right on the beach. AEP hearing tests enable addressing difficult conservation questions and concerns.

Beaked whales (*Mesoplodon densirostris*) are a group of highly elusive small whales that are capable of diving to depths exceeding 3000 meters and holding their breath for close to four hours (Quick et al., 2020). They gained notoriety following an infamous mass stranding in the Bahamas (Evans & England, 2001) that was believed to have been caused by U.S. Navy activities. This incident spurred a strong interest in understanding the hearing abilities of beaked whales. During the rehabilitation of a wild young Blainville's beaked whale that had stranded off the coast of Maui, Hawaii, its hearing was tested, revealing exceptional hearing sensitivity between 40 and 80 kHz (Pacini et al., 2011), the frequency range where its primary echolocation click energy is found. Interestingly, the whale also appeared to hear signals above 100 kHz (see Figure 3), indicating a broader hearing range than previously thought.

Auditory testing was not limited to stranded wild animals. New possibilities emerged to answer lingering questions, including the high-frequency hearing capabilities of white-beaked dolphins (*Lagenorhynchus albirostris*). In a study by Mitson (1990), white-beaked dolphins' echolocation signals were recorded while they were feeding on sand-eels and responding to high-frequency sonars. Mitson reported echolocation click energy with frequencies as high as 305 kHz, well above the typical upper hearing frequency limit for odontocetes of about 150 kHz. However, the question of whether white-beaked dolphins could hear frequencies over 300 kHz remained unanswered. These dolphins are often observed off the coast of Iceland during the summer months, and for several decades, temporary dolphin captures have been taking place for scientific purposes off Tampa Bay, Florida, on an annual basis to monitor a population of bottlenose dolphins. Therefore, it did not seem too much of a reach to attempt to temporarily capture a white-beaked dolphin, place it onboard a boat in a water-filled foam-lined box for a short period of time, and examine its hearing (see Figure 4). A group organized around Lee Miller's lab at the University of Southern Denmark (Nachtigall et al., 2008) accomplished this effort with two white-beaked dolphins. While the animals did not hear over 300 kHz, the dolphins did hear as well as harbor porpoises up to near 180 kHz, and the technique to catch and release and to measure hearing was demonstrated to be viable. Although the effort worked very well for the white-beaked dolphins, a similar attempt organized by the same group to catch the larger mysticete minke whale (*Balaenoptera acutorostrata*)

**Fig. 3:** Beaked whale (*Mesoplodon densirostris*) in a rehabilitation facility. Photo: Aude Pacini

**Fig. 4:** Testing the hearing of the white-beaked dolphin (*Lagenorhynchus albirostris*) temporarily held aboard ship. Photo: Marine Mammal Research Program, University of Hawaii

was unsuccessful. Unfortunately, no behavioral or evoked potential measures of hearing of mysticete whales are currently available. It is generally believed that the smaller toothed dolphins and whales, the odontocetes, evolved high-frequency hearing and that odontocetes have excelled in echolocation, while the mysticetes have not taken the same evolutionary path. High-frequency directional echolocation type signals are not usually recorded from the larger mysticete whales, while every odontocete recorded has shown echolocation-type signals (Surlykke et al., 2014). Most mysticete vocalizations are of lower frequency compared to those of odontocetes. Measuring hearing at low frequencies using AEP is generally more difficult than measuring high-frequency hearing.

New techniques for measuring hearing are under development so that the basic hearing of healthy wild animals can be tested in the future. Developing these techniques requires access to animals in marine parks and research facilities that have established audiograms. Detectable startle responses to sounds as unexpectedly quiet as 140 dB re 1 (µPa) have been observed in false killer whales (*Pseudorca crassidens*), and startle responses tend to stay at a relatively set level above threshold for mammals (Koch and Schnitzler, 1997). If that is true with cetaceans, then one could obtain thresholds across the auditory spectrum and subtract the set amount to estimate an audiogram. This would be particularly helpful in attempting to estimate the thresholds of large mysticete whales.

Auditory evoked potential measures typically require non-invasive suction cup electrodes to record the small electrical signals from the brain, with wires connected to the recording and processing equipment. So far, animals in human care, recently captured prior to release, or stranded have been the primary sources for new species audiograms. Archival tags attached to wild animals have been used effectively to obtain a great deal of interesting data on the acoustics and behavior of wild animals. The tags attach temporarily to the animals via suction cups and are recovered later. The initial data processing and data storage occur directly on the tag, without the need for wires. Smith et al. (2021) have developed a new tag that can be attached to free-swimming harbor porpoises. Evoked potential responses of sounds presented to the animal were recorded on the attached tag, allowing a „wireless“ measure of acoustic thresholds. If this exciting new procedure continues to develop, and the tags can be placed on wild free-swimming animals, the audiograms of many animals, including new species, can be measured. If new techniques for measuring low-frequency hearing are also developed, the hearing of large mysticete whales can finally be measured.

## Zusammenfassung

Die ersten Messungen des Gehörsinns von Zahnwalen wurden mit in Menschenobhut trainierten Tieren und etablierten psychophysikalischen Verfahren durchgeführt, die ein sehr empfindliches Gehör bei sehr hohen Frequenzen zeigten. Diese Verfahren sind jedoch in der Regel sehr zeitaufwändig und erfordern speziell trainierte Tiere. Neue Verfahren, bei denen das auditorisch evozierte Potenzial des Gehirns als Reaktion auf Geräusche gemessen wird, ermöglichten schnellere Hörtests und eine rasche Messung des Gehörs von untrainierten Tieren, auch von gestrandeten Tieren. Infolgedessen erweiterte sich das Wissen über das Hörvermögen von Zahnwalen rasch. Die Entwicklung neuer Verfahren wurde fortgesetzt, einschließlich der möglichen Einbeziehung von Hörmessungen, die über Schreckreaktionen und über evozierte Hörpotentiale von freischwimmenden Wildtieren mit temporären, mit Saugnäpfen befestigten Markierungen durchgeführt wurden. Das Verstehen des Hörens von Meeressäugetieren hat nach wie vor Priorität, um sicherzustellen, dass geeignete Managemententscheidungen getroffen werden, um die Auswirkungen des vom Menschen verursachten Unterwasserlärms auf diese Arten zu minimieren.

## References

André, M., & Nachtigall, P.E. (2007). Electrophysiological Measurements of Hearing in Marine Mammals. Aquatic Mammals, 33(1), 1-5. https://doi.org/10.1578/am.33.1.2007.1

Branstetter, B.K., St. Leger, J., Acton, D., Stewart, J., Houser, D., Finneran, J.J., & Jenkins, K. (2017). Killer whale (*Orcinus orca*) behavioral audiograms. The Journal of the Acoustical Society of America, 141(4), 2387-2398. https://doi.org/10.1121/1.4979116

Bullock, T. H, & Ridgway, S.H. (1972). Evoked potentials in the central auditory system or alert porpoises to their own and artificial sounds. The Journal of Neurobiology, 3(1), 79-99. https://doi.org/10.1002/neu.480030107

Dolphin, W.F., Au, W.W.L., Nachtigall, P.E., & Pawloski, J. (1995). Modulation rate transfer functions to low-frequency carriers in three species of cetaceans. Journal of Comparative Physiology A, 177(2), 235–245. https://doi.org/10.1007/bf00225102

Evans, D.L., & England, G.R. (2001). Joint interim report: Bahamas marine mammal stranding event of 15–16 March 2000. US Department of Commerce, Washington, D.C. National Oceanographic and Atmospheric Administration, & US Department of the Navy. https://repository.library.noaa.gov/view/noaa/16198

Finneran, J.J. (2015). Noise-induced hearing loss in marine mammals: A review of temporary threshold shift studies from 1996 to 2015. The Journal of the Acoustical Society of America, 138(3*)*, 1702-1726. https://doi.org/10.1121/1.4927418

Frantzis, A. (1998). Does acoustic testing strand whales? Nature, 392(6671), 29. https://doi.org/10.1038/32068

Götz, T., Pacini, A.F., Nachtigall, P.E., & Janik, V.M. (2020). The startle reflex in echolocating odontocetes: basic physiology and practical implications. The Journal of Experimental Biology, 223(5). https://doi.org/10.1242/jeb.208470

Hall, J.D., & Johnson, C.S. (1972). Auditory thresholds of a killer whale *Orcinus orca* Linnaeus. The Journal of the Acoustical Society of America, 51(2B), 515-517. https://doi.org/10.1121/1.1912871

Houser, D.S., & Finneran, J.J. (2006). A comparison of underwater hearing sensitivity in bottlenose dolphins *Tursiops truncatus* determined by electrophysiological and behavioral methods. The Journal of the Acoustical Society of America, 120(3), 1713-1722. https://doi.org/10.1121/1.2229286

Johnson, C.S. (1966). Auditory thresholds of the bottlenose porpoise (*Tursiops truncatus* Montague) (Naval Ordnance Station Technical Report 4178*).* U.S. Naval Ordnance Test Station, China Lake, CA, United States. https://apps.dtic.mil/sti/citations/AD0643381

Koch, M., & Schnitzler, H.-U. (1997). The acoustic startle response in rats- circuits mediating evocation, inhibition and potentiation. Behavior and Brain Research, 89(1-2), 35-49. https://doi.org/10.1016/s0166-4328(97)02296-1

Melnick, W. (1991). Human temporary threshold shifts (TTS) and damage risk. The Journal of the Acoustical Society of America, 90(1), 147-154. https://doi.org/10.1121/1.401308

Nachtigall, P.E., Au, W.W.L., Pawloski, J.L., & Moore, P.W.B. (1995). Risso's dolphin (*Grampus griseus*) hearing thresholds in Kaneohe Bay, Hawaii. In R.A. Kastelein, J.A. Thomas,& P.E. Nachtigall (Eds), Sensory Systems of Aquatic Mammals (pp. 49-53). Woerden, NL: De Spil Publishers.

Nachtigall, P.E., Lemonds, D.W., & Roitblat, H.L. (2000). Psychoacoustic studies of dolphin and whale hearing. In W.W.L. Au, R.R. Fay, & A.N. Popper (Eds), Hearing by Whales and Dolphins. Springer Handbook of Auditory Research, Vol. 12 (pp. 156-224). Heidelberg & Berlin: Springer. https://doi.org/10.1007/978-1-4612-1150-1_4

Nachtigall, P.E., Pawloski, J.L., & Au, W.W.L. (2003). Temporary threshold shifts and recovery following noise exposure in the Atlantic bottlenosed dolphin (*Tursiops truncatus*). The Journal of the Acoustical Society of America, 113(6), 3425–3429. https://doi.org/10.1121/1.1570438

Nachtigall, P.E., Supin, A.Y., Pawlowski, J.L., & Au, W.W.L. (2004). Temporary threshold shifts after noise exposure in a bottlenose dolphin (*Tursiops truncatus*) measured using evoked auditory potentials. Marine Mammal Science, 20(4), 673-687. https://doi.org/10.1111/j.1748-7692.2004.tb01187.x

Nachtigall, P.E., Yuen, M.E., Mooney, T.A., & Taylor, K.A**.** (2005). Hearing measurements from a stranded infant Risso's dolphin (*Grampus griseus*). The Journal of Experimental Biology, 208(21), 4181,4188. https://doi.org/10.1242/jeb.01876

Nachtigall, P.E., Mooney, T A., Taylor, K.A., Miller, L.A., Rasmussen, M.H., Akamatsu, T., Teilman, J., Linnenschmidt, M., & Vikingsson, G.A. (2008). Shipboard measurements of the hearing of the white-beaked dolphin *Lagenorhynchus albirostris*. The Journal of Experimental Biology, 211(4), 642-647. https://doi.org/10.1242/jeb.014118

National Marine Fisheries Service. (2018). Revisions to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0): Underwater Thresholds for Onset of Permanent and Temporary Threshold Shifts. (NOAA Technical Memorandum NMFS-OPR-59). U.S. Department of Commerce, National Oceanic and Atmospheric Administration. https://media.fisheries.noaa.gov/dam-migration/tech_memo_acoustic_guidance_%2820%29_%28pdf%29_508.pdf

Pacini, A.F., Nachtigall, P.E. Kloepper, L.N., Linnenschmidt, M., Sogorb, A., & Matias, S. (2010). Audiogram of a formerly stranded long-finned pilot whale (*Globicephala melas*) measured using auditory evoked potentials. The Journal of Experimental Biology, 213(18), 3138-3143. https://doi.org/10.1242/jeb.044636

Pacini, A.F., Nachtigall, P.E. Quintos, C.T., Schofield, D., Look, D., Levine, G.A., & Turner, J.A. (2011). Audiogram of a stranded Blainville's beaked whale (*Mesoplodon densirostris*) measured using auditory evoked potentials. *The Journal of Experimental Biology, 214*(14), 2409-2415. https://doi.org/10.1242/jeb.054338

Quick, N.J., Cioffi, W.R., Shearer, J.M., Fahlman, A., & Read, A. (2020). Extreme diving in mammals: first estimates of behavioral aerobic dive limits in Cuvier's beaked whales. Journal of Experimental Biology 223(18), 1-6.

Ridgway, S.H., Bullock, T.H., Carder, D.A., Seeley, R.L., Woods, D., & Galambos, R. (1981). Auditory brainstem response in dolphins. Proceedings of the National Academy of Sciences of the United States of America, 78(3), 1943-1947. https://doi.org/10.1073/pnas.78.3.1943

Schlundt, C.E., Finneran, J.J., Carder, D.A., & Ridgway, S.H. (2000). Temporary shift in masked hearing thresholds of bottlenose dolphins, *Tursiops truncatus*, and white whales, *Delphinapterus leucas*, after exposure to intense tones. The Journal of the Acoustical Society of America, 107(6), 3496-3508. https://doi.org/10.1121/1.429420

Smith, A.S., Madsen, P.T., Johnson, M., Tyack, P., & Wahlberg, M. (2021). Toothed whale auditory brainstem responses measured with a non-invasive, on-animal tag. JASA Express Letters, 1(9). https://doi.org/10.1121/10.0006454

Supin, A.Y., & Popov, V.V. (1995). Envelope-following response and modulation transfer function in the dolphin's auditory system. Hearing Research, 92(1-2), 38-46. https://doi.org/10.1016/0378-5955(95)00194-8

Supin, A.Y., Popov V.V., & Mass A.M. (2001). The sensory physiology of aquatic mammals. New York: Springer Publishing. https://doi.org/10.1007/978-1-4615-1647-7

Surylykke, A., Nachtigall, P.E., Fay, R.R., & Popper, A.N. (2014). Biosonar. Springer Handbook of Auditory Research (Vol. 51). Berlin & Heidelberg: Springer. https://doi.org/10.1007/978-1-4614-9146-0

Szymanski, M.D., Bain, D.E., Kiehl, K., Pennington, S., Wong, S., & Henry, K.R. (1999). Killer whale (*Orcinus orca*) hearing: Auditory brainstem response and behavioral audiograms. The Journal of the Acoustical Society of America, 106(2), 1134-1141. https://doi.org/10.1121/1.427121

Weilgart, L. (2007) The impacts of anthropogenic ocean noise on cetaceans and implications for management, Canadian Journal of Zoology, 85(11), 1091-1116. https://doi.org/10.1139/Z07-101

Yuen, M.E., Nachtigall, P.E., Supin, A.Y., & Breese, M. (2005). Behavioral and auditory evoked potential audiograms of a false killer whale (*Pseudorca crassidens*). The Journal of the Acoustical Society of America, 118(4), 2688-2695. https://doi.org/10.1121/1.2010350

DER ZOOLOGISCHE GARTEN
THE ZOOLOGICAL GARDEN

doi:10.53188/zg0017

Zool. Garten N.F. 91 (2023) 123-133

# Applying Navy Dolphin Medicine to Conservation Medicine for Small Cetaceans

## Anwendung der Delfinmedizin der Navy auf die Artenschutzmedizin für kleine Cetaceen

Cynthia R. Smith[1*], Forrest M. Gomez[1], Ashley Barratclough[1], Abby M. McClain[1], Barbara K. Linnehan[1], Jennifer M. Meegan[1], Kyle Ross[1], Marina Ivančić[2], Ryan Takeshita[1], Veronica Cendejas[1], Betsy A. Lutmerding[3], Carolina R. Le-Bert[3], & Sam H. Ridgway[1,3]

[1]National Marine Mammal Foundation, San Diego, California, 92106, USA; [2]ZooRadOne, Plainfield, Illinois, 60544, USA; [3]US Navy Marine Mammal Program, NIWC Pacific, San Diego, California, 92152, USA

## Abstract

Marine mammal veterinarians play an important role in the conservation of small cetaceans, specifically with regard to the application of their unique expertise to wild animal health assessments and the continual advancement of medical tools, techniques, and approaches to cetacean care. The US Navy Marine Mammal Program (Navy) has cared for common bottlenose dolphins (*Tursiops truncatus*) for over 60 years and has established a comprehensive clinical practice aimed at providing the best possible care to Navy animals, per US Secretary of the Navy instruction. To date, the Navy has contributed more than 1200 publications to marine mammal science, ranging from discoveries in physiology, acoustics, and anatomy, to advanced diagnostic techniques for marine mammal healthcare. This knowledge has been directly applied to the conservation of at-risk, threatened, and endangered small cetaceans, especially dolphins. Three case studies demonstrate the translation of Navy medicine to conservation medicine, to include: (1) conducting diagnostic ultrasound evaluations of wild dolphins following the *Deepwater Horizon* oil spill; (2) predicting health impacts of freshwater exposure on wild dolphins; and (3) developing minimally-invasive aging techniques for dolphins. The case examples are relevant to all veterinarians caring for and/or evaluating the health of small cetaceans in zoo-

*Corresp. author:
E-Mail: executive.director@nmmf.org (Cynthia R. Smith)

logical settings, marine mammals rehabilitation centers, or in the wild. The aquatic mammal medical community must continue to find opportunities to translate managed animal medicine and care into conservation medicine, integrating our veterinary knowledge into conservation action plans for at-risk cetaceans and species recovery.

**Keywords:** dolphin, veterinary, medicine, conservation, cetaceans

## Introduction

The US Navy Marine Mammal Program (Navy) has cared for common bottlenose dolphins (*Tursiops truncatus*) for more than 60 years (NIWC Pacific, 2023). Navy dolphins spend a portion of their time swimming freely in the open ocean as part of operational training plans and in support of the animals' health and welfare. When the animals are not at sea, they are cared for in open ocean enclosures, which are located in bays, sounds, and estuaries co-inhabited by local marine life. The US Secretary of the Navy dictates that Navy marine mammals are provided the highest quality of humane care and treatment (SECNAV INSTRUCTION 3900.41H, 2018). Caring for the animals in this way has allowed veterinarians, animal care experts, and biologists to continuously monitor their health and behavior in a controlled, natural environment that closely mimics the living conditions of their wild counterparts (Houser, Finneran, & Ridgway, 2010; Smith et al., 2012; Smith et al., 2013a; Venn-Watson, Jensen, Smith, Xitco, & Ridgway, 2015; Linnehan et al., 2020; Ivančić et al., 2020). The high quality care provided in an ocean environment has resulted in long average lifespans, with Navy dolphins living an average of 32.5 years (Venn-Watson et al., 2015).

The Navy is a leader in marine mammal science and medicine, contributing more than 1200 publications to the scientific literature, ranging from discoveries regarding basic physiologic, acoustic, and anatomic adaptations to the ocean environment, to advanced diagnostic techniques for marine mammal healthcare (Department of the Navy, 1998; Ridgway, 2008; Houser et al., 2010; NIWC Pacific, 2023). Since 2007, the National Marine Mammal Foundation (NMMF) has provided medical, training, and research support to the Navy. To date, the NMMF has added 350 publications to the marine mammal peer-reviewed literature, many of which involve Navy animals (NMMF, 2023). Much of the knowledge gained can be directly applied to the conservation of at-risk small cetaceans. This has led to a rich history of translating Navy medicine into conservation tools, techniques, and strategies for wild marine mammals, facilitated through partnerships with nonprofit organizations, government agencies, expert consultants, private institutions, and universities (Houser et al., 2010; NIWC Pacific, 2023; NMMF, 2023).

Over the years, direct applications have included conservation planning for endangered cetaceans such as the Yangtze river dolphin (*Lipotes vexillifer*) in China (Ridgway, Norris, & Cornell, 1998) and the vaquita porpoise (*Phocoena sinus*) in Mexico (Rojas-Bracho et al., 2019); medical database development for the Southern Resident killer whale (*Orcinus orca*) in the US Pacific Northwest (Lutmerding et al., 2019); advancement of diagnostic techniques for application to field assessments of small cetaceans (Smith et al., 2013a; Wells et al., 2014; Ivančić et al., 2020; Linnehan et al., 2020; Barratclough et al., 2021a); health assessments of at-risk cetaceans including those impacted by the *Deepwater Horizon* (DWH) oil spill in the northern Gulf of Mexico (Schwacke et al., 2014; Smith et al., 2017; Barratclough et al., 2019a; Linnehan et al., 2021; Smith et al., 2022); and the development of minimally-invasive aging techniques to inform population assessments of marine mammals (Barratclough et al., 2019b; Barratclough et al., 2021b; Barratclough et al., 2023). Through improvements in care provided to the Navy's marine mammals, we are developing and applying tools, techniques, and knowledge gained to the conservation of at-risk marine mammals.

To demonstrate the translation of Navy dolphin medicine to conservation medicine, we will review the following three case examples where Navy medical knowledge was applied to wild cetacean conservation efforts: (1) conducting diagnostic ultrasound evaluations of wild dolphins following the DWH oil spill; (2) predicting health impacts of freshwater exposure on dolphins; and (3) developing minimally-invasive aging techniques for dolphins.

## Case One: Applying Diagnostic Ultrasound Techniques to Wild Dolphin Health Assessments Following the *Deepwater Horizon* Oil Spill

The DWH oil spill resulted in large-scale contamination of bays, sounds, and estuaries in the northern Gulf of Mexico (Michel et al., 2013). More than 1000 miles of shoreline were oiled along the US Gulf Coast from Texas to Florida (ERMA, 2015). NOAA conducted a Natural Resource Damage Assessment (NRDA) to determine the potential adverse health effects of the oil spill and associated contaminants on wildlife (DWH NRDA Trustees, 2016). Catch-and-release health assessments of wild dolphins were performed in Barataria Bay, Louisiana, and Mississippi Sound, MS, which were heavily impacted by the oil spill (Schwacke et al., 2014; Smith et al., 2017). Marine mammal veterinarians from diverse backgrounds were called upon to apply their collective expertise to the damage assessment. More than 150 live bottlenose dolphins were examined during the catch-and-release health assessments from 2011 to 2014. These comprehensive medical exams utilized numerous diagnostic tools and techniques developed with marine mammals in human care, summarized in Schwacke et al. (2014) and Smith et al. (2017).

Diagnostic ultrasound was an essential tool used in the wild dolphin medical exams, providing a rapid and data-rich evaluation of internal organ health. Full body ultrasounds were conducted by experienced sonographers (CRS, FMG, & JMM) either in water, out of the water, or a combination of both, on all dolphins stable enough for the procedure (Fig. 1). Portable, rugged ultrasound units outfitted with heads-up displays were utilized in the field, based on proven use with Navy dolphins and other managed marine mammals in various ocean environments (Fig. 2). Ultrasound protocols developed for and validated with Navy dolphins were employed in the field, including evaluation of lungs, marginal lymph nodes, kidneys, liver, pancreas, and when applicable, fetal health (Venn-Watson, Smith, Johnson, Daniels, & Townsend, 2010; Smith et al., 2012; Smith et al., 2013a; Smith et al., 2013b; Seitz, Smith, Marks, Venn-Watson & Ivančić, 2016; Martony et al., 2017; Ivančić et al., 2020). Additional protocols developed by aquarium and zoologic institutions were utilized to evaluate the dolphin gastrointestinal system, ovaries, testes, and fetal growth (Williamson et al., 1990; Robeck et al., 1998; Brook et al., 2000; Brook, 2001; Lacave et al., 2004; Robeck et al., 2005; Yuen et al., 2009; Fiorucci et al., 2015; Saviano et al., 2020). Decades of sonographer experience with dolphins in human care were applied to the determination of normal versus abnormal organ health.

Pulmonary ultrasound evaluation proved to be particularly important in this case, aiding in the documentation of an increased prevalence of moderate to severe lung disease in dolphins living within the oil spill footprint (Barataria Bay, LA, and Mississippi Sound, MS) versus those living in an unoiled bay (Sarasota Bay, FL) (Schwacke et al., 2014). Although there was some evidence that pulmonary health was slightly improving four years after the spill (Smith et al., 2017), ultrasound examinations performed in 2017 and 2018 showed persistent and even worsening pulmonary disease in oil-impacted dolphins (Smith et al., 2022). Based


**Fig. 1:** A diagnostic ultrasound exam of a wild dolphin during NOAA's DWH oil spill investigation performed by an experienced sonographer (CRS). The animal was placed into a stretcher and then transferred to the deck of a vessel for examination. The sonographer used a portable ultrasound unit outfitted with heads-up-display goggles and wore a dark visor to block out the sun, allowing for better visualization of the projected image. The animal was monitored by veterinary and animal care staff, and a portable ECG unit outfitted with 'sticky' leads was used to monitor the heart rate. (Photo: NOAA, Permit #932-1905/MA-009526)

**Fig. 2:** A routine diagnostic ultrasound procedure with a Navy dolphin performed by an experienced sonographer (FMG). A portable ultrasound unit was utilized, outfitted with heads-up-display goggles. The animal voluntarily slid into an animal transporter and was carefully transferred to the deck for examination. She was continuously monitored by veterinary and animal care staff, and her heart rate was monitored with a portable ECG unit outfitted with suction cup electrodes. (Photo: US Navy)

on the comprehensive health data available for these dolphins, chronic pulmonary disease was likely a significant factor in the overall poor health of dolphins living within the DWH oil spill footprint, defined in Schwacke et al. (2022). As determined by diagnostic ultrasound, dolphins born *after* the DWH oil spill did not have an elevated prevalence of pulmonary disease. Additional catch-and-release studies are needed to determine if the prevalence of lung disease in dolphins born after the spill remains low, and if dolphins alive during the DWH spill event show evidence of improvement, stabilization, or further degradation over time (Schwacke et al., 2023).

In addition to lung disease, veterinarians utilized other diagnostic tests to diagnose numerous adverse health effects in live dolphins impacted by the DWH oil spill, which included an impaired stress response, altered immune response, poor body condition, and increased mortality rates (Schwacke et al., 2014; DWH NRDA Trustees, 2016; Smith et al., 2017; Takeshita et al., 2017; de Guise et al., 2021). At the conclusion of NOAA's damage assessment, questions remained regarding the long-term impacts of oil exposure. For example, dolphins living within the oil spill footprint were experiencing high rates of reproductive failure, but the underlying etiology was unknown. Additionally, there were concerns regarding the potential for an emerging cardiac issue in dolphins, which had been documented in fish, birds, and humans impacted by the oil spill (reviewed in Takeshita et al, 2021a).

In order to better understand the reproductive and cardiac health effects in wild dolphins, we needed more advanced ultrasound techniques. We carefully examined our Navy medicine needs and looked for overlap and intersections between what would benefit Navy dolphins and wild dolphins. As a result, we began work with Navy dolphins to refine procedures for reproductive ultrasound and echocardiography, and then applied the advanced reproductive and cardiac health techniques to wild dolphins impacted by the oil spill. This led to novel protocols, based on human fetal ultrasound techniques, that allowed for the rapid assessment of fetal, placental, and maternal health in pregnant Barataria Bay dolphins (Ivančić et al., 2020), as well as the ability to comprehensively evaluate the health of adult dolphin hearts (Linnehan et al., 2020; Linnehan et al., 2021). At the conclusion of the study, we had diagnosed placental dysfunction in the majority of Barataria Bay dolphin pregnancies, and we detected cardiac anomalies in several of the adult dolphins living within the oil spill footprint. Overall, the Navy dolphin medical program allowed for the advancement of diagnostic imaging techniques to improve Navy animal care, the care of other dolphins in human care, and the rapid assessment of at-risk dolphins in the wild.

## Case Two: Predicting Health Impacts of Freshwater Exposure on Wild Dolphins

In the aftermath of the DWH oil spill disaster, a major restoration project has been planned for Barataria Bay, Louisiana, called the Mid-Barataria Sediment Diversion (MBSD) project (Louisiana Deepwater Horizon Trustee Implementation Group, 2021; U.S. Army Corps of Engineers, 2023). The MBSD project is meant to partially restore marsh in the Barataria basin and reduce land loss along the barrier islands. Central to the plan is the controlled diversion of the Mississippi River into Barataria Bay, which would carry nutrients and sediment into the basin to help rebuild wetlands. According to the US Army Corp of Engineers' Final Environmental Impact Statement (2023), the MBSD project would create a maximum of 27 square miles of land build in the mid-Barataria Basin by 2050. In the process, the salinity of the bay would be intermittently and substantially reduced, which could cause significant harm to Barataria Bay dolphins. These dolphins have demonstrated strong site fidelity and are unlikely to leave despite low salinity conditions (Lane et al., 2015; Wells et al., 2017; Takeshita et al., 2021b; Schwacke et al., 2022; Thomas et al., 2022).

Numerous questions have emerged during consideration of the planned restoration project, including the following: (1) how long can bottlenose dolphins survive in a freshwater and/or a very low salinity environment; (2) what sub-clinical and clinical physiologic effects occur and on what timeline in low saline environments; and (3) when do freshwater-induced skin lesions begin to occur? Navy clinicians began data-mining historical records to look for relevant data to help address these conservation questions, since operational Navy dolphins have traveled to various salinity environments throughout their lifetime. Over several decades, data was collected and archived from the animals in various aquatic environments. These data were collated and analyzed to help characterize physiologic responses to low salinity and to develop a timeline of potential health consequences (McClain et al., 2020). The study documented changes in serum electrolytes, osmolality, adrenal hormones, and skin integrity in response to low salinity conditions.

The Navy dolphin dataset provided unique and otherwise difficult to obtain information about bottlenose dolphin physiology and health effects of a specific environmental challenge. The study was made available through peer-review publication to conservationists, environmental planners, and policy makers, and informed an expert elicitation and subsequent modeling effort aimed at predicting how the MBSD project would impact Barataria Bay dolphins (Schwacke et al. 2022; Thomas et al. 2022). The resulting model predicted that the ~2000 bottlenose dolphins living in Barataria Bay are unlikely to survive prolonged periods of freshwater. If the MBSD project moves forward as proposed, Barataria Bay dolphins could go functionally extinct within 50 years (Thomas et al., 2022). This case example demonstrates how archived Navy medical data can help inform scientific predictions regarding the potential consequences of habitat alteration and environmental changes to an at-risk dolphin population.

## Case Three: Developing Minimally-Invasive Aging Techniques for Wild Dolphins

Estimating the age of individual animals in wild dolphin populations, especially those at-risk, is essential to understanding population demographics, interpreting biological data, and determining recovery trajectories (Schwacke et al., 2021). For decades, the gold standard of age estimation in live and dead bottlenose dolphins involved counting growth layer group (GLG) in a longitudinal section of a mandibular tooth, requiring tooth extraction and analysis (Ridgway et al., 1975; Hohn, 1980; Hohn et al., 1989; Read et al., 1993). Some variation has been documented in GLG-based age estimates (Kimura, 1980; Barratclough et al, 2023); however, it was the best available option for decades. During live animal catch-and-release health assessments, veterinary dental and anesthetic techniques were refined to allow for the safe and humane extraction of a single tooth for this purpose (reviewed in Townsend, Smith, & Rowles, 2018). In an effort to replace invasive techniques with less invasive options, marine mammal veterinarians led the development of minimally-invasive methods for age estimation. These alternative methods included the radiographic assessment of pectoral flipper bone maturation, dental X-ray analysis, and epigenetic age assessment.

Pectoral flipper radiography technique development for age estimation of bottlenose dolphins was led by D. García-Párraga in an aquarium setting, with collaboration from multiple institutions caring for bottlenose dolphins, including the Navy (Barratclough et al., 2019b). Pectoral flipper radiographs were performed with dolphins of known ages and changes in bone maturation were assigned numerical scores in order to calculate age estimates. Ages could be properly estimated with decreasing precision as animals aged; specifically, within 3 months in dolphins < 5 years old, to within 5 years in dolphins > 30 years old. The technique was applied by Barratclough et al. (2023) to wild bottlenose dolphins and Navy dolphins of known ages for comparison to dental GLG analysis. Pectoral flipper radiograph age estimates were comparable in accuracy to dental GLG analysis, establishing the usefulness of this minimally-invasive radiographic procedure for age estimation in live bottlenose dolphins. The technique allowed for same-day age estimates across a broad range of age categories. It should be noted that a dental X-ray technique for age estimation was also established with wild dolphins of known ages using the pulp:tooth area ratio method (Herrman, 2020). This method can reliably provide same-day estimates for bottlenose dolphin ages up to about 10 years of age.

Epigenetic age estimation based on DNA methylation was refined for managed bottlenose dolphins using archived Navy dolphin blood and skin samples (Barratclough et al., 2021b). DNA methylation is the addition of methyl groups to cytosine-phosphate-guanine (CpG) sites and occurs systematically with age, therefore methylation assessment can provide a chronological age estimate. Epigenetic age analysis has been further evaluated for wild bottlenose dolphins with a focus on skin samples collected via dart biopsy, in order to provide a remote option for age estimates of free-ranging animals. Additionally, epigenetic aging methods have been applied to an at-risk population of bottlenose dolphins, Lahille's dolphins (*Tursiops truncatus gephyreus*) found along the east coast of South America (Barratclough et al., 2022). Approximately 600 Lahille's dolphins remain and only 360 are considered capable of reproducing (Vermeulen et al., 2019). Providing age-related context for existing biological data and population demographics could enhance species recovery plans.

The managed animal community as a whole contributed to these important technique advancements for estimating dolphin ages using minimally-invasive techniques, which will likely replace the more invasive tooth extraction procedure in wild dolphins. The Navy dolphin population played an important role by assisting with the validation of radiographic and epigenetic techniques, specifically through the utilization of archived biological samples from known age animals collected periodically over the animals' lifetime. Collaborations among veterinarians caring for dolphins in zoological settings and rehabilitation centers allowed for rapid progress in the development of minimally invasive techniques, effectively advancing marine mammal medicine for the benefit of both managed and wild dolphins.

## Conclusion

Marine mammals in human care have a clear role in the conservation of at-risk species, specifically with regard to advancements of medical tools, diagnostic techniques, and veterinary approaches. Caring for managed marine mammals provides invaluable comparisons to wild animals, including physiologic and pathologic responses to environmental challenges. Veterinary practitioners charged with caring for marine mammals have unique skillsets that enhance our ability to rapidly, safely, and accurately examine and assess wild marine mammals. Navy clinicians who are charged with providing the highest quality care to the Navy's dolphins have demonstrated the effective application of their medical practice to the conservation of at-risk cetaceans. The examples provided are relevant to all veterinarians caring for small cetaceans in zoological settings and marine mammal rehabilitation centers, and during health assessments of wild animals. The aquatic mammal medical community must continue to translate managed animal medicine into conservation medicine. With aquatic mammals around the world facing continued anthropogenic threats and ever-changing environmental stressors, integrating veterinary knowledge into conservation action plans for species recovery and survival is critical.

## Acknowledgments

We thank the veterinarians, technicians, animal care experts, and support staff of the National Marine Mammal Foundation, US Army, US Navy, and collaborating institutions for their unwavering dedication to the health and welfare of Navy and wild marine mammals.

## Zusammenfassung

Tierärzte, die auf marine Säugetiere spezialisiert sind, spielen eine wichtige Rolle bei dem Schutz von Kleinwalen, insbesondere im Hinblick auf die Anwendung ihres Fachwissens bei der Bewertung des Gesundheitszustands von Wildtieren und die kontinuierliche Weiterentwicklung medizinischer Instrumente, Techniken und Ansätze für die Pflege dieser Tiere. Das Programm für Meeressäuger der US-Marine (Navy) hält seit über 60 Jahren Große Tümmler (Tursiops truncatus) und hat eine umfassende klinische Praxis etabliert, die darauf abzielt, auf Anweisung des US-Marineministers die bestmögliche Pflege für Navy-Tiere zu gewährleisten. Bis heute hat die Marine mit mehr als 1200 Veröffentlichungen zur Forschung an Meeressäugern beigetragen. Die Studien reichen von Entdeckungen in der Physiologie, der Akustik und Anatomie bis hin zu fortschrittlichen Diagnosetechniken für die medizinische Versorgung von Meeressäugern. Dieses Wissen wurde direkt für den Schutz gefährdeter, bedrohter und vom Aussterben bedrohter Kleinwale, insbesondere von Delfinen, eingesetzt. In drei Fallstudien wird gezeigt, inwieweit Wissen aus der Veterinärmedizin des Navy Programms für den Schutz von Delphinarten angewendet werden kann, darunter: (1) Durchführung von diagnostischen Ultraschalluntersuchungen bei wild lebenden Delfinen nach der Deepwater Horizon Ölkatastrophe; (2) Vorhersage der gesundheitlichen Auswirkungen von Süßwasser auf wild lebende Delfine; und (3) Entwicklung minimal-invasiver Methoden zur Altersbestimmung von Delfinen. Die Fallbeispiele sind für alle Tierärzte relevant, die sich in zoologischen Einrichtungen, Rehabilitationszentren für Meeressäuger oder in freier Wildbahn um Kleinwale kümmern und/oder deren Gesundheit beurteilen. Die Gemeinschaft der auf Meeressäuger spezialisierten Tiermediziner sollte weiterhin an Möglichkeiten arbeiten um ihr Fachwissen in Aktionspläne für den Schutz gefährdete Delphine zu integrieren.

## References

Barratclough, A., Wells, R.S., Schwacke, L.H., Rowles, T.K., Gomez, F.M., Fauquier, D., Sweeney, J., Townsend, F.I., Hansen, L., Zolman, E.S., Balmer, B.C., & Smith, C.R. (2019a). Health assessments of common bottlenose dolphins (*Tursiops truncatus*): past, present, and potential conservation applications. Frontiers in Veterinary Science, 6, 444.

Barratclough, A., Sanz-Requena, R., Marti-Bonmati, L., Schmitt, T.L., Jensen, E., & García-Párraga, D. (2019b). Radiographic assessment of pectoral flipper bone maturation in bottlenose dolphins (*Tursiops truncatus*), as a novel technique to accurately estimate chronological age. PLoS One, 26,14(9), e0222722.

Barratclough, A., Gomez, F.M., Morey, J.S., Meegan, J.M., Parry, C., Schwacke, L., Jensen, E.D., & Smith, C.R. (2021a). Biochemical and hematological biomarkers of reproductive failure in bottlenose dolphins, *Tursiops truncatus*. Diseases of Aquatic Organisms, 144, 197-208.

Barratclough, A., Smith, C.R., Gomez, F.M., Photopoulou, T., Takeshita, R., Pirotta, E., Thomas, L., McClain, A.M., Parry, C., Zoller, J.A., Horvath, S., & Schwacke, L.H. (2021b). Accurate epigenetic aging in bottlenose dolphins (*Tursiops truncatus*), an essential step in the conservation of at-risk dolphins. Journal of Zoological and Botanical Gardens, 2(3), 416-420.

Barratclough, A., Schwacke, L., Gomez, F.M., Tatsch, A., Secchi, E., Fruet, P., Horvath, S., & Smith, C.R. (2022). Translational medicine application of epigenetics to endangered dolphin conservation. In Proceedings of the International Association of Aquatic Animal Medicine Annual Meeting, May 16-26, 2022. Available online at https://www.vin.com/apputil/project/defaultadv1.aspx?pid=28857&catid=&id=10902814&meta=generic&authorid=

Barratclough, A., McFee, W.E., Stolen, M., Hohn, A., Lovewell, G., Gomez, F.M., Smith, C.R., García-Párraga, D., Wells, R., Parry, C., Daniels, R., Ridgway, S.H., & Schwacke, L.H. (2023) How to estimate age of old bottlenose dolphins (*Tursiops truncatus*); by tooth or pectoral flipper? Frontiers in Marine Science, 10.

Brook, F.M., Kinoshita, R., Brown, B., & Metreweli, C. (2000). Ultrasonographic imaging of the testis and epididymis of the bottlenose dolphin, *Tursiops truncatus aduncas*. Journal of Reproduction and Fertility, 119(2), 233-40.

Brook, F.M. (2001). Ultrasonographic imaging of the reproductive organs of the female bottlenose dolphin, *Tursiops truncatus aduncas*. Reproduction, 121(3), 419-28.

Deepwater Horizon Natural Resource Damage Assessment (NRDA) Trustees. (2016) Deepwater Horizon Oil Spill: Final Programmatic Damage Assessment and Restoration Plan and Final Programmatic Environmental Impact Statement. Available online at http://www.gulfspillrestoration.noaa.gov/restoration-planning/gulf-plan

De Guise, S., Levin, M., Jasperse, L., Herrman, J., Wells, R.S., Rowles, T., & Schwacke, L. (2021). Long-term immunological alterations in bottlenose dolphins a decade after the Deepwater Horizon oil spill in the northern Gulf of Mexico: Potential for multigenerational effects. Environmental Toxicology and Chemistry, 40(5), 1308-1321.

Department of the Navy. (1998). Annotated bibliography of publications from the U. S. Navy's Marine Mammal Program. (TD 627, Revision D). San Diego, CA: Space and Naval Warfare Systems Center, San Diego.

Lutmerding, B.A., Gomez, F.M., Clowers, L., Daniels, R., Smith, C.R., Barre, L., Gilardi, K., Venn-Watson, S., & Gaydos, J.K. (2019). Development of a killer whale health database to assess individual and population health of Southern Resident killer whales (*Orcinus orca*). In Proceeding of the International Association of Aquatic Animal Medicine Annual Conference, May 18-22, 2019, Durban, South Africa.

ERMA. (2015). Environmental Response Management Application. Washington, DC: National Oceanic and Atmospheric Administration. Available online at http://gomex.erma.noaa.gov/

Fiorucci, L., García-Párraga, M.R., Grande, F., Flanagan, C., Rueca, F., Busechian, S., Bianchi, B., Arbelo, M., & Saviano, P. (2015). Determination of the main reference values in ultrasound examination of the gastrointestinal tract in clinically healthy bottlenose dolphins *(Tursiops truncatus*). Aquatic Mammals, 41(3), 284-94.

Herrman, J.M., Morey, J.S., Takeshita, R., De Guise, S., Wells, R.S., McFee, W., Speakman, T., Townsend, F., Smith, C.R., Rowles, T., & Schwacke, L. (2020). Age determination of common bottlenose dolphins (*Tursiops truncatus*) using dental radiography pulp:tooth area ratio measurements. PLoS One, 15(11): e0242273.

Hohn, A.A. (1980). Age determination and age related factors in the teeth of Western North Atlantic bottlenose dolphins. Scientific Reports of the Whales Research Institute, 32, 39-66.

Hohn, A.A., Scott, M.D., Wells, R.S., Sweeney, J.C., & Irvine, A.B. (1989). Growth layers in teeth from known-age, free-ranging bottlenose dolphins. Marine Mammal Science, 5, 315-342.

Houser, D.S., Finneran, J.J., & Ridgway, S.H. (2010). Research with Navy marine mammals benefits animal care, conservation and biology. International Journal of Comparative Psychology, 23(3), 249-268.

Ivančić, M, Gomez, F.M., Musser, W.B., Barratclough, A., Meegan, J.M., Waitt, S.M., Cárdenas Llerenas, A., Jensen, E.D., & Smith, C.R. (2020). Ultrasonographic findings associated with normal pregnancy and fetal well-being in the bottlenose dolphin (*Tursiops truncatus*). Veterinary Radiology & Ultrasound, 61(2), 215-226.

Kimura, M. (1980). Variability in techniques of counting dentinal growth layer groups in a tooth of a known-age dolphin, *Tursiops truncatus*. Age Determination of Toothed Whales and Sirenians, 3, 161.

Lacave, G., Eggermont, M., Verslycke, T., Brook, F., Salbany, A., Roque, L., & Kinoshita, R. (2004). Prediction from ultrasonographic measurements of the expected delivery date in two species of bottlenosed dolphin (*Tursiops truncatus* & *Tursiops aduncus*). Veterinary Record, 154(8), 228-33.

Lane, S.M., Smith, C.R., Mitchell, J., Balmer, B.C., Barry, K.P., McDonald, T., Mori ,C.S., Rosel, P.E., Rowles, T.K., Speakman, T.R., Townsend, F.I., Tumlin, M.C., Wells, R.S., Zolman, E.S., & Schwacke, L.H. (2015). Reproductive outcome and survival of common bottlenose dolphins sampled in Barataria Bay, Louisiana, USA, following the Deepwater Horizon oil spill. Proceedings of the Royal Society B: Biological Sciences, 282, 20151944.

Linnehan, B.K., Hsu, A., Gomez, F.M., Huston, S.M., Takeshita, R., Colegrove, K.M., Rowles, T.K., Barratclough, A., Musser, W.B., Harms, C.A., Cendejas, V., Zolman, E.S., Balmer, B.C., Townsend, F.I., Wells, R.S., Jensen, E.D., Schwacke, L.H., & Smith, C.R. (2020). Standardization of dolphin cardiac auscultation and characterization of heart murmurs in managed and free-ranging bottlenose dolphins (*Tursiops truncatus*). Frontiers in Veterinary Science, 28,7, 570055.

Linnehan, B.K., Gomez, F.M., Huston, S.M., Hsu, A., Takeshita, R., Colegrove, K.M., Harms, C.A., Barratclough, A., Deming, A.C., Rowles, T.K., Musser, W.B., Zolman, E.S., Wells, R.S., Jensen, E.D., Schwacke, L.H., & Smith, C.R. (2021). Cardiac assessments of bottlenose dolphins (*Tursiops truncatus*) in the Northern Gulf of Mexico following exposure to Deepwater Horizon oil. PLoS One, 16(12), e0261112.

Louisiana Deepwater Horizon Trustee Implementation Group. (2021). Draft Phase II Restoration Plan #3.2: Mid-Barataria Sediment Diversion. Available online at https://www.gulfspillrestoration.noaa.gov/sites/default/files/2021-03%20LA%20MBSD%20Draft%20Plan%20Mid-Barataria-Restoration-Plan_Main.pdf

Martony, M.E., Ivančić, M., Gomez, F.M., Meegan, J.M., Nollens, H.H., Schmitt, T.L., Erlacher-Reid, C.D., Carlin, K.P., & Smith, C.R. (2017). Establishing marginal lymph node ultrasonographic characteristics in health bottlenose dolphins (*Tursiops truncatus*). Journal of Zoo and Wildlife Medicine, 48(4), 961-971.

McClain, A.M., Daniels, R., Gomez, F.M., Ridgway, S.H., Takeshita, R., Jensen, E.D., & Smith, C.R. (2020) Physiological effects of low salinity exposure on bottlenose dolphins (*Tursiops truncatus*). Journal of Zoological and Botanical Gardens, 1(1), 61-75.

Michel, J., Owens, E.H., Zengel, S., Graham, A., Nixon, Z., Allard, T., Holton, W., Reimer, P.D., Lamarche, A., White, M., Rutherford, N., Childs, C., Mauseth, G., Challenger, G., & Taylor E. (2013). Extent and degree of shoreline oiling: *Deepwater Horizon* oil spill, Gulf of Mexico, USA. PLoS One, 8(6), e65087.

National Marine Mammal Foundation. (2023) *NMMF publications*. Available online at https://www.nmmf.org/about-nmmf/nmmf-publications/

NIWC Pacific. (2023). Scientific contributions of the US Navy Marine Mammal Program 1959-2020; Scientific contributions of the US Navy Marine Mammal Program 2021. Available online at https://www.niwcpacific.navy.mil/marine-mammal-program/

Read, A., Wells, R., Hohn, A., & Scott, M. (1993). Patterns of growth in wild bottlenose dolphins, *Tursiops truncatus*. Journal of Zoology, 231(1), 107-23.

Robeck, T.R., McBain, J.F., Mathey, S., & Kraemer, D.C. (1998). Ultrasonographic evaluation of the effects of exogenous gonadotropins on follicular recruitment and ovulation induction in the Atlantic bottlenose dolphin (*Tursiops truncatus*). Journal of Zoo and Wildlife Medicine, 29(1), 6-13.

Robeck, T.R., Steinman, K.J., Yoshioka, M., Jensen, E., O'Brien, J.K., Katsumata, E., Gili, C., McBain, J.F., Sweeney, J., Monfort, S.L. (2005). Estrous cycle characterisation and artificial insemination using frozen-thawed spermatozoa in the bottlenose dolphin (*Tursiops truncatus*). Reproduction, 129(5), 659-74.

Ridgway, S.H., Green, R.F., Sweeney, J.C. (1975). Mandibular anesthesia and tooth extraction in the bottlenose dolphin. Journal of Wildlife Diseases, 11, 415-418.

Ridgway, S.H., Norris, K.S., Cornell, L.H. (1989). Some considerations for those wishing to propagate platanistoid dolphins. In W.F. Perrin, R.L. Brownell, Jr., Z. Kaiya, & L. Jiankang (Eds), Biology and conservation of river dolphins (pp. 159-167). IUCN Species Survival Commission Occasional Papers, No. 3. Gland, Switzerland: IUCN.

Ridgway, S.H. (2008). History of veterinary medicine and marine mammals: A personal perspective. Aquatic Mammals, 34.4, 471-513.

Rojas-Bracho, L., Gulland, F., Smith, C.R., Taylor, B.L., Wells, R.S., Thomas, P.O., Bauer, B., Heide-Jørgensen, M., Teilmann, J., Dietz, R., Balle, J., Jensen, M., Sinding, M., Jaramillo-Legoretta, A., Grant, A., Read, A., Westgate, A., Colegrove, K., Gomez, F., Martz, K., Rebolledo, R., Ridgway, S., Rowles, T., van Elk, N., Boehm, J., Cardenas-Hinojosa, G., Constantine, R., Nieto-Garcia, E., Phillips, W., Sabio, D., Sanchez, R., Sweeney, J., Townsend, F., Vivanco, J., Vivanco, J., & Walker, S. (2019). A field effort to capture critically endangered vaquitas (*Phocoena sinus*) for protection from entanglement in gillnets. Endangered Species Research, 38, 11-27.

Saviano, P., Fiorucci, L., Grande, F., Macrelli, R., Troisi, A., Polisca, A., & Orlandi, R. (2020). Pregnancy and fetal development: Cephalic presentation and other descriptive ultrasonographic findings from clinically healthy bottlenose dolphins (*Tursiops truncatus*) under human care. Animals (Basel), 10(5), 908.

Schwacke, L.H., Smith, C.R., Townsend, F.I., Wells, R.S., Hart, L.B., Balmer, B.C., Collier, T.K., De Guise, S., Fry, M.M., Guillette, L.J., Lamb, S.V., Lane, S.M., McFee, W.E., Place, N.J., Tumlin, M.C., Ylitalo, G.M., Zolman, E.S., & Rowles, T.K. (2014). Health of common bottlenose dolphins (*Tursiops truncatus*) in Barataria Bay, Louisiana, following the Deepwater Horizon oil spill. Environmental Science & Technology, 48(1), 93-103.

Schwacke, L.H., Marques, T.A., Thomas, L., Booth, C.G., Balmer, B.C., Barratclough, A., Colegrove, K., De Guise, S., Garrison, L.P., Gomez, F.M., Morey, J.S., Mullin, K.D., Quigley, B.M., Rosel, P.E., Rowles, T.K., Takeshita, R., Townsend, F.I., Speakman, T.R., Wells, R.S., Zolman, E.S., & Smith, C.R. (2022). Modeling population effects of the Deepwater Horizon oil spill on a long-lived species. Conservation Biology, 36(4), e13878.

Schwacke, L.H., Thomas, L., Wells, R.S., Rowles, T.K., Bossart, G., Townsend, F., Mazzoil, M., Allen, J.B., Balmer, B.C., Barleycorn, A.A., Barratclough, A., Burt, M.L., De Guise, S., Fauquier, D., Gomez, F.M., Kellar, N.M., Schwacke, J.H., Speakman, T.R., Stolen, E., Quigley, B.M., Zolman, E.S., & Smith, C.R. (2023). An expert-based system to predict population survival rate from health data. Conservation Biology (epub ahead of print).

SECNAV INSTRUCTION 3900.41H. (2018). Acquisition, transport, care, and treatment of Navy marine mammals. Available online at https://www.secnav.navy.mil/doni/Directives/03000%20Naval%20Operations%20and%20Readiness/03-900%20Research,%20Development,%20Test%20and%20Evaluation%20Services/3900.41H.pdf

Seitz, K.E., Smith, C.R., Marks, S.L., Venn-Watson, S.K., & Ivančić, M. (2016). Liver ultrasonography in dolphins: Use of ultrasonography to establish a technique for hepatobiliary imaging and to evaluate metabolic disease-associated liver changes in bottlenose dolphins (*Tursiops truncatus*). Journal of Zoo and Wildlife Medicine, 47(4), 1034-1043.

Smith, C.R., Solano, M., Lutmerding, B.A., Johnson, S.P., Meegan, J.M., Le-Bert, C.R., Emory-Gomez, F., Cassle, S., Carlin, K., & Jensen, E.D. (2012). Pulmonary ultrasound findings in a bottlenose dolphin *Tursiops truncatus* population. Diseases of Aquatic Organisms, 101, 243-255.

Smith, C.R., Venn-Watson, S., Wells, R.S., Johnson, S.P., Maffeo, N., Balmer, B.C., Jensen, E.D., Townsend, F.I., & Sakhaee, K. (2013a). Comparison of nephrolithiasis prevalence in two bottlenose dolphin (*Tursiops truncatus*) populations. Frontiers in Endocrinology, 16, 4, 145.

Smith, C.R., Jensen, E.D., Blankenship, B.A., Greenberg, M., D'Agostini, D.A., Pretorius, D.H., Saenz, N.C., Noll, N., & Venn-Watson, S.K. (2013b). Fetal omphalocele in an Atlantic bottlenose dolphin (*Tursiops truncatus*). Journal of Zoo and Widlife Medicine, 44(1), 87-92.

Smith, C.R., Rowles, T.K., Hart, L.B., Townsend, F.I., Wells, R.S.., Zolman, E.S., Balmer, B.C., Quigley, B., Ivančić, M., McKercher, W., Tumlin, M.C., Mullin, K.D., Adams, J.D., Wu, Q., McFee, W., Collier, T.K., & Schwacke, L.H. (2017). Slow recovery of Barataria Bay dolphin health following the Deepwater Horizon oil spill (2013-2014), with evidence of persistent lung disease and impaired stress response. Endangered Species Research, 33, 127-142.

Smith, C.R., Rowles, T.K., Gomez, F.M., Ivančić, M., Colegrove, K.M., Takeshita, R., Townsend, F.I., Zolman, E.S., Morey, J.S., Cendejas, V., Meegan, J.M., Musser, W., Speakman, T.R., Barratclough, A., Wells, R.S., & Schwacke, L.H. (2022). Poor pulmonary health in Barataria Bay dolphins in the eight years following the Deepwater Horizon oil spill. Frontiers in Marine Science, 9.

Takeshita, R., Sullivan, L., Smith, C.R., Collier, T.K., Hall, A., Brosnan, T., Rowles, T., & Schwacke, L.H. (2017). The Deepwater Horizon oil spill marine mammal injury assessment. Endangered Species Research, 33, 95-106.

Takeshita, R., Bursian, S.J., Colegrove, K.M., Collier, T.K., Deak, K., Dean, K.M., De Guise, S., DiPinto, L.M., Elferink, C.J., Esbaugh, A.J., Griffitt, R.J., Grosell, M., Harr, K.E., Incardona, J.P., Kwok, R.K., Lipton, J., Mitchelmore, C.L., Morris, J.M., Peters, E.S., Roberts, A.P., Rowles, T.K., Rusiecki, J.A., Schwacke, L.H., Smith, C.R., Wetzel, D.L., Ziccardi, M.H., & Hall, A.J. (2021a) A review of the toxicology of oil in vertebrates: what we have learned following the Deepwater Horizon oil spill. Journal of Toxicology & Environmental Health – Part B: Critical Reviews, 24(8), 355-394.

Takeshita, R., Balmer, B.C., Messina, F., Zolman, E.S., Thomas, L., Wells, R.S., Smith, C.R., Rowles, T.K., & Schwacke, L.H. (2021b). High site-fidelity in common bottlenose dolphins despite low salinity exposure and associated indicators of compromised health. PLoS One, 16(9), e0258031.

Thomas, L., Marques, T.A., Booth, C., Takeshita, R., & Schwacke, L.H. (2022) Model predicts catastrophic decline of common bottlenose dolphin (*Tursiops truncatus*) population under proposed land restoration project in Barataria Bay, Louisiana, USA. Marine Mammal Science, 38(4), 1654-1664.

Townsend, F.I., Smith, C.R., & Rowles, T.K. (2018). Health assessment of bottlenose dolphins in capture – release studies. CRC Handbook of Marine Mammal Medicine, 3rd edition. CRC Press.

U.S. Army Corps of Engineers. (2023). Mid-Barataria Sediment Diversion, Final Environmental Impact Statement. Available online at https://www.mvn.usace.army.mil/Missions/Regulatory/Permits/Mid-Barataria-Sediment-Diversion-EIS/

Venn-Watson, S., Jensen, E.D., Smith, C.R., Xitco, M., & Ridgway, S.H. (2015). Evaluation of annual survival and mortality rates and longevity of bottlenose dolphins (*Tursiops truncatus*) at the United States Navy Marine Mammal Program from 2004 through 2013. Journal of the American Veterinary Association, 246, 893-898.

Vermeulen, E., Fruet, P., Costa, A., Coscarella, M., & Laporta, P. (2019). *Tursiops truncatus* ssp. *gephyreus.* The IUCN Red List of Threatened Species 2019.

Wells, R.S., Smith, C.R., Sweeney, J.C., Townsend, F.I., Fauquier, D.A., Stone, R., Langan, J., Schwacke, L., & Rowles, T.K. (2014). Fetal survival of common bottlenose dolphins (*Tursiops truncatus*) in Sarasota Bay, Florida. Aquatic Mammals, 40(3), 252-259.

Wells, R.S., Schwacke, L.H., Rowles, T.K., Balmer, B.C., Zolman, E., Speakman, T., Townsend, F.I., Tumlin, M.C., Barleycorn, A., & Wilkinson, K. (2017). Ranging patterns of common bottlenose dolphins *Tursiops truncatus* in Barataria Bay, Louisiana, following the Deepwater Horizon oil spill. Endangered Species Research, 33, 159-180.

Williamson, P., Gales, N.J., & Lister, S. (1990). Use of real-time B-mode ultrasound for pregnancy diagnosis and measurement of fetal growth rate in captive bottlenose dolphins (*Tursiops truncatus*). Journal of Reproduction and Fertility, 88(2), 543-548.

Yuen, Q.W., Ying, M.T., Brook, F.M., & Kinoshita, R.E. (2009). Reliability of 2D ultrasound measurements of testis size in dolphins taken under voluntary behavior. Ultrasound in Medicine and Biology, 35(6), 1005-1009.

DER ZOOLOGISCHE GARTEN
THE ZOOLOGICAL GARDEN

doi:10.53188/zg0018

Zool. Garten N.F. 91 (2023) 135-153

# 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.

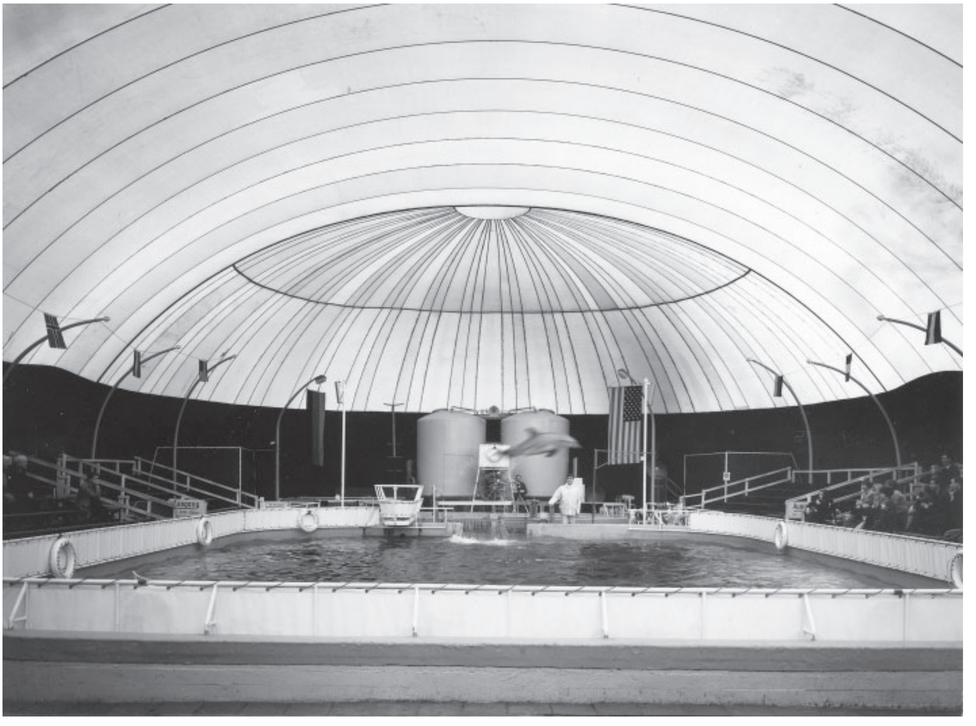

**Fig. 1:** The first dolphinarium in Germany opened 1965 in Duisburg (Photo by Zoo Duisburg).

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)

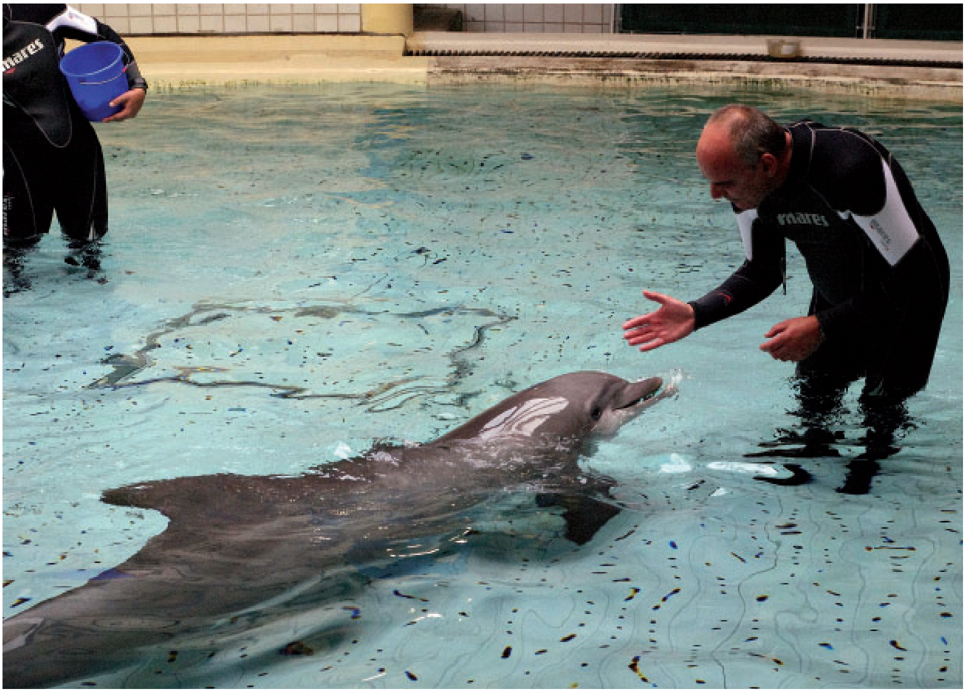

**Fig. 3:** Lifting platforms allow trainers to directly approach the dolphins in shallow water and thus facilitate, among other things, medical training, or interventions on newborn animals. In the photo shown here, the lifting platform was raised to a water depth of approx. 60 cm in an otherwise 4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

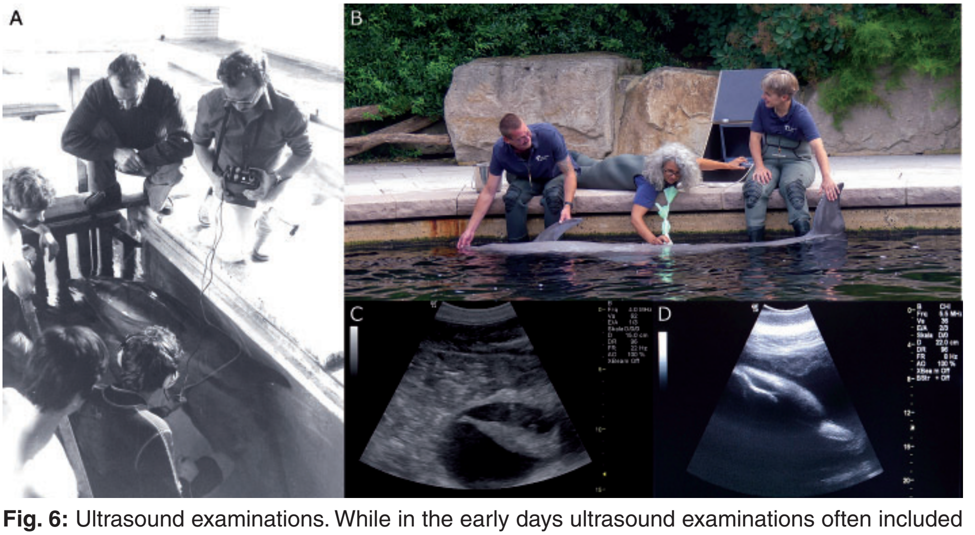


**Fig. 6:** Ultrasound examinations. While in the early days ultrasound examinations often included a restriction of the animal (A), today's progress in medical training allows veterinarians to conduct a sonogram to monitor the status of a pregnant female (B) as well as the unborn calf (C, D) on a voluntary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

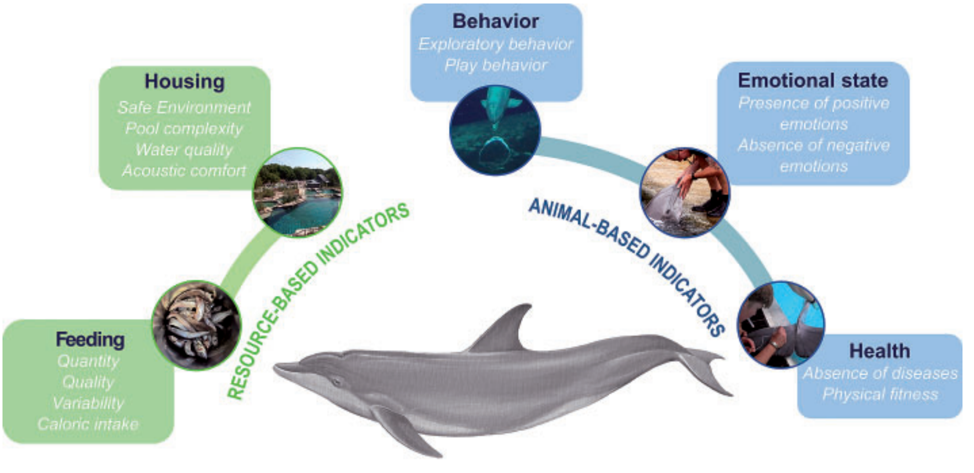


**Fig. 9:** The main structure of the Dolphin Welfare Evaluation Tool (Dolphin WET) includes the five principles following the Five Domains model (Mellor et al., 2020; Rogers Brambell, 1965) and prioritizes animal-based indicators. (Dolphin by J. Mazur)

### 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 dolphinariums 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-

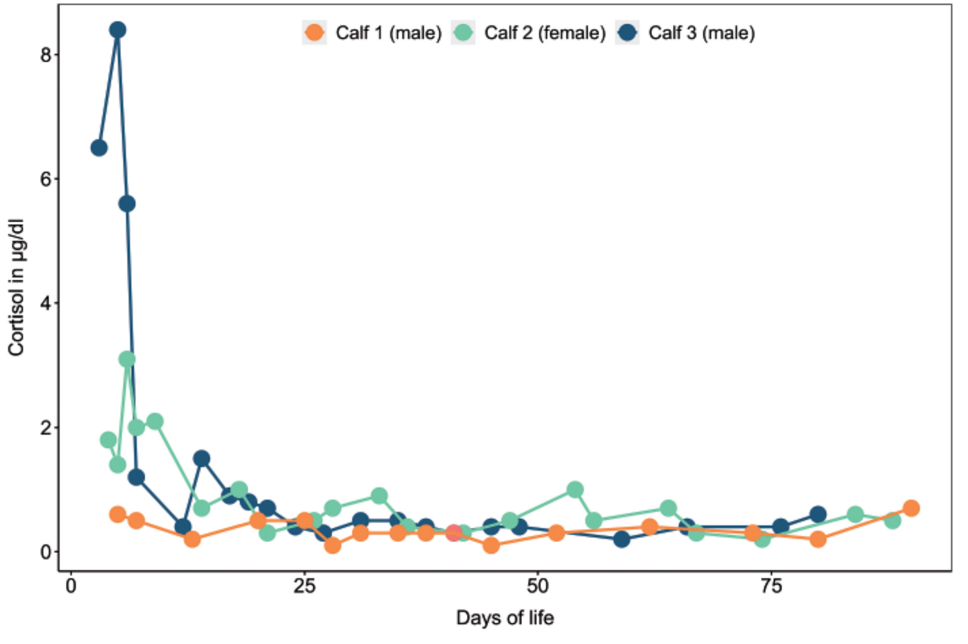


**Fig. 10:** Cortisol levels of three calves born at Zoo Duisburg in 2011 over the first 90 days of life decrease to baseline levels within days after birth. Cortisol measurements were carried out each time blood samples were taken.

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 stress-less 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.

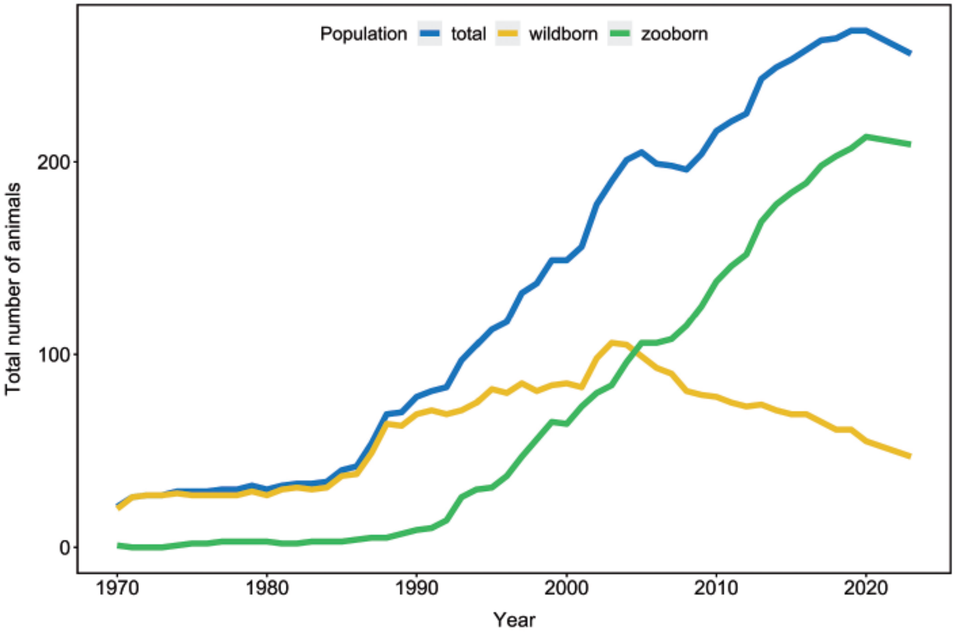


**Fig. 11:** Development of the EEP population since 1970 comparing the percentage of wild born versus zoo born animals across all EEP facilities.

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)

## References


Adisasmito, W.B., Almuhairi, S., Behravesh, C.B., Bilivogui, P., Bukachi, S.A., Casas, N., Cediel Becerra, N., Charron, D.F., Chaudhary, A., Ciacci Zanella, J.R., Cunningham, A.A., Dar, O., Debnath, N., Dungu, B., Farag, E., Gao, G.F., Hayman, D.T.S., Khaitsa, M., Koopmans, M.P.G., Machalaba, C., Mackenzie, J.S., Markotter, W., Mettenleiter, T.C., Morand, S., Smolenskiy, V., & Zhou, L. (2022). One Health: A new definition for a sustainable and healthy future. PLoS Pathogens, 18(6), e1010537. https://doi.org/10.1371/journal.ppat.1010537

Baumgartner, K., Lacave, G., Sweeney, J.C., & Will, H. (2018). A Suggested Birth Protocol for Bottlenose Dolphins (*Tursiops truncatus*) – Updated 2015, Zoo Nuremberg. Aquatic Mammals, 44(1), 100-109. https://doi.org/10.1578/AM.44.1.2018.100

Brando, S.I. (2010). Advances in Husbandry Training in Marine Mammal Care Programs. International Journal of Comparative Psychology, 23(4), 777-791. https://dx.doi.org/10.46867/ijcp.2010.23.04.03

Byers, O, Lees, C., Wilcken, J., & Schwitzer, C (2013). The One Plan Approach: The Philosophy and Implementation of CBSG’s Approach to Integrated Species Conservation Planning. WAZA Mag., 14, 2-5.

Caldwell, M. C., & Caldwell, D. K. (1965). Individualized Whistle Contours in Bottle-nosed Dolphins (*Tursiops truncatus*). Nature, 207 (4995), 434-435. https://doi.org/10.1038/207434a0

Caldwell, M.C., & Caldwell, D.K. (1968). Vocalization of Naive Captive Dolphins in Small Groups. Science, 159 (3819), 1121-1123. https://doi.org/10.1126/science.159.3819.1121

Caldwell, David K., & Caldwell, M.C. (1966). Observations on the distribution, coloration, behavior and audible sound production of the spotted dolphin, *Stenella plagiodon* (Cope). Contributions in Science, 104, 1-28. https://www.biodiversitylibrary.org/part/241093

Connor, R.C., Wells, R.S., Mann, J., & Read, A.J. (2000). The bottlenose dolphin: social relationships in a fission-fusion society. In J. Mann, R.C. Connor, P.L. Tyack, & H. Whitehead (Eds), Cetacean societies: Field studies of dolphins and whales (pp. 91-126). University of Chicago Press, Chicago.

Couquiaud, L. (2005). Special Issue: Survey of Cetaceans in Captive Care. Aquatic Mammals, 31(3), 283-287. https://doi.org/10.1578/AM.31.3.2005.283

Defran, R.H., & Pryor, K. (1980). The Behavior and Training of Cetaceans in Captivity. In L.M. Herman (Ed.) Cetacean behavior: Mechanism and functions (pp. 319-358). John Wiley & Sons, New Jersey.

Galligan, T.M., Schwacke, L.H., Houser, D.S., Wells, R.S., Rowles, T., & Boggs, A.S.P. (2018). Characterization of circulating steroid hormone profiles in the bottlenose dolphin (*Tursiops truncatus*) by liquid chromatography-tandem mass spectrometry (LC-MS/MS). General and Comparative Endocrinology, 263, 80-91. https://doi.org/10.1016/j.ygcen.2018.04.003

Gimmel, A.E.R., Baumgartner, K., & Liesegang, A. (2016). Vitamin blood concentration and vitamin supplementation in bottlenose dolphins (*Tursiops truncatus*) in European facilities. BMC Veterinary Research, 12(1), 180. https://doi.org/10.1186/s12917-016-0818-1

Gimmel, A., Baumgartner, K., Bäckert, S., Tschudin, A., Lang, B., Hein, A., Marcordes, S., Wyss, F., Wenker, C., & Liesegang, A. (2022): Effects of Storage Time and Thawing Method on Selected Nutrients in Whole Fish for Zoo Animal Nutrition. Animals, 12, 2847. https://doi.org/10.3390/ani12202847

Herman, L.M. (2012). Historical Perspectives: Birthing a Dolphin Research Laboratory: The Early History of the Kewalo Basin Marine Mammal Laboratory. Aquatic Mammals, 38(1), 102-125. https://doi.org/10.1578/AM.38.1.2012.102

Houser, D.S., Finneran, J.J., & Ridgway, S.H. (2010). Research with Navy Marine Mammals Benefits Animal Care, Conservation and Biology. International Journal of Comparative Psychology, 23(3), 249-268. https://escholarship.org/uc/item/3pm7v89g

Hüttner, T., Fersen, L. von, Miersch, L., Czech, N.U., & Dehnhardt, G. (2022). Behavioral and anatomical evidence for electroreception in the bottlenose dolphin (*Tursiops truncatus*). The Anatomical Record. 305, 592-608. https://doi:10.1002/ar.24773

Jaakkola, K., & Willis, K. (2019). How long do dolphins live? Survival rates and life expectancies for bottlenose dolphins in zoological facilities vs. wild populations. Marine Mammal Science, 35, 1418-1437. https://doi.org/10.1111/mms.12601

Kucklick, J., Schwacke, L., Wells, R., Hohn, A., Guichard, A., Yordy, J., Hansen, L., Zolman, E., Wilson, R., Litz, J., Nowacek, D., Rowles, T., Pugh, R., Balmer, B., Sinclair, C., & Rosel, P. (2011). Bottlenose dolphins as indicators of persistent organic pollutants in the western North Atlantic Ocean and northern Gulf of Mexico. Environmental Science & Technology, 45(10), 4270-4277. https://doi.org/10.1021/es1042244

Meegan, J., Gomez, F., Barratclough, A., Smith, C., Sweeney, J., Ruoppolo, V., Kolesnikovas, C., Pinho da Silva Filho, R., Lima Canabarro, P., Laporta, P., Loureiro, J.P., Alvarez, K., Rodriguez Heredia, S.A., Cabrera, A., Faiella, A., Saubidet, A., & von Fersen, L. (2022). Rescue and Rehabilitation of Neonatal Franciscana Dolphins, Care and Hand-rearing Protocol, Alliance for Franciscana Dolphin Conservation Research, Rescue and Rehabilitation (AFCR3), 01-2022.

Mellor, D.J., Beausoleil, N.J., Littlewood, K.E., McLean, A.N, McGreevy, P.D., Jones, B., & Wilkins, C. (2020). The 2020 Five Domains Model: Including Human-Animal Interactions in Assessments of Animal Welfare. Animals, 10(10), 1870. https://doi.org/10.3390/ani10101870

Miedler, S., Schmitt, T., Reidarson, T., & McBain, J. (2007). Transthoracic cardiac ultrasound examination in bottlenose dolphins (*Tursiops truncatus*). Proceedings of the 38th Annual International Association for Aquatic Animal Medicine Conference; 2007 May 5–9. Orlando, FL. Available online at: https://www.vin.com/apputil/content/defaultadv1.aspx?pId=11257&catId=32376&id=3865385

Miedler, S., Fahlman, A., Valls Torres, M., Álvaro Álvarez, T., & Garcia-Parraga, D. (2015). Evaluating cardiac physiology through echocardiography in bottlenose dolphins: using stroke volume and cardiac output to estimate systolic left ventricular function during rest and following exercise. Journal of Experimental Biology. 218 (Pt 22), 3604-3610. https://doi.org/10.1242/jeb.131532

Miller, L.J., Zeigler-Hill, V., Mellen, J., Koeppel, J., Greer, T., & Kuczaj, S. (2013). Dolphin shows and interaction programs: benefits for conservation education? Zoo Biology, 32(1), 45-53. https://doi.org/10.1002/zoo.21016

Monreal-Pawlowsky, T., Carbajal, A., Tallo-Parra, O., Sabés-Alsina, M., Monclús, L., Almunia, J., Fernández-Bellon, H., & Lopez-Bejar, M. (2017). Daily salivary cortisol levels in response to stress factors in captive common bottlenose dolphins (*Tursiops truncatus*): A potential welfare indicator. The Veterinary Record, 180(24), 593. https://doi.org/10.1136/vr.103854

Pedernera-Romano, C., Valdez, R.A., Singh, S., Chiappa, X., Romano, M.C., & Galindo, F. (2006). Salivary cortisol in captive dolphins (*Tursiops truncatus*): a non-invasive technique. Animal Welfare, 15(4), 359-362. https://doi.org/10.1017/S0962728600030682

Pryor, K. (2002): Don‘t shoot the dog! The new art of teaching and training (Revised edition). Ringpress Books Ltd., Lydney.

Romano, T.A., Keogh, M.J., Kelly, C., Feng, P., Berk, L., Schlundt, C.E., Carder, D.A., & Finneran, J.J. (2004). Anthropogenic sound and marine mammal health: measures of the nervous and immune systems before and after intense sound exposure. Canadian Journal of Fisheries and Aquatic Sciences, 61(7), 1124-1134. https://doi.org/10.1139/f04-055

Rosen, D., & Worthy, G. (2018), Nutrition and Energetics. In: CRC Handbook of Marine Mammal Medicine, 3rd ed. (Gulland, F.M.D., Dierauf, L.A., & Whitman, K.L. eds). CRC Press, Boca Raton.

Rickert, D., Simon, R., von Fersen, L., Baumgartner, K., Bertsch, T., Kirschbaum, C., & Erhard, M. (2021). Saliva and Blood Cortisol Measurement in Bottlenose Dolphins (*Tursiops truncatus*): Methodology, Application, and Limitations. Animals, 12(1), 22. http://doi.org/10.3390/ani12010022

Sweeney, J., Stone, R., Campbell, M., & Ridgway, S. (2010). Comparative survivability of *Tursiops* neonates from three U.S. institutions for the decades 1990-1999 and 2000-2009. *Aquatic Mammals, 36*(3):248-261, https://doi.org/10.1578/AM.36.3.2010.248

Suzuki, M., Tobayama, T., Katsumata, E., Uchida, S., Ueda, K., Yoshioka, M., & Aida, K. (2002). Secretory patterns of cortisol in Indo-Pacific bottlenose dolphins and killer whales. Fisheries Science, 68 (suppl.), 451-452. https://doi.org/10.2331/fishsci.68.sup1_451

Suzuki, M., Tobayama, T., Katsumata, E., Yoshioka, M., & Aida, K. (1998). Serum Cortisol Levels in Captive Killer Whale and Bottlenose Dolphin. Fisheries Science, 64(4), 643–647. https://doi.org/10.2331/fishsci.64.643

Suzuki, M., Uchida, S., Ueda, K., Tobayama, T., Katsumata, E., Yoshioka, M., & Aida, K. (2003). Diurnal and annual changes in serum cortisol concentrations in Indo-Pacific bottlenose dolphins *Tursiops aduncus* and killer whales *Orcinus orca*. General and Comparative Endocrinology, 132(3), 427-433. https://doi.org/10.1016/S0016-6480(03)00100-X

Ternes, K. (2022). Ex situ management of the Amazon River dolphin (*Inia geoffrensis humboldtiana*): previous experiences, successes, and constraints. Zoologischer Garten N.F., 90(2), 183-218. https://doi.org/10.53188/zg0009

Ugaz, C., Valdez, R.A., Romano, M.C., & Galindo, F. (2013). Behavior and salivary cortisol of captive dolphins (*Tursiops truncatus*) kept in open and closed facilities. Journal of Veterinary Behavior, 8(4), 285–290. https://doi.org/10.1016/j.jveb.2012.10.006

van Elk, N., & Hartmann, M. (2013): *Tursiops truncatus* EEP. Internal report for the Bottlenose Dolphin EEP.

Whitham, J.C., Bryant, J.L., & Miller, L.J. (2020). Beyond Glucocorticoids: Integrating Dehydroepiandrosterone (DHEA) into Animal Welfare Research. Animals, 10(8), 1381. https://doi.org/10.3390/ani10081381

DER
ZOOLOGISCHE
GARTEN
THE ZOOLOGICAL GARDEN

doi:10.53188/zg0021

Zool. Garten N.F. 91 (2023) 155-173

# Recent Progress and Future Directions for Conservation of the Yangtze Finless Porpoise (*Neophocaena asiaorientalis asiaorientalis*)

## Fortschritte und zukünftige Maßnahmen zur Erhaltung des Jangtse-Schweinswals (*Neophocaena asiaeorientalis asiaorientalis*)

Yujiang Hao[1], Ghulam Nabi[2], Zhigang Mei[1], Jinsong Zheng[1], Kexiong Wang[1], Ding Wang[1*]

[1]Institute of Hydrobiology, the Chinese Academy of Sciences, Wuhan, Hubei 430072, PR China
[2]Ministry of Education Key Laboratory of Molecular and Cellular Biology; Key Laboratory of Animal Physiology, Biochemistry and Molecular Biology of Hebei Province, College of Life Sciences, Hebei Normal University, Shijiazhuang, 050024, Hebei Province, PR China

## Abstract

With the functional extinction of the Yangtze River dolphin or baiji (*Lipotes vexillifer*) based on the survey conducted in 2006, the Yangtze finless porpoise (*Neophocaena asiaorientalis*) is now the only surviving freshwater cetacean species in the Yangtze River. Due to similar threats from various anthropogenic activities in the Yangtze region, the natural population of the Yangtze finless porpoise (YFP) has been experiencing a drastic decline in the past few decades. Various conservation activities have been implemented to prevent the YFP from suffering the same fate as the baiji. Significant progress has been made recently, including natural habitat restoration, increasing the *ex-situ* population, and captive breeding success. Although there is a glimmer of hope, there are still some scientific and technical issues that need to be addressed to further improve the effectiveness and efficiency of the program through integrative planning for the whole conservation practice, which may include: 1) managing the *ex-situ* reserves as metapopulations; 2) replanning and managing the natural reserves and key habitats; 3) further improving research on the conservation biology of small cetaceans; 4) further encouraging public involvement. In general, this paper aims to review the implemented measures and re-

*Corresp. author:
E-Mail: wangd@ihb.ac.cn (Ding Wang)

cent progress achieved for the conservation of the critically endangered YFP and addresses the existing questions for further conservation practice of this species. Furthermore, we hope that this work will shed light on the conservation of other endangered small cetaceans in the world.

**Keywords:** Yangtze finless porpoise, small cetacean, conservation biology, *ex-situ,* Yangtze River

## Introduction

In July 2020, there were 131 recognised cetacean species and subspecies in the world, with 22 listed as critically endangered (CR) and 20 as endangered (EN), according to the IUCN – SSC Cetacean Specialist Group. It has been widely realised that biodiversity in freshwater systems is at more risk than other systems (Allan & Flecker, 1993; Nabi et al., 2021a). Therefore, it is not surprising that, among the seven dolphin and porpoise species and subspecies living in freshwater habitats, three are recognised as critically endangered and four as endangered (Wang et al., 2013; Minton et al., 2017; da Silva et al., 2018; Braulik et al., 2019; da Silva et al., 2020). The Yangtze River, also called the Mother River of China, is the largest river in China. It originates in Qinghai, crosses through 9 provinces and two cities, and finally empties into the East China Sea at Shanghai City (Bergmann et al., 2012; Xia et al., 2021). The river is also famous for being one of the two big rivers in the world that harbour two cetacean species (Wang, 2009). Due to the effects of various human activities, however, the Yangtze River dolphin, or baiji (*Lipotes vexillifer*), was driven to functional extinction in 2007 (Turvey et al., 2007). Thus, the Yangtze finless porpoise (*Neophocaena asiaorientalis asiaorientalis*, YFP) is now the only freshwater cetacean species in this river.

The YFP is the only freshwater species or subspecies in the family Phocoenidae. It is exclusively endemic to the middle and lower reaches of the Yangtze River and its two adjoining lakes – Poyang Lake and Dongting Lake (Gao & Zhou, 1993). Since the late 1980s, several studies have reported a continuous decline in the number of YFPs (Zhang et al., 1993; Wang et al., 1998; Wang et al., 2000; Zhao et al., 2008). For example, in the early 1990s, the total number of YFPs was reported to be about 2,600 (Zhang et al., 1993), but by 2006 it has reduced drastically to approximately 1,800 individuals (Zhao et al., 2008) and only 1,045 individuals in 2012. The annual decline rate of this population in the river's main stem increased from about 6% to nearly 14%, which means that half of the YFP population in the main stem was lost in the six years from 2006 to 2012 (Mei et al., 2012). Consequently, the status of the YFP was re-evaluated as Critically Endangered in 2013 from its previous classification of Endangered on the IUCN's Red List of Threatened Species (Wang et al., 2013; Mei et al., 2012).

To protect the baiji and the YFP, the Chinese government launched a series of conservation actions beginning in the late 1980s that have been reviewed in detail by the Institute of Hydrobiology of the Chinese Academy of Sciences (Wang, 2009, 2015). Its actions fall into three main activity categories: *in-situ* conservation, *ex-situ* management, and a captive breeding program. Since the early 1990s, some hot spots have been recognised and established as *in-situ* nature reserves to protect the baiji and YFP's key habitats. Eight YFP nature reserves have been established, including three national, four provincial, and one municipal reserve. Over an extended period, however, its natural habitat in the Yangtze basin has continuously deteriorated due to the pressure of economic development despite the establishment of nature reserves (Wang, 2009). *Ex-situ* conservation practice was therefore recognised as an urgent and indispensable measure to protect a 'seed population' amid the quick decline of the wild population of the YFP. The first *ex-situ* population of YFPs was established in 1990 at Tian-E-Zhou Oxbow in Hubei Province, where an *ex-situ* attempt was planned for the highly endangered baiji. Although the *ex-situ* population of the baiji was not established for various reasons at that time, the YFP population in this oxbow developed very well, which established a model of *ex-situ* conservation for YFP (Wang, 2015) and led to the establishment of two other *ex-situ* reserves, in He-Wang-Miao Oxbow in Hubei Province and Xi-Jiang in Anhui Province, respectively. Captive breeding has also been considered an important complementary conservation strategy (Wang et al., 2005). Since the first captive population was established in 1996 in the Baiji Dolphinarium or Yangtze Cetacean Breeding and Research Centre (YCBRC), four calves have been born under human care. In addition, two more captive breeding populations have been established in commercial aquariums, despite some controversies.

Although the integrative strategy for protecting the Yangtze River cetaceans was proposed as early as the mid-1980s, only some progress was achieved until recent years. According to the survey conducted in 2017, the declining rate of the YFP population has been reversed for the first time, and the estimated number of individuals in 2017 was 1,012, which is not statistically different from the number in 2012 (Huang et al., 2020). According to a statement by the Ministry of Agriculture and Rural Affairs, the rapidly declining population trend of the YFP has been successfully curtailed. More encouragingly, a newly completed whole-range survey in September and October in 2022 revealed that the YFP population just bottomed out with a statistic number of 1249 (unpublished data). In addition, the three *ex-situ* reserve populations have also increased significantly in the past several years. The dire trajectory of the YFP seems to have eased considerably in only the past few years. The interesting question is: what led to this significant change after the YFP had suffered such a long period of population decline? Compared to the baiji, why is the YFP so fortunate as to be able to grasp this last straw of hope? There is no doubt that this potential recovery of the YFP population convincingly suggests the effectiveness of present conservation measures, even though they made people lose confidence for many years (Wang, 2015). Therefore, we want to review the recent progress achieved and provide some suggestions on future directions to further improve the effectiveness of these measures. Moreover, we also want to take the YFP as an example to be used in protecting or saving other endangered small cetaceans from the brink of extinction.

## Progress in *ex-situ* protection

Worried about the tremendous population decline of the baiji in the 1980s, Chinese researchers suggested establishing *ex-situ* populations for the Yangtze cetaceans and initiated this practice in the early 1990s. Tian-E-Zhou Oxbow in Shishou County, in Hubei Province, was finally selected as an ideal place to introduce the baiji and Yangtze finless porpoise. This oxbow was initially a part of the mainstream of the Yangtze River but was cut off by currents in 1972. It is an old course of the Yangtze River about 21 km long and 1–2 km wide, with a habitat quite similar to that of the mainstream (Zhang et al., 2003). For security, five porpoises were captured and introduced into the oxbow in 1990 as a pre-test for the introduction of baiji (Wang, 2009). Several additional introductions were conducted over the following years. Although it has been proved that the YFP can live and reproduce well in the oxbow, the population fluctuated until 2010 due to various problems, including poor infrastructure and management. Since 2010, the reserve has managed the fishing activity well, and the YFP population has begun to increase quickly. According to the 2015 survey, the 2015 population exceeded more than 60 individuals (from 25 animals in 2010), a net increase of 108% (Wang, 2015). This population further increased to 100 individuals, according to the latest capture survey conducted in April 2021

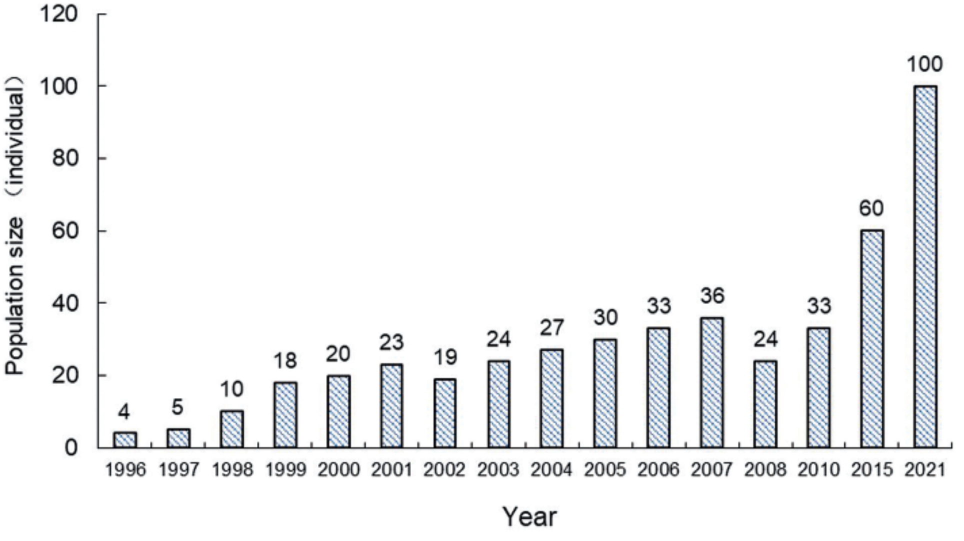


**Fig. 1:** YFP population increase in the Tian-E-Zhou Oxbow

(unpublished data) (Fig. 1).

Inspired by the success of the Tian-E-Zhou population, in 2015 the Ministry of Agriculture (MOA) established the second *ex-situ* reserve for the YFP in He-Wang-Miao Oxbow in Jianli County of Hubei Province, with technical support from the Institute of Hydrobiology at the Chinese Academy of Sciences (IHB). Twelve animals were introduced from Poyang Lake (8) and Tian-E-Zhou Oxbow (4) through three translocations in 2015 and 2017, respectively. The He-Wang-Miao Oxbow is about 30 km long, and its lower mouth is still connected to the Yangtze River; therefore, its water quality and fish resources are even better than the Tian-E-Zhou oxbow's. The carrying capacity is estimated to sustain about 110 YFPs, much higher than the Tian-E-Zhou Oxbow. Encouragingly, since 2016, new babies have been sighted every year. With the introduction of another eight and six animals from Tian-E-Zhou Oxbow in 2021 and 2022 respectively, the present population is estimated to be around 40, which will undoubtedly be the largest potential *ex-situ* YFP population.

In 2015, with the combined efforts of local fishery administrations and the Ministry of Agriculture and Rural Affairs (the present name of MOA), the third *ex-situ* reserve was established in Xijiang Oxbow, Anqing, in Anhui Province. This is a smaller oxbow with the capacity to hold about 20 animals. Eighteen animals had been introduced into this oxbow, and two new-born calves have been reported. Besides the three natural *ex-situ* reserves for the YFPs, another small seminatural *ex-situ* population was established in 1993 in a small channel between two islets in the Tongling section of the Yangtze River (Xian et al., 2010). This channel is about 1.6 km long and 80-220 m wide, with about ten animals living here. Although the YFPs can forage naturally, they must be fed twice a day due to the limited amount of fish resources in the channel (Xian et al., 2010). Therefore, considering its small size and need for extensive human intervention, it is not consensually recommended as an appropriate method for *ex-situ* conserving the YFPs.

The YFPs in the *ex-situ* reserves total around 130 animals, which has set a solid foundation for restoring its natural population in the Yangtze River. *Ex-situ* management actions to conserve YFPs provided the first positive example of *ex-situ* management for small cetaceans, which was seen as the Dawn of Hope for the conservation of the endangered small cetaceans in the world, according to the IUCN Report of the 2018 workshop on *ex-situ* options for cetacean conservation (IUCN, 2018). In November 2019, the IUCN cetacean specialist group organised another symposium to investigate Chinese researchers' *ex-situ* achievements in YFPs. Inspired by the progress on the YFP *ex-situ* conservation work, the IUCN cetacean specialist group proposed introducing the One Plan Approach (see von Fersen and Miller in this special issue) methodology, including *ex-situ* options to conserve other endangered or threatened small cetacean species.

## Efforts on Habitat Protection

Habitat protection is a fundamental measure for the conservation of wild animals, which benefits not just a single species but the entire ecosystem (Schelle, 2010), and, in the case of the YFP, through improved natural water flow, increased fish resources, and improved habitat quality. Therefore, since the mid-1980s, *in-situ* conservation has been suggested as one of the three major measures for Yangtze River cetaceans. Currently, a total of eight natural reserves have been established near the Yangtze River and its appended lakes (Fig. 2). The sum of the total length of the six reserves in the Yangtze River is approximately 494.5 km, accounting for nearly 30% of the area of the middle and lower reaches of the Yangtze River. For example, the Dongting YFP reserve accounts for about 26% of the size of Dong Lake. In comparison, the Poyang YFP reserve only accounts for a small proportion of the size of the lake (1.6%), even though it is the most important habitat for the wild YFP population (Zhao et al., 2008; Mei et al., 2012; Huang et al., 2020). The establishment of reserves, however, cannot protect the habitat of the YFPs without strong enforcement.

Although scientists have desperately called for immediate actions to protect the Yangtze cetaceans (Wang et al., 2000; Wang, 2009, 2015), due to continuous and extended developmental pressure in the Yangtze region, conservation measures have not been able to be fully implemented, even in the reserve regions. Human activities, such as shipping, fishing, hydro-project construction, sand-dredging, and urbanisation, are vital for developing the local economy and communities, so excluding or mitigating their impacts is difficult. Although the impacts of the individual anthropogenic activities were not quantitatively assessed, it is widely accepted that the cumulative effects of these activities are responsible for deteriorating the habitat of the YFP and other aquatic animals. Among these impacts, overfishing is seen as the major contributor to

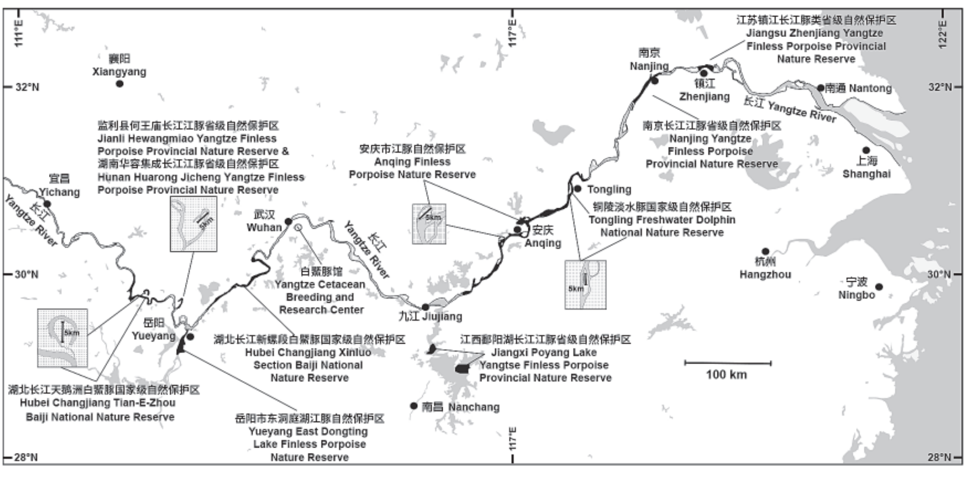


**Fig. 2:** YFP nature reserves in the Yangtze (by Frank).

the serious collapse of fish resources (Chen et al., 2002; Wei et al., 2007; Chen et al., 2009) and consequently destroys the foundation for a prosperous population of YFPs. In addition, food scarcity can cause detrimental nutrition stress in top predators (Wang, 2009; Schelle, 2010), which can fundamentally compromise the immunity, reproduction, and ultimately survival of the animals (Rosen, 2009; Nabi et al., 2017a, 2020a, 2020b). Moreover, various non-selective, illegal, and harmful fishing methods, such as electrofishing (Smith & Reeves, 2000), rolling hooks, and gill nets (Schelle, 2010), have been widely used in the Yangtze River and its adjoining lakes, even in some reserve sections. Like other small cetaceans, YFPs are prone to becoming entangled in fishing nets, which can cause severe injuries and predispose them to various infections and ultimately death by drowning (Schelle, 2010). Based on our preliminary investigation of the carcasses of YFPs collected in the Yangtze River, nearly one third of the identified causes of death were related to fishing activities (unpublished data).

To protect the fish resources, the Ministry of Agriculture and Rural Affairs, the major authority for freshwater biodiversity conservation in China, has implemented a seasonal fishing ban or spring fishing moratorium on the Yangtze River since 2002. It seems, however, that the three- or four-month seasonal fishing ban has not effectively protected the fish resources in the Yangtze River. As a result, the fish resources have declined continuously even after the implementation of the fishing ban, and it was announced that the biodiversity integrity index of the Yangtze River had reached the worst 'fish-free' level (People, 2018). Although the fishing ban was strictly enforced and the spawning and hatching of various fish species were well protected during the spring fishing ban period, fishing activities always increased immediately after the ban lifted. Controlling and enforcing fishing gear and methods during the fishing season is much more difficult than completely stopping fishing activity during the no-fishing period. Increased illegal fishing at night has been reported during the fishing season, with detrimental fishing practices on Poyang Lake and other water regions (Mei et al., 2020). With the continuous decline of fish stocks in the whole ecosystem, sustaining enough prey for the YFPs living in the reserves in a flowing riverine system is impossible, even with the strictest enforcement in the reserve sections. Despite the nearly 20-year seasonal fishing ban, however, it seems that the biodiversity integrity of the Yangtze River was still on the track to collapse, as shown by the stunning evidence of the likely extinction of baiji and the Chinese paddlefish (*Psephurus gladius*) and the quick decline of the YFP population and many other aquatic animals during this period (Turvey et al., 2007; Mei et al., 2012; Zhang et al., 2020).

An ichthyologist at the Institute of Hydrobiology proposed a complete fishing ban in 2006, when the shortcomings of the seasonal fishing ban were recognised. Still, more than 230,000 fishermen depend on fishing in the Yangtze basin. The trade-off between biodiversity protection and fishing livelihoods has long been negotiated. In the face of deteriorating environmental conditions and a booming economy, the 10-year fishing ban was finally implemented in all protected areas in early 2020 and throughout the entire Yangtze basin on 1 January 2021 (Mei et al., 2020). The central and local governments along the Yangtze have provided special funds for the retraining of fishers in new jobs by teaching them new skills and providing them with benefits, like social security. With the help of some NGOs, some fishers have been trained and appointed as fisheries wardens. They still live on the boats and do not fish but assist law-enforcement agencies in regulating fishing activities. Although there remains a lack of solid scientific data, it has been reported that the fish stocks have shown obvious signs of recovery, at least in some regions. In Lake Poyang, for example, the largest freshwater lake in China and the most important habitat for YFP, fish stocks increased significantly despite having a complete fishing ban for less than two years in this region. According to the Jiangxi Provincial Fisheries and Research Institute, the fish community structure in Poyang Lake is improving, and the fish resources have been replenished (People, 2021). Moreover, some rare or endangered fish species, such as the common sucker (*Myxocyprinus asiaticus*) and (*Ochetobius elongatus* Kner, 1867), also re-emerged in Poyang Lake, according to the latest survey conducted by the local institute.

The waterfront zone is an important wetland, flood-storage area, and detention area of the Yangtze River and plays important roles in economic, social, and ecological functions (Duan et al., 2020). Several surveys of the YFP have shown that these animals are more frequently sighted in sections with more natural waterfront zones (Mei et al., 2012; Huang et al., 2020, Chen et al., 2020). Anthropogenic activities, however, have significantly occupied and disturbed this vital component of the Yangtze ecosystem. The ecologically sensitive waterfront of the Yangtze River measures 3,943.2 km, accounting for 49.9% of the total length of the Yangtze River, among which about 1,625 km were artificially disturbed, accounting for 41.2% of the total length of the ecologically sensitive waterfront. This is even higher than the overall development and use rate of the main stem of the Yangtze River (36.7%), indicating that the existing protection areas played only a limited role in conserving the natural coastlines of the Yangtze River (Duan et al., 2020). The Ministry of Water Resources launched a campaign on cleaning and restoration actions for the coastline of the Yangtze River in 2016 based on the Guidelines for Development Along the Yangtze Economic Belt approved by the Political Bureau of the Central Committee of the CPC in 2016. According to the MWR, by October 2020, 2,441 projects suspected of violating laws and regulations had been cleaned up and remedied, accounting for 98.9% of the total. Furthermore, 158 km of the Yangtze River coastline had been restored, and 121,300 $m^2$ of beaches and banks were rehabilitated. This campaign has been significantly changing the Yangtze River's waterfront zone, thus rehabilitating the Yangtze ecosystem's ecological functions.

Water pollution is seen as another important factor in the deterioration of the habitat of the YFP (Wang, 2009, 2015). Another major cause is the reduction of fish resources, since fish are more vulnerable to various pollutants in water and tend to accumulate pollutants in their bodies (Jia et al., 2017). Previous studies have reported the bioaccumulation of toxic chemical pollutants in different fish and other aquatic species endemic to the Yangtze River (Shao et al., 2005; Xian et al., 2008; Su et al., 2010). YFPs are at the top of the food chain and can, therefore, bio-accumulate various toxic pollutants by ingesting polluted prey (Schelle, 2010). Dong et al. (2006) reported the deaths of five YFPs in Dongting Lake from pesticide exposure. More recently, Xiong et al. (2019) and Zhang et al. (2020) reported several organic pollutants in blubber and trace elements in various tissues. Although acute mortality caused by pollutants is rare, accumulated toxins in animals can cause multiple problems, such as reproductive failure, an imbalance in biochemical homeostasis, and cardiovascular, hepatic, and renal problems (Willett et al., 1998; Stahl et al., 2011; Nabi et al., 2019, 2021b), which can compromise the animals' survival.

As one of China's most important economic belts, the Yangtze River has long suffered from tremendous amounts of industrial wastewater, agricultural effluents, ship navigation wastes, and urban sewage (Floehr et al., 2013). The deteriorated water quality poses a grave threat to public health (Lu et al., 2008) and aquatic biodiversity (Ullah et al., 2021a, b). The Yangtze River was even rated as one of the top ten 'risk rivers' globally by the World Wildlife Fund in 2007 (Wong et al., 2007). Although actions on pollution prevention have long been continuously conducted along the Yangtze basin, a systematic and thorough campaign on water-pollution control in the Yangtze basin has been overwhelmingly implemented throughout the whole basin under the supervision of the Ministry of Ecology and Environment since 2016. According to the Ministry of Economy and Labour, 228 chemical enterprises along the Yangtze River have been relocated or renovated, including all the outdated chemical enterprises within one km of the Yangtze River. At the same time, pollution from non-point agricultural sources has been significantly reduced by, for instance, decreasing the use of and increasing the efficiency of chemical fertilisers and pesticides and applying green crop disease and insect prevention and control technology. Furthermore, centralised sewage-treatment facilities in all cities along the mainstream of the Yangtze River have been established, and nearly 24,000 sewage outlets in total from the cities along the river have been eliminated. Moreover, 33,872 pollutant reception facilities for ships were completed in the Yangtze Economic Belt to reduce pollution from the ports and piers. As a result of these measures, remarkable improvements have been achieved, with the good water quality sections (grade I to grade III) increasing to 96.7% of the Yangtze River basin, 14.9% higher than that in 2015. Moreover, in 2020, for the first time, the water quality of the whole mainstream reached Grade II (News China, 2022).

Acoustic pollution, particularly from ships, is another potent stressor for all cetaceans of any age (Wright et al., 2007). A sudden loud noise can kill nearly any cetacean (Claridge, 2006), but, more commonly, it causes damage to their external and internal organs (Cox et al., 2006). Chronic acoustic pollution can cause hearing loss (Finneran et al., 2002) and mask their vocalisations essential for foraging, mother-offspring bonding, navigation, and escape from predators (Marine Mammals Commission, 2007). Furthermore, exposure to chronic acoustic pollution can directly suppress the Hypothalamic-pituitary-gonadal (HPG) axis and compromise fertility (Nabi et al., 2018a). Additionally, daily social behavioural patterns, such as group cohesion (Nowacek et al., 2001), travel direction, behavioural state (Miller et al., 2008), dive duration, and breathing synchrony, can be negatively compromised by acoustic pollution (Nabi et al., 2018b). Acoustic pollution can also directly reduce the foraging efficiency of cetaceans (IWC, 2007), which can consequently compromise their survival (Wright et al., 2007). Many cases have been reported of YFPs' being killed or severely injured by propeller strikes (Zhou & Zhang, 1991; Chen et al., 1997). Therefore, scientists have long petitioned to regulate shipping or navigation in the Yangtze River (Wang et al., 1998, 2000; Wang et al., 2006; Wang, 2009, 2015).

The Yangtze River is the major artery of China's inland water transportation, which is called the Golden Channel of the Chinese economy (Schelle, 2010; Fu et al., 2010). According to the Ministry of Transport (MOT), shipping along the Yangtze River contributes more than 200 billion yuan directly and 4.3 trillion yuan indirectly to economic and social development along the river every year (MOT, 2020). It is impossible to reduce the Yangtze River's shipping ability due to its function as a backbone of the economy. Thus, it is not easy to regulate the huge shipping industry. The MOT has issued regulations and standards for preventing and controlling noise pollution from ships in the Yangtze River and strengthened on-site supervision. Moreover, it has pledged to investigate further technical measures, such as new and green energy engines, to control noise pollution in the river. In some reserve sections, boat-speed control has been proposed and is notified automatically by radio when a boat or ship enters the reserve section, which might help mitigate the effects of noise pollution and shipping on the animals in the region.

Although it is impossible to solve all problems at once, with the implementation of a series of campaigns by various departments, particularly the complete 10-year fishing ban and waterfront zone-cleaning and restoration actions, the environment and ecology of the Yangtze River have been changing significantly. In general, the habitat of the YFPs is gradually improved by the evidence of frequent sightings and reports of YFPs from different regions. For instance, the Nanjing Provincial YFP Natural Reserve now can be seen as a successful example of an *in situ* nature reserve of YFPs in the urban section of the busy channel of the Yangtze River although it is the latest natural reserve established in October 2014. Thanks to strict enforcement of all fishing controls, including recreational fishing, and the restoration of the river's natural shorelines, the YFP population has increased significantly, from 20 to 50 animals, since its establishment in 2014, and the population continues to grow steadily. In addition to management by the Nanjing local authorities, the participation of the local population, including NGOs and volunteers, has also contributed significantly to the recovery of the YFP in this section. The

Yichang section, just down to the Gezhou Dam, is another encouraging example. Historically, it was not a traditional hotspot of the YFP but a provincial nature reserve for the threatened Chinese sturgeon. With the environmental improvement of this region, a small group of YFPs explored it in 2015 and now dwell in the reserve. The present number of residents is estimated at 15 to 20 animals, and they have now become a famous symbol of this city, attracting many local photographers every day. The Poyang and Dongting Lakes are the two most important habitats for YFPs (Zhao et al., 2008; Mei et al., 2013) and have been seen as the last refuge of the YFPs. In addition to the intensive fishing activities, illegal sand dredging was another threat contributing to the deteriorating habitat of the YFP and the survival of other aquatic animals in the two lakes (Jing, 2008; Wang, 2015). Due to the local economy's dependence on sand-dredging, the sand-dredging ban has faced imaginable difficulties in these regions. Thanks to the strong implementation of the Great Conservation Project for the Yangtze River proposed by the central government, sand-dredging has been strictly suppressed and regulated. As a result, the former muddy lakes are now becoming clean and calm. Regional surveys conducted by the local institutes have shown that the population of the YFP is increasing, which has been confirmed by the 2022 survey (unpublished data).

## Progress in the Captive Breeding Programme

As early as 1986, at the first symposium on Biology and conservation of Freshwater Cetaceans in the World, Chinese researchers identified captive breeding as the last of the three major conservation measures for the Yangtze River dolphins. A male baiji named Qi-Qi was rescued on 11 January 1980 and raised in captivity in the Baiji dolphinarium for 22 years and 186 days, making him one of the longest-lived freshwater dolphins under human care. Although attempts were made to find a breeding partner for him, the captive breeding program for baiji finally failed with the death of Qi-Qi on 14 July 2002 (Wang, 2009).

The long-time husbandry of Qi-Qi, however, led to important knowledge about and experience in the care of small freshwater dolphins that is now helping Chinese researchers and trainers to keep YFPs under human care. The first group of YFPs, two females and one male, was successfully introduced to the Baiji dolphinarium or the Yangtze Cetacean Breeding and Research Centre in 1996. The first calf, named Tao-Tao, was born on 5 July 2005 (Wang et al., 2005). Although several other calves were born in captivity in the following years, however, all calves died prematurely, possibly due to the old facility, maternal problems, or poor nutritional management. The rearing pools in the Baiji dolphinarium were reconstructed in 2008, and three young females from Poyang Lake were introduced in 2009 (Yang-Yang) and 2011 (F7 and F9), respectively. Moreover, Chinese researchers have investigated and improved the husbandry and management of captive animals, including grouping, monitoring, and nutritional adjustment during the females' different physiological stages. In 2018, the second male calf, 'E-Bo', was born successfully and has now fully matured. Furthermore, the male second-generation baby YYC (Yang-Yang's calf) was born in 2020, which is named Han-Bao later and now is fully independent of his mother. In 2022, the first female second-generation baby was born, which further enhances the reproductive success of this captive population. Presently, it has totally 11 animals in this captive population and provides a dependable research platform for the small cetacean biology.

Although captive breeding of YFPs remains challenging, the whole process, including pregnancy, delivery, and nursing, is now common and natural in the Baiji dolphinarium. The protocols and procedures for the management and husbandry of captive YFPs have been significantly improved (Hao et al., 2019), and the experiences in keeping and breeding YFPs in human care made at the Baiji dolphinarium have also been applied to a net cage project in the Tian-E-Zhou oxbow. In recent years, two calves were born in the net cage in 2016 and 2020. The first calf was released to the oxbow in 2020 after she was confirmed to be fully matured, and the second calf is now also already completely independent.

Although it remains controversial to use captive breeding as a conservation measure, there is no doubt that keeping even a small group of animals can build a significant amount of knowledge and experience in handling and caring for the animals, which is in turn important for wild animal rescue and handling. Moreover, it provides an exclusive opportunity for the public to know more about this species, significantly inspiring their concern, love, and care for these unique small cetaceans in the Yangtze River. However, in the case of the YFP, the contribution of captive breeding programs to enhancing the wild populations in the Yangtze River or in the oxbow river reserves remains to be seen. Even though, and amid suspicious public opinions, two captive populations were established in two commercial aquaria in 2019 and 2020, respectively, with individuals taken from the two of the YFP ex-situ reserves. Considering the difficulties of reintroducing animals born under human care back into the wild, the effect of these commercial breeding programs to the endangered YFP wild population is still uncertian compared to the promising network of natural ex-situ reserves along the Yangtze River.

## Future direction for the conservation of the YFP

After decades of efforts by Chinese researchers, conservationists, governmental authorities, and NGOs, a systematic conservation strategy has been established, and the terminal trajectory of the YFPs has been fundamentally changed. Despite this success, more scientific and conservation issues still need to be addressed to further strengthen the foundation of the progress and restore the natural population of YFPs in the Yangtze River.

### Managing the *ex-situ* populations as a metapopulation

The *ex-situ* reserves are relatively small areas for a large population of YFPs. For example, the carrying capacity of the Tian-E-Zhou oxbow is estimated at only 89 animals total, according to the Ecopath Model (Li, 2017). Using the same model, the carrying capacity of the He-Wang-Miao oxbow is estimated at 110 animals (unpublished data), while the carrying capacity of the Anqing Xi-Jiang oxbow is much smaller, at less than 30 animals. Using a stable population model, the threshold for the population size to persist for 100 years requires 113 animals, and 472 animals are needed to persist for 500 years (Mei et al., 2021). Based on this data, it is evident that none of the present *ex-situ* reserves can sustain the progress of the YFP population for long. It is, therefore, important to manage the *ex-situ* populations as a metapopulation. Moreover, in small and fragmented populations, the loss of the population's genetic structure and genetic diversity may alter the species' demography and increase its risk of extinction (Frankham et al., 2002). The population decline, combined with the restricted gene flow, can cause a serious loss of genetic diversity and result in genetically fragmented populations (Chen et al., 2014). Therefore, the artificial exchange of individuals among the *ex-situ* populations is critical to maintaining genetic diversity and a self-sustaining *ex-situ* population. According to a model simulation, for the Tian-E-Zhou population, at least two animals each year need to be exchanged with other *ex-situ* populations or natural populations to maintain their genetic diversity.

A genetic-diversity management program has been implemented for *ex-situ* populations. The Institute of Hydrobiology, supervised by the SFAO, introduced four animals from Poyang Lake into the Tian-E-Zhou Oxbow in 2015 and 2018. In return, in 2015 and 2020, four and eight animals, respectively, were translocated to the newly established He-Wang-Miao population.

Moreover, two males were translocated from the Tian-E-Zhou Oxbow to the Anqing Xijiang Oxbow. The preliminary genetic evaluation demonstrated that, with these movements, the genetic diversity of the Tian-E-Zhou population has significantly improved (Wang Ding, personal communication). In the long run, functional connectivity through artificial exchanges among *ex-situ* populations is required to maintain the genetic biodiversity and population dynamics.

With the population reaching or even surpassing the carrying capacity of the Tian-E-Zhou oxbow, it is now urgent to evaluate the optimum sustainable population (OSP) to maintain healthy population development. With the increase in the *ex-situ* population, the animal's net reproductive rate and nutritional status, as indicated by body mass index (BMI), has shown an obvious decline in the Tian-E-Zhou population (unpublished data). Therefore, it is now a reality that determines how many animals need to be translocated out each year to maintain an optimal sustainable population. Moreover, sewage discharge, the allocation of water resources, fishery management, carrying capacity improvement, and water quality control are some new issues in managing *ex-situ* reserves. Therefore, further investigation is needed to develop the categories required for establishing and manipulating the *ex-situ* reserves, including criteria for location, size, topography, water quality, fish availability, wetlands, climate, and the surrounding communities. Another important question is how to re-evaluate the role of *ex-situ* populations for the recovery of the natural population of YFPs in the Yangtze River.

## Boosting habitat restoration and natural population recovery

Decades of environmental degradation on the Yangtze River due to rapid and unregulated development had almost driven the YFP into the vortex of extinction, prompting even conservationists to ponder its future (Wang, 2015). The change in China's development philosophy gives the YFP a chance to grasp the last straw of hope. The significant changes in the Yangtze ecosystem reignited the hope that the natural habitats of the YFP and other aquatic animals in the Yangtze could be restored. In the context of the greater protection of the Yangtze River and the 10-year fishing ban, the following measures are proposed to further boost the recovery of the natural population of YFPs.

## Re-establish the connection of some tributaries and lakes to the main stem of the Yangtze River to reconstruct its ecological function

Historically, the Yangtze River was connected with numerous lakes and tributaries that were disconnected from the main stem of the Yangtze for, among other purposes, flood control and irrigation projects. Only a few lakes remain directly connected with the main stem, like Dongting and Poyang Lakes. These barriers significantly reduced the ecological function and biomass of the ecosystem by impeding the breeding or foraging migration of some fish species and curtailing the free movements and gene flow of aquatic organisms (Morita et al., 2009). The construction of the Three Gorges Dam significantly reduced the probability of a major flood in the Yangtze River to one in 100 years. It, therefore, provides the possibility to reconnect the main stem of the Yangtze to some of its tributaries and lakes through a thorough and objective ecological evaluation.

## Readjust the nature reserves according to hotspot or habitat changes of the YFPs

Eight natural protected areas are presently established for the YFP. Due to various anthropogenic activities, however, the habitats and distribution of the YFP differ from decades ago, when the reserves were established. It is necessary to readjust the reserve areas according to the present results from the series of surveys (Zhao et al., 2008; Mei et al., 2013;

Huang et al., 2020). Some important habitats of the YFP, e.g., the Balijiang section or the mouth of Poyang Lake, the Jingjiangmen section or the mouth of Dongting Lake (Huang et al., 2020), should be designated as protected areas for the YFPs. Previous YFP population surveys have also shown that the distribution of the YFP in the mainstream of the Yangtze River is highly correlated with the characteristics of the river shoreline. This suggests that protecting the nature shoreline of the Yangtze River is key to the protection of the natural habitat of the YFP. Therefore, it is highly recommended that the functional zoning adjustment of the YFP reserve in the main stem of the Yangtze River should focus on protecting the river coastline environment, which should be designated as the core protection area of the reserves (Liu et al., 2020).

## Continue regular surveys across the range to monitor population trends and assess the level of threat

With the implementation of the Greater Protection of the Yangtze River, it is optimistic to expect that the natural population will increase gradually in the foreseeable future. Therefore, it is recommended to conduct a population viability analysis according to the recent data from the surveys to project the population trajectory, which can be used to assess the effectiveness of conservation strategies. Moreover, with the *ex-situ* population reaching carrying capacity, it is time to evaluate the possibility of releasing some of the animals from the *ex-situ* reserves, such as Tian-E-Zhou Oxbow, to certain natural habitats to restore the wild populations.

## Improve research on the conservation biology of small cetaceans

The recovery of the YFP population is a good example of how species can be conserved and can thus serve as a model species for the conservation of small cetaceans. Advanced technologies can be tested in natural, *ex-situ,* and captive populations of YFPs to conserve other threatened small cetaceans worldwide. Although integrated conservation activities have improved the status of the YFP, many knowledge gaps still exist that would allow us to refine the conservation system and technologies further. For example, the traditional population survey is relatively laborious and time-consuming, and its result is prone to be affected or even biased by the visual differences of individual observers. Moreover, the fast-developing drone (i.e., unmanned aerial vehicle) technology allows for the establishment of drone-based survey technology, which could be more efficient and accurate. Furthermore, remote-sensing technology is highly recommended for habitat investigation, planning, and management.

Genetic diversity (Zheng et al., 2005), divergence (Yang et al., 2002), correlation between environmental factors and genome size (Bo et al., 2006), adaptation to the environment (Ruan et al., 2016), renal transcriptome sequencing (Ruan et al., 2015), and basic information about the finless porpoise biology (Zeng et al., 2017a, 2017b; Xiao et al., 2018; Ji et al., 2019; Zeng et al., 2019) have been studied. Additional studies are needed to investigate inbreeding depression-related loci, gene-environment interactions, overdominance, epistasis, and genetic susceptibility, which are important for animal conservation (Khan et al., 2016). Historical information related to the origin, speciation time, ancestral effective population size, and microevolution of the YFPs needs to be collected.

The *ex-situ* reserves for the YFP can serve as a model for the Yangtze River ecosystem. A series of scientific or technological issues can be investigated on this platform: e.g., the energy flow and balance in the closed ecosystem, the function and interaction of the top predator, the YFP, with its prey and other aquatic organisms, and the biodiversity variation and gene flow in the closed population with changes in the population size. Moreover, changes in population dynamics and the reproductive performance of the population with the population size approaching the carrying capacity of the closed reserve ecosystem can also be studied.

For the captive breeding population of YFPs, artificial insemination (AI) technology can be a useful tool in conserving endangered species. Improving the genetic material, increasing the overall population, and enabling breeding at different times and different geographical locations can be achieved by AI. AI also ensures breeding in the presence of behavioural, physiological, and physical abnormalities after a male's death (Jane, 2011). Current research is in progress to investigate the ovulation period through hormones and ultrasound in captive female YFPs. Training male YFPs for semen collection has also been started. There are still various challenges regarding AI, however, including gamete preservation and the development of a protocol for AI. Thus, combined contributions from various field experts are needed to overcome and establish a sustainable captive population.

Advanced molecular techniques can help explain how different toxicants, pathogens, and other parasites can disrupt the cellular machinery of YFPs. Furthermore, there is also a need to develop viable cell lines and improve medical husbandry techniques to understand the cellular and physiological responses of YFPs to various anthropogenic stressors. When using advanced molecular and other physiological methods, criteria are needed for animal translocations and release practices considering the genetic diversity and richness, disease risk assessment, and health screening of the YFPs. Post-release assessments via satellite-linked telemetry are also needed to understand whether the animal can re-adapt to its natural environment.

## Further encourage public involvement

Public involvement is a key factor in conservation, especially for the protection of flagship species that act as ambassadors for the entire ecosystem. The giant panda is a good example of this model, where conservation action is focused on this charismatic species to achieve conservation success for other species as well. The YFP is also an intriguing species that could act as a symbol for the conservation of the Yangtse River in general. It was not well protected before, partly because it was not well known by the public due to its evasive behaviour. The activities conducted to educate the public coordinated by the Chinese government, media, and NGOs over the last few years, however, have informed the public about the status of the YFP. The Baiji Dolphinarium of IHB has played a key role in this campaign by providing pictures, videos, and TV programmes. With the YFP becoming more popular, more and more people have become concerned and even joined forces to protect this species. Every year, many visitors of different ages and nationwide volunteers come to see the porpoise. Ten delegates of the Chinese People's Political Consultative Conference (CPPCC) submitted a joint proposal to upgrade the YFP to a First Grade National Protected Animal during the fifth meeting of the 12$^{th}$ session of its 2017 conference, which contributed significantly to its upgrading in 2020 and is a clear indication of public awareness. Wuhan Baiji Conservation Foundation (WBCF) was the first NGO established in 1996 for the conservation of the Yangtze River cetaceans. Recently, however, over 20 organisations have been directly involved in the conservation of the YFP in different regions, such as Poyang Lake and Dongting Lake, and the Wuhan, Anqing, Nanjing, and Zhenjiang sections. These NGOs organise various public educational events, conduct surveys, report illegal activities, and report stranding events of YFPs, which have contributed and will continue to contribute to the restoration of the natural population of YFPs in the Yangtze River.

## Conclusions

Since the extinction of the Yangtze River dolphin in 2006, the YFP is now the only freshwater cetacean endemic to the Yangtze River. Unfortunately, like the baiji, the YFP also faced tremendous pressures resulting from various anthropogenic activities. As a result, YFPs have been on an accelerated path to extinction for the last few decades. Different measures, such as promoting public awareness, a fishing ban, *in-situ* conservation, *ex-situ* conservation, captive breeding, and various biological research programmes have been carried out to conserve YFPs. Only recently fruitful results have been achieved through the integrative use of these conservation tools, as shown by the quickly increasing population in *ex-situ* reserves, significantly slowing the decline rate of the natural population and making progress on captive breeding and public education projects. By comparing the conservation process of the baiji and YFPs, an integrated conservation plan, including *ex-situ* options, is important to draw a threatened cetacean species out of the extinction vortex. *Ex-situ* measures should be implemented early enough to ensure that one or more seed populations can be established without significantly affecting the natural population. The protection of the natural habitat is the fundamental measure for restoring the wild population of endangered cetacean species. Therefore, significant conservation measures should be implemented to mitigate or eliminate the major threats from the species' hotspots (e.g., fishing). Natural habitat protection, however, always conflicts with the livelihoods and economy of local communities. Therefore, it needs the strong support of political and legitimate enforcement, which also needs to be backed up by the nation's strong economy, such as implementing the 10-year fishing ban in the Yangtze River. Captive breeding can support filling the knowledge gap and educating the public about the protection of the cetacean species. Still, it seems costly and inefficient to save a cetacean species by reproducing many animals in captivity. From our experience with YFP, we suggest using integrated conservation tools to protect endangered small cetacean species by considering *ex-situ* options as early as possible to establish seed populations, protect natural habitats as much as possible, and fill the knowledge gap as quickly as possible by all means possible, including through a small-scale captive breeding program. If these measures could be implemented properly, changing the fate of any endangered cetacean species is highly possible.

## Acknowledgements

We are thankful to the National Key R&D Program of China (2021YFD1200304) for financial support.

## Zusammenfassung

Mit dem Aussterben des Jangtse-Delfins oder Baiji (*Lipotes vexillifer*) auf Grundlage der im Jahr 2006 durchgeführten Erhebung ist der Jangtse-Schweinswal (*Neophocaena asiaorientalis*) nun die einzige überlebende Süßwasser-Cetacea-Art im Jangtse-Fluss. Aufgrund ähnlicher Bedrohungen durch verschiedene anthropogene Aktivitäten in der Jangtse-Region hat die natürliche Population des Jangtse-Schweinswals (YFP) in den letzten Jahrzehnten einen drastischen Rückgang erlebt. Um zu verhindern, dass dem YFP das gleiche Schicksal wie dem Baiji widerfährt, wurden verschiedene Schutzmaßnahmen ergriffen. In letzter Zeit wurden erhebliche Fortschritte erzielt, darunter die Wiederherstellung natürlicher Lebensräume, die Vergrößerung

der Ex-situ-Population und die erfolgreiche Zucht in Menschenobhut. Obwohl es einen Hoffnungsschimmer gibt, müssen noch einige wissenschaftliche und technische Fragen geklärt werden, um die Effektivität und Effizienz des Programms durch eine integrative Planung für die gesamte Erhaltungspraxis weiter zu verbessern, die Folgendes umfassen kann 1) Management der Ex-situ-Reservate als Metapopulationen; 2) Neuplanung und Management der natürlichen Reservate und der wichtigsten Lebensräume; 3) weitere Verbesserung der Forschung über die Erhaltungsbiologie von Kleinwalen; 4) weitere Förderung der Beteiligung der Öffentlichkeit. Im Allgemeinen zielt dieser Beitrag darauf ab, einen Überblick über die durchgeführten Maßnahmen und die jüngsten Fortschritte bei der Erhaltung der stark gefährdeten YFP zu geben und die bestehenden Fragen für die weitere Erhaltungspraxis für diese Art zu erörtern. Darüber hinaus hoffen wir, dass diese Arbeit Licht auf die Erhaltung anderer gefährdeter Kleinwale in der Welt werfen wird.

## References

Allan, J.D., & Flecker, A.S. (1993). Biodiversity conservation in running waters: Identifying the major factors that threaten destruction of riverine species and ecosystems. BioScience, 43, 32-43.

Bergmann, A., Bi, Y., Chen, L., Floehr, T., Henkelmann, B., Holbach, A., Hollert, H., Hu, W., Kranzioch, I., Klumpp, E., Küppers, S., Norra, S., Ottermanns, R., Pfister, G., Roß-Nickoll, M., Schäffer, A., Schleicher, N., Schmidt, B. Scholz-Starke, B., Schramm, K.-W., Subklew, G., Tiehm, A., Temoka, C., Wang, J., Westrich, B., Wilken, R.-D., Wolf, A., Xiang, X., & Yuan, Y. (2012). The Yangtze-Hydro Project: A Chinese–German environmental program. Environmental Science and Pollution Research, 19, 1341-1344.

Bo, D., Ding, W., Xianfeng, Z., Zheng, G., & Jing, Z. (2006). Genome size determination of Yangtze finless porpoise *Neophocaena phocaenoides asiaeorientalis*. Acta Zoologica Sinica, 5, 731-737.

Braulik, G.T., Noureen, U., Arshad, M., and Reeves, R.R. (2015). Review of status, threats, and conservation management options for the endangered Indus River blind dolphin. Biological Conservation, 192, 30-41. https://doi.org/10.1016/j.biocon.2015.09.008

Chen, D.Q., Duan, X.B., Liu, S.P., Shi, W.G., & Wang, B. (2002). (长江渔业资源变动和管理对策) On the dynamics of fishery resources of the Yangtze River and its management. Acta Hydrobiologica Sinica, 26, 685-690.

Chen, D.Q., Xiong, F., Wang, K., & Chang, Y. (2009). Status of research on Yangtze fish biology and fisheries. Environmental Biology of Fishes, 85, 337–357.

Chen, M., Yu, D., Lian, Y., & Liu, Z. (2020). Population abundance and habitat preference of the Yangtze finless porpoise in the highest density section of the Yangtze River. Aquatic Conservation: Marine and Freshwater Ecosystems, 30, 1088-1097.

Chen, M., Zheng, J., Wu, M., Ruan, R., Zhao, Q., & Wang, D. (2014). Genetic diversity and population structure of the critically endangered Yangtze finless porpoise (*Neophocaena asiaeorientalis asiaeorientalis*) as revealed by mitochondrial and microsatellite DNA. International Journal of Molecular Sciences, 15, 11307-11323.

Chen, P., Liu, R., Wang, D., & Zhang, X. (1997). Biology, rearing, and conservation of baiji. Science Press, Beijing, China.

Claridge, D.E. (2006). Fine-scale distribution and habitat selection of beaked whales. Dissertation, Department of Zoology, University of Aberdeen, Scotland.

Cox, T.M., Ragen, T.J., Read, A.J., Vos, E., Baird, R.W., Balcomb, K., Barlow, J., Caldwell, J., Cranford, T., & Crum, L. (2006). Understanding the impacts of anthropogenic sound on beaked whales. Journal of Cetacean Research and Management, 7, 177–187.

da Silva, V., Martin, A., Fettuccia, D., Bivaqua, L., & Trujillo, F. (2020). *Sotalia fluviatilis*. The IUCN Red List of Threatened Species 2020: e.T190871A50386457. https://dx.doi.org/10.2305/IUCN.UK.2020-3.RLTS.T190871A50386457.en.

da Silva, V., Trujillo, F., Martin, A., Zerbini, A. N., Crespo, E., Aliaga-Rossel, E., & Reeves, R. (2018). *Inia geoffrensis*. The IUCN Red List of Threatened Species 2018: e.T10831A50358152. https://dx.doi.org/10.2305/IUCN.UK.2018-2.RLTS.T10831A50358152.en.

Dong, W.W., Xu, Y., Wang, D., & Hao, Y. (2006). Mercury concentrations in Yangtze finless porpoises (*Neophocaena phocaenoides asiaorientalis*) from eastern Dongting Lake, China. Fresenius Environmental Bulletin, 15, 1-7.

Duan, X., Zou, H., & Wang, X. (2020). Protection and scientific utilization of waterfront resources in the Yangtze River Economic Belt. Bulletin of Chinese Academy of Sciences, 35, 970-976.

Finneran, J.J., Schlundt, C.E., Dear, R., Carder, D.A., & Ridgway, S.H. (2002). Temporary shift in masked hearing thresholds in odontocetes after exposure to single underwater impulses from a seismic water gun. Journal of the Acoustical Society of America, 111, 2929-2940.

Floehr, T., Xiao, H., Scholz-Starke, B., Wu, L., Hou, J., Yin, D., Zhang, X., Ji, R., Yuan, X., & Ottermanns, R. (2013). Solution by dilution? A review on the pollution status of the Yangtze River. Environmental Science and Pollution Research International, 20, 6934–6971.

Frankham, R. (2008). Genetic adaptation to captivity in species conservation programs. Molecular Ecology, 17, 325-333.

Fu, B., Wu, B., Lue, Y., Xu, Z.H., Cao, J.H., Niu, D., Yang, G. S., & Zhou, Y. M. (2010). Three Gorges Project: Efforts and challenges for the environment. Progress in Physical Geography, 34, 741-754.

Gao, A., & Zhou, K. (1993). Growth and reproduction of three populations of finless porpoise. *Neophocaena phocaenoides*, in Chinese waters. Aquatic Mammals, 19, 3-12.

Hao, Y.J., Nabi, G., Deng, X.J., & Wang, D. (2019). Non-invasive fecal steroid measurements for monitoring the reproductive status of critically endangered Yangtze finless porpoises (*Neophocaena asiaeorientalis asiaeorientalis*). Frontiers in Endocrinology, 10, 606.

Huang, J., Mei, Z.G., Chen, M., Han, Y., Zhang, X.Q., Moore, J.E., Zhao, X.J., Hao, Y.J., Wang, K.X., & Wang, D. (2020). Population survey showing hope for population recovery of the critically endangered Yangtze finless porpoise. Biological Conservation, 241, 108315.

International Whaling Commisssion (IWC) (2007). Report of the scientific committee. Annex K Report of the Standing Working Group on Environmental Concerns. Journal of Cetacean Research and Management, 9, 227-296.

Jane, J.M. (2011). Artificial insemination: Current and future trends. In: Artificial insemination in farm animals (Milad, M., ed.). InTech. Available at: http://dx.doi.org/10.5772/713

Jefferson, T.A. (2002). Preliminary analysis of geographic variation in cranial morphometrics of the finless porpoise (*Neophocaena phocaenoides*). The Raffles Bulletin of Zoology, 10, 3-14.

Ji, J., Nabi, G., Zeng, X., Hao, Y., & Wang, D. (2019). Histological variation of blubber morphology in the endangered East Asian finless porpoise (*Neophocaena asiaeorientalis sunameri*) with ontogeny and reproductive states. Zoological Studies, 58, e42.

Jia, Y., Wang, L., Qu, Z., Wang, C., & Yang, Z. (2017). Effects on heavy metal accumulation in freshwater fishes: species, tissues, and sizes. Environmental Science and Pollution Research International, 24, 9379-9386.

Jing, X. (2008). Change detection of hydro-acoustic environment for Yangtze finless porpoise using remote sensing in Poyang Lake. Dissertation, Wuhan University, China.

Khan, S., Nabi, G., Ullah, M. W., Yousaf, M., Manan, S., Siddique, R., & Hou, H. (2016). Overview on the role of advance genomics in conservation biology of endangered species. International Journal of Genomics, 2016, 3460416.

Li, Y.T. (2017). Study on the habitat selection, carrying capacity and population viability analysis of the Yangtze finless porpoise in Tian-E-Zhou oxbow – The theory of ex situ conservation. Dissertation.

Lu, W.Q., Xie, S.H., Zhou, W.S., Zhang, S.H., & Liu, A.L. (2008). Water pollution and health impact in China: A mini-review. Open Environmental Sciences, 2, 1–5.

Marine Mammals Commission (2007). Marine mammals and noise: A sound approach to research and management: A report to Congress from the Marine Mammal Commission. https://www.mmc.gov/wp-content/uploads/fullsoundreport.pdf

Mei, Z., Cheng, P., Wang, K., Wei, Q., Barlow, J., & Wang, D. (2020). A first step for the Yangtze. Science, 367, 1314.

Mei, Z., Huang, S.L., Hao, Y., Turvey, S.T., Gong, W., & Wang, D. (2012). Accelerating population decline of Yangtze finless porpoise (*Neophocaena asiaeorientalis asiaeorientalis*). Biological Conservation, 153, 192-200.

Miller, L.J., Solangi, M., & Kuczaj, S.A. (2008). Immediate response of Atlantic bottlenose dolphins to high-speed personal watercraft in the Mississippi Sound. Journal of the Marine Biological Association, 88, 1139-1143.

Minton, G., Smith, B.D., Braulik, G.T., Kreb, D., Sutaria, D., and Reeves, R.R. (2017). *Orcaella brevirostris*. The IUCN Red List of Threatened Species 2017. http://dx.doi.org/10.2305/IUCN.UK.2017-3.RLTS.T15419A50367860.en

Morita, K., Morita, S., & Yamamoto, S. (2009). Effects of habitat fragmentation by damming on salmonid fishes: Lessons from white-spotted charr in Japan. Ecological Research, 24, 711–722.

Ministry of Transportation (MOT) (2020). The cargo handling capacity of the mainstream of the Yangtze River exceeded 3 billion tons. https://cjhy.mot.gov.cn/hydt/slxw/202012/t20201230_200790.shtml.

Nabi, G., Ahmad, S., McLaughlin, R.W., Hao, Y., Khan, S., Ahmad, N., Ahmad, S., Kiani, M.S., Wu, Y., & Li, D. (2021a). Deteriorating habitats and conservation strategies to repopulate the endangered Indus River Dolphin (*Platanista gangetica minor*): A lesson learned from the conservation practices of the Yangtze Finless Porpoise (*Neophocaena asiaeorientalis*). Frontiers in Marine Science, 8, 561905.

Nabi, G., Hao, Y., McLaughlin, R.W., & Wang, D. (2018b). The possible effects of high vessel traffic on the physiological parameters of the critically endangered Yangtze finless porpoise (*Neophocaena asiaeorientalis ssp. asiaeorientalis*). Frontiers in Physiology, 9, 1665.

Nabi, G., Hao, Y., Zeng, X., & Wang, D. (2017b). Assessment of Yangtze finless porpoises (*Neophocaena asiaorientalis*) through biochemical and hematological parameters. Zoological Studies, 56, e31

Nabi, G., Hao, Y., Zeng, X., Jinsong, Z., McLaughlin, R.W., & Wang, D. (2017a). Hematologic and biochemical differences between two free-ranging Yangtze finless porpoise populations: The implications of habitat. PLoS One, 12, e0188570.

Nabi, G., Li, Y., McLaughlin, R.W., Mei, Z., Wang, K., Hao, Y., Zheng, J., & Wang, D. (2020a). Immune responses of the critically endangered Yangtze Finless Porpoises (*Neophocaena asiaeorientalis ssp. asiaeorientalis*) to escalating anthropogenic stressors in the wild and seminatural environments. Frontiers in Physiology, 10, 1594.

Nabi, G., McLaughlin, R.W., Hao, Y., Wang, K., Zeng, X., Khan, S., & Wang, D. (2018a). The possible effects of anthropogenic acoustic pollution on marine mammals' reproduction: An emerging threat to animal extinction. Environmental Science and Pollution Research, 25, 19338-45.

Nabi, G., McLaughlin, R.W., Khan, S., Hao, Y., & Chang, M.X. (2020b). Pneumonia in endangered aquatic mammals and the need for developing low-coverage vaccination for their management and conservation. Animal Health Research Reviews, 21, 122-130.

Nabi, G., Robeck, T.R., Hao, Y., & Wang, D. (2019). Hematologic and biochemical reference interval development and the effect of age, sex, season, and location on hematologic analyte concentrations in critically endangered Yangtze finless porpoise (*Neophocaena asiaeorientalis ssp. asiaeorientalis*). Frontiers in Physiology, 10, 792.

Nabi, G., Robeck, T.R., Yujiang, H., Tang, B., Zheng, J., Wang, K., & Wang, D. (2021b). Circulating concentrations of thyroid hormones and cortisol in wild and seminatural Yangtze finless porpoise (*Neophocaena asiaeorientalis*). Conservation Physiology, 9, coab034.

News China (2022). Ministry of Ecology and Environment: 84.9% of the country's water bodies have excellent water quality. http://news.china.com.cn/2022-01/24/content_78008677.htm

Nowacek, S.M., Wells, R.S., & Solow, A.R. (2001). Short-term effects of boat traffic on bottlenose dolphins, *Tursiops truncatus*, in Sarasota Bay, Florida. Marine Mammal Science, 17, 673-688.

People. (2019). Fish species in the Yangtze River are on brink of extinction as water quality declines. http://en.people.cn/n3/2018/1119/c90000-9519946.html

People. (2021). The fishing ban brings rare fish back to China's largest freshwater lake. http://en.people.cn/n3/2021/0414/c90000-9839003.html

Rosen, D.A. (2009). Steller sea lions *Eumetopias jubatus* and nutritional stress: Evidence from captive studies. Mammal Review, 39, 284-306.

Ruan, R., Guo, A.H., Hao, Y., Zheng, J.S., & Wang, D. (2015). *De novo* assembly and characterization of narrow-ridged finless porpoise renal transcriptome and identification of candidate genes involved in osmoregulation. International Journal of Molecular Sciences, 16, 2220-2238.

Ruan, R., Wan, X.L., Zheng, Y., Zheng, J.S., & Wang, D. (2016). Assembly and characterization of the MHC class I region of the Yangtze finless porpoise (*Neophocaena asiaeorientalis asiaeorientalis*). Immunogenetics, 68, 77-82.

Schelle, P. (2010). River dolphins and people: shared rivers, shared future. WWF International.

Shao, B., Hu, J., Yang, M., An, W., & Tao, S. (2005). Nonylphenol and nonylphenol ethoxylates in river water, drinking water, and fish tissues in the area of Chongqing, China. Archives of Environmental Contamination and Toxicology, 48, 467-473.

Smith, B.D., & Reeves, R.R. (2000). Report of the workshop on the effects of water development on river cetaceans, 26–28 February 1997, Rajendrapur, Bangladesh. In: Biology and conservation of freshwater cetaceans in Asia, Switzerland and Cambridge (Reeves, R.R., Smith, B.D., & Kasuya, T., eds). Gland: IUCN.

Stahl, T., Mattern, D., & Brunn, H. (2011). Toxicology of perfluorinated compounds. Environmental Sciences Europe, 23, 1-52.

Su, G., Gao, Z., Yu, Y., Ge, J.C., Wei, S., Feng, J.F., Liu, F.Y., Giesy, J.P., Lam, M.H., & Yu, H.X. (2010). Polybrominated diphenyl ethers and their methoxylated metabolites in anchovy (*Coilia* sp.) from the Yangtze River Delta, China. Environmental Science and Pollution Research International, 17, 634-642.

Taylor, B.L., Abel, G., Miller, P., Gomez, F., von Fersen, L., DeMaster, D., Reeves, R.R., Rojas-Bracho, L., Wang, D., Hao, Y. & Cipriano, F. (eds) (2020). Ex-situ options for cetacean conservation. Report of the 2018 workshop, Nuremberg, *Germany.* Occasional Paper of the IUCN Species Survival Commission No. 66. Gland, Switzerland: IUCN. https://doi.org/10.2305/IUCN.CH.2020.SSC-OP.66.en

The Paper News. (2021). Behind the moving the Yangtze finless porpoise into the aquariums: Discussion and controversy on the way of conservation. https://www.thepaper.cn/newsDetail_forward_12702512

Turvey, S.T., Pitman, R.L., Taylor, B.L., Barlow, J., Akamatsu, T., Barrett, L.A., Zhao, X., Reeves, R.R., Stewart, B.S., Wang, K., Wei, Z., Zhang, X., Pusser, L.T, Richlen, M., Brandon, J.R., & Wang, D. (2007). First human-caused extinction of a cetacean species? Biology Letters, 3, 537–540.

Ullah, S., Li, Z., Hassan, S., Ahmad, S., Guo, X., Wanghe, K., & Nabi, G. (2021a). Heavy metals bioaccumulation and subsequent multiple biomarkers based appraisal of toxicity in the critically endangered *Tor putitora*. Ecotoxicology and Environmental Safety, 228, 113032.

Ullah, S., Ahmad, S., Altaf, Y., Dawar, F.U., Anjum, S. I., Baig, M.M., Fahad, S., Al-Misned, F., Atique, U., Guo, X., Nabi, G., & Wanghe, K. (2021b). Bifenthrin induced toxicity in *Ctenopharyngodon idella* at an acute concentration: A multi-biomarkers based study. Journal of King Saud University-Science, 32, 101752.

Wang, D. (2009). Population status, threats and conservation of the Yangtze finless porpoise. Chinese Science Bulletin, 54, 3473–3484.

Wang, D. (2015). Progress achieved on natural ex situ conservation of the Yangtze finless porpoise. IUCN SSC – Cetacean Specialist Group, 2015. Available at: https://iucn-csg.org/progress-achieved-on-natural-ex-situ-conservation-of-the-yangtze-finless-porpoise/

Wang, D., Hao, Y., Wang, K., Zhao, Q., Chen, D., Wei, Z., & Zhang, X. (2005). Aquatic resource conservation: The first Yangtze finless porpoise successfully born in captivity. Environmental Science and Pollution Research International, 12, 247-250.

Wang, D., Liu, R., Zhang, X., Ian, Y., Wei, Z., Zhao, Q., & Wang, X. (2000). Status and conservation of the Yangtze finless porpoise. Biology and Conservation of Freshwater Cetaceans in Asia, 1, 81-85.

Wang, D., Turvey, S.T., Zhao, X., & Mei, Z. (2013). *Neophocaena asiaorientalis* ssp. *asiaorientalis.* The IUCN Red List of Threatened Species. Version 3.1 https://www.iucnredlist.org/species/43205774/45893487

Wang, D., Zhang, X., & Liu, R. (1998). Conservation status and the future of baiji and finless porpoise in the Yangtze River of China. Ecology and environment protection in the large water conservancy projects of the Yangtze River. Environmental Science Press, by Huang, Z., Beijing, China, 218-226.

Wang, K., Wang, D., Zhang, X., Pfluger, A., & Barrett, L. (2006). Range-wide Yangtze freshwater dolphin expedition: The last chance to see baiji? Conservation Biology, 13, 418-424.

Wei, Q., Wang, D., & Wang, L. (2007). Aquatic biodiversity conservation. In G.S. Yang, L.D. Weng, & L.F. Li (Eds), Yangtze conservation and development report (pp. 90-113). Wuhan, China: Changjiang Press.

Willett, K.L., Ulrich, E.M., & Hites, R.A. (1998). Differential toxicity and environmental fates of hexachlorocyclohexane isomers. Environmental Science and Technology, 32, 2197-2207.

Wong, C., Williams, C., Collier, U., Schelle, P., & Pittock, J. (2007). World's top 10 rivers at risk. World Wildlife Fund for Nature. http://www.unwater.org/downloads/worldstop10riversatriskfinalmarch13_1.pdf

Wright, A.J., Soto, N.A., Baldwin, A.L., Bateson, M., Beale, C.M., Clark, C., Deak, T., Edwards, E.F., Fernández, A., Godinho, A., Hatch, L.T., & Martin, V. (2007). Do marine mammals experience stress related to anthropogenic noise? International Journal of Comparative Psychology, 20, 274-316.

Xia, J., Li, Z., Zeng, S., Zou, L., She, D., Cheng, D. (2021). Perspectives on eco-water security and sustainable development in the Yangtze River Basin. Geoscience Letters, 8, 1-9.

Xian, Q., Ramu, K., Isobe, T., Sudaryanto, A., Liu, X., Gao, Z., Takahashi, S., Yu, H., & Tanabe, S. (2008). Levels and body distribution of Polybrominated Diphenyl Ethers (PBDEs) and Hexabromocyclododecanes (HBCDs) in freshwater fishes from the Yangtze River, China. Chemosphere, 71, 268-276.

Xian, Y.J., Wang, K.X., Dong, L.J., Hao, Y.J., & Wang, D. (2010). Some observations on the sociosexual behavior of a captive male Yangtze finless porpoise calf (*Neophocaena phocaenoides asiaeorientalis*). Marine and Freshwater Behaviour and Physiology, 43, 221–225.

Xiao, Y., Nabi, G., Hao, Y., & Wang, D. (2018). Hormonal regulation of testicular development in the finless Porpoise *Neophocaena asiaeorientalis sunameri*: Preliminary evidence from testicular histology and immunohistochemistry. Zoological Studies, 57, e41.

Xiong, X., Qian, Z.Y., Mei, Z.G., Wu, J.H., Hao, Y.J., Wang, K.X., Wu, C.X., Wang, D. (2019). Trace elements accumulation in the Yangtze finless porpoise (*Neophocaena asiaeorientalis asiaeorientalis*) – a threat to the endangered freshwater cetacean. Science of the Total Environment, 686, 797-804.

Yang, G., Ren, W., Zhou, K., Liu, S., Ji, G., Yan, J., & Wang, L. (2002). Population genetic structure of Finless porpoises, *Neophocaena phocaenoides*, in Chinese waters, inferred from mitochondrial control region sequences. Marine Mammal Science,18, 336-347.

Zeng, X., Chen, M., Zhigang, L., Daoping, Y., Shiang-Lin, H., Jiwei, Y., Fei, F., Ding, W., Yujiang, H., & Nabi, G. (2019). Characterization of milk protein composition of the Yangtze finless porpoise. Marine Mammal Science, 35, 252-260.

Zeng, X., Huang, S., Qian, Z., Hao, Y., Wang, D., Ji, J., & Nabi, G. (2017a). Characterization of milk composition in narrow-ridged finless porpoises (*Neophocaena asiaeorientalis*) at different lactation stages. Marine Mammal Science, 33, 803-816.

Zeng, X., Huang, S.L., Hao, Y., Wang, D., Ji, J., Deng, X., & Nabi, G. (2017b). Ultrasonography of mammary glands in finless porpoises (*Neophocaena asiaeorientalis*) at different reproductive stages. Marine Mammal Science, 34, 529-540.

Zhang, H., Jarić, I., Roberts, D.L., He, Y., & Wei, Q (2019). Extinction of one of the world's largest freshwater fishes: Lessons for conserving the endangered Yangtze fauna. Science of The Total Environment, 710, 136242.

Zhang, K., Qian, Z.Y., Ruan, Y.F., Hao, Y.J., Dong, W.W., Li, K., Mei, Z.G., Wang, K.X., Wu, C.X., Wu, J.H., Zheng, J.S., Lam, P.K.S., & Wang, D. (2020). First evaluation of legacy persistent organic pollutant contamination status of stranded Yangtze finless porpoises along the Yangtze River Basin, China. Science of the Total Environment, 710, 136446.

Zhang, X., Liu, R., Zhao, Q., Guocheng, Z.H., Zhuo, W.E., Xiaoqiang, W.A., & Jian, Y.A. (1993). The population of finless porpoise in the middle and lower reaches of Yangtze River. Acta Theriologica Sinica, 13, 260-270.

Zhang, X., Wang, D., Liu, R., Wei, Z., Hua, Y., Wang, Y., Chen, Z., & Wang, L. (2003). The Yangtze River dolphin or Baiji (*Lipotes vexillifer*): population status and conservation issues in the Yangtze River, China. Aquatic Conservation: Marine and Freshwater Ecosystem, 13, 51-64.

Zhao, X., Barlow, J., Taylor, B.L., Pitman, R.L., Wang, K., Wei, Z., Stewart, B.S., Turvey, S.T., Akamatsu, T., Reeves, R.R., & Wang, D. (2008). Abundance and conservation status of the Yangtze finless porpoise in the Yangtze River, China. Biological Conservation, 141, 3006-3018.

Zheng, J.S., Xia, J.H., He, S.P., & Wang, D. (2005). Population genetic structure of the Yangtze finless porpoise (*Neophocaena phocaenoides asiaeorientalis*): Implications for management and conservation. Biochemical Genetics, 43, 307-320.

Zhou, K., & Zhang, X. (1991). Baiji, the Yangtze River dolphin and other endangered animals of China. Yilin Press, Nanjing, China.

DER ZOOLOGISCHE GARTEN
THE ZOOLOGICAL GARDEN

doi:10.53188/zg0022

Zool. Garten N.F. 91 (2023) 175-189

# A stepwise approach for science-based conservation of Lahille's bottlenose dolphins (*Tursiops gephyreus*) with emphasis on the Patos Lagoon population

## Ein schrittweiser, wissenschaftlich fundierter Ansatz zum Schutz des Lahille Großen Tümmlers (*Tursiops gephyreus*) mit besonderem Fokus auf die Population in der Lagune Dos Patos (Brasilien)

Eduardo R. Secchi[1,2], Pedro F. Fruet[1,2,3], Rodrigo C. Genoves[1,2,3], & Lorenzo von Fersen[4]

[1]Laboratório de Ecologia e Conservação da Megafauna Marinha (ECOMEGA), Instituto de Oceanografia, Universidade Federal do Rio Grande - FURG, Avenida Itália km 8, Rio Grande, RS, Brazil.
[2]Museu Oceanográfico "Prof. Eliézer C. Rios", FURG, Brazil.
[3]Kaosa, Rio Grande, RS, Brazil.
[4]Nuremberg Zoo & YAQU PACHA, Am Tiergarten 30, D-90480 Nuernberg, Germany.

## Abstract

Here we describe nearly 20 years of research conducted in collaboration with several institutions from Brazil, Uruguay and Argentina that resulted in the formal status assessment of the Lahille's bottlenose dolphin (*Tursiops gephyreus*) and actions for its conservation, with emphasis on the systematic research and conservation process for the Patos Lagoon Estuary (PLE) population. This conservation process can be viewed as a puzzle, for which several pieces of key information were combined, and thus a proper assessment of the conservation status could be made. First, we identified intraspecific structure that can be treated as independent management units (hereafter referred as populations), then population-specific life history parameters, abundance and non-natural removal (in this case bycatch) rates were estimated for the PLE population. Then, these data fed Population Viability Analysis (PVA) models that were developed to

*Corresp. author:
E-Mail: edu.secchi@furg.br (Eduardo R. Secchi)

assess the status of the PLE population and the effects of several scenarios of removal rates. Entanglement in gillnets is possibly the greatest threat to the viability of this population. Although the PLE population seems stable throughout the study period, PVA models suggest that even a low removal rate of adult females may cause a marked population decline in three generations (ca. 60 years). Parameter uncertainty does not change the conclusion that no-fishing zones are needed to reduce the risk of PLE population decline. Scientific-based advice was considered and a no-fishing zone that covers the PLE core area was established. Full compliance of the regulation is expected to increase survival rates and long-term viability of the PLE. Nevertheless, Lahille's bottlenose dolphin is suspected to present a low abundance and some of its population units remain poorly known and not sufficiently protected. We identified main research gaps and provided future directions for the conservation of this species throughout its distribution range.

**Keywords:** Cetacean, Western South Atlantic, management

## Background

Bottlenose dolphins (*Tursiops* spp.) have a widespread distribution throughout the globe and occupy a variety of marine and estuarine habitats from tropical to temperate waters (Wells & Scott, 2009). The genus is globally abundant and is often found in small populations throughout its range, manly in coastal regions associated with rivers, estuaries, bays and fjords (e.g., Sarasota Bay, Florida (Wells et al., 1987); Moray Firth, Scotland (Wilson, 1995); Kvarneri, Croatia (Bearzi et al., 1997); Doubtful Sound, New Zealand (Haase & Schneider, 2001); Patos Lagoon estuary, RS, Brazil (Castello & Pinedo, 1977)), but also in oceanic waters associated with islands or other oceanographic features (e.g., Saint Peter and Saint Paul Archipelago, Brazil (Caon & Ott, 2004); Azores, Portugal (Quérouil et al., 2007); Bermuda, North America (Klatsky et al., 2007); continental shelf-break and slope (Di Tullio et al., 2016)).

While there is presently no evidence to suggest that bottlenose dolphins are threatened globally, many coastal regional populations are at risk of extinction due to human impacts that include bycatch, hunting, pollution, and prey depletion (Gowans et al., 2007; Reeves, 2003; Vermeulen et al., 2019). The viability of these populations depends, in part, on appropriate management based on robust scientific information of their life history, abundance and impact factors. In the western South Atlantic Ocean (wSAO), the genus *Tursiops* is also widely distributed, occurring from the Amazon River mouth, Brazil, to Tierra del Fuego, Argentina, and Malvinas/Falkland Islands (Bastida et al., 2018). However, the occurrence of coastal populations is restricted to a small geographical range between southern Brazil and central Argentina. These coastal populations are small and locally adapted to specific habitats such as estuaries, rivers and bays (Fig. 1; e.g., Baia Norte, SC (Flores & Fontoura, 2006); Imaruí, Mirim and Santo Antônio Lagoon complex, SC (Simões-Lopes & Fabian, 1999); Mampituba river mouth (Laporta et al., 2016); Tramandaí river mouth (Hoffmann, 2004); Patos Lagoon estuary (e.g., Castello & Pinedo, 1977); La Coronilla, Uruguay (Laporta & Dimitriadis, 2004); Bahía San Antonio, Rio Negro Province (Vermeulen & Cammareri, 2009); and Peninsula Valdes, Chubut Province, Argentina (Würsig & Würsig, 1979), though, this later population seems to have disapeared or moved from the Peninsula during the last few decades (e.g., Vermeulen et al., 2017)). These coastal dolphins represent a different lineage of the genus *Tursiops,* and a species level recognition was recently claimed (Lahille's bottlenose dolphin, *Tursiops gephyreus* – Wickert et al., 2016; Hohl et al., 2020), although Marine Mammalogy's Committee on Taxonomy argues that the lineages should be recognized at a subspecies level (Costa et al., 2016, 2019; Marine Mammalogy's Committee on Taxonomy, 2018). Their distribution overlaps with a series of human activities harmful to


**Fig. 1:** Lahille's bottlenose dolphin (*Tursiops gephyreus*) coastal distribution in the western South Atlantic Ocean, comprising the states of southern Brazil, Santa Catarina (SC) and Rio Grande do Sul (RS), Uruguay (UY) and Bahía San Antonio in Argentina (AR). The Patos Lagoon estuary (PLE) is highlighted in yellow, the site of the largest known resident population of the species.

dolphins and other cetaceans, making them highly vulnerable to human impacts. Due to their vulnerability, the low number of individuals representing the entire lineage and declining sightings in some localities, the Lahille's bottlenose dolphin was recently listed as Vulnerable under criterion D1of the IUCN (Vermeulen et al., 2019).

Until recently, little attention has been given to relevant conservation issues of Lahille's bottlenose dolphins in the Southwest Atlantic Ocean (wSAO), despite their great vulnerability to a series of human activities in coastal areas and the poor health status reported for some local populations due to intense skin diseases and high levels of PCBs and DDTs (e.g., Fruet et al., 2016; Righetti et al., 2019; Van Bressem et al., 2015). Bycatch in gillnets, however, is recognized as the main threat to these coastal dolphins and is known to occur throughout their range (Fruet et al., 2012; Fruet et al., 2021). Relatively high bycatch rates have been documented in the Patos Lagoon Estuary and adjacent marine coast (PLE) in southern Brazil, which is home to the largest population of Lahille's bottlenose dolphins. Although incidental captures of dolphins in gillnets seem to occur only sporadically and were not considered a cause for concern in the past (e.g., Pinedo, 1986), the increased number of observed individuals with evidence of interaction with fisheries (nets attached to the body and rostrum, mutilated appendages) and the significant increase in reported mortality on adjacent coastal beaches since the early 2000s have raised concerns about the viability of this population (Fruet et al., 2012, Prado et al., 2016). To reduce this negative interaction, a resolution was implemented in 2012 through the Ministry of Fisheries and Aquaculture and the Ministry of Environment to regulate gillnet fishing in southern Brazil and establish a fishing exclusion zone in the final portion of the PLE and adjacent shallow coastal waters (Fig. 2) based on a spatial overlap analysis study of the area preferred by dolphins and gillnet fishing (Di Tullio et al., 2015).

Despite increasing evidence that some of the populations could be at risk and that a management plan was necessary to mitigate the sources of impact, the development and implementation of such a plan were hampered by the lack of basic scientific information for a proper assessment of the population's conservation status. Furthermore, although some studies were being conducted with Lahille's bottlenose dolphins throughout the wSAO, they were conducted without institutional cooperation and common goals aimed at species conservation. Information was largely published in grey literature or was not published at all, making assessment of the current conservation status of the species difficult. In the late 2000s, following a successful approach used to increase knowledge on Franciscana dolphins (e.g., Secchi, 2002), South American researchers organized the First Workshop on the Research and Conservation of Tursiops truncatus: Integrating knowledge about species in the Southwest Atlantic Ocean (wSAO), held in Rio Grande, Rio Grande do Sul state (RS), Brazil, in May 2010. Relevant topics such as taxonomy, ecology, and threats were discussed, information was updated, and future action and research recommendations were provided. After this first workshop, the number of publications in peer-reviewed scientific journals and the knowledge on the species' taxonomy, ecology and conservation status increased significantly. A second workshop was held in 2017 to evaluate progress regarding the recommendations made during the first workshop and to further discuss the taxonomy of bottlenose dolphins in the wSAO. Results and recommendations were presented to the Scientific Committee of the International Whaling Commission in 2018 and a series of research and policy recommendations were set and reiterated by the Committee to National Delegates in subsequent years (IWC, 2019, 2021, 2022). An assessment was conducted by the International Union for Conservation of Nature (IUCN) for the first time for Lahille's bottlenose dolphins in 2019, listing it as VULNERABLE under criterion D1 (Vermeulen et al., 2019). A Task Team was formed in 2020 under the auspices of IWC to deal with Lahille's bottlenose dolphin research and conservation in the wSAO (IWC, 2021).

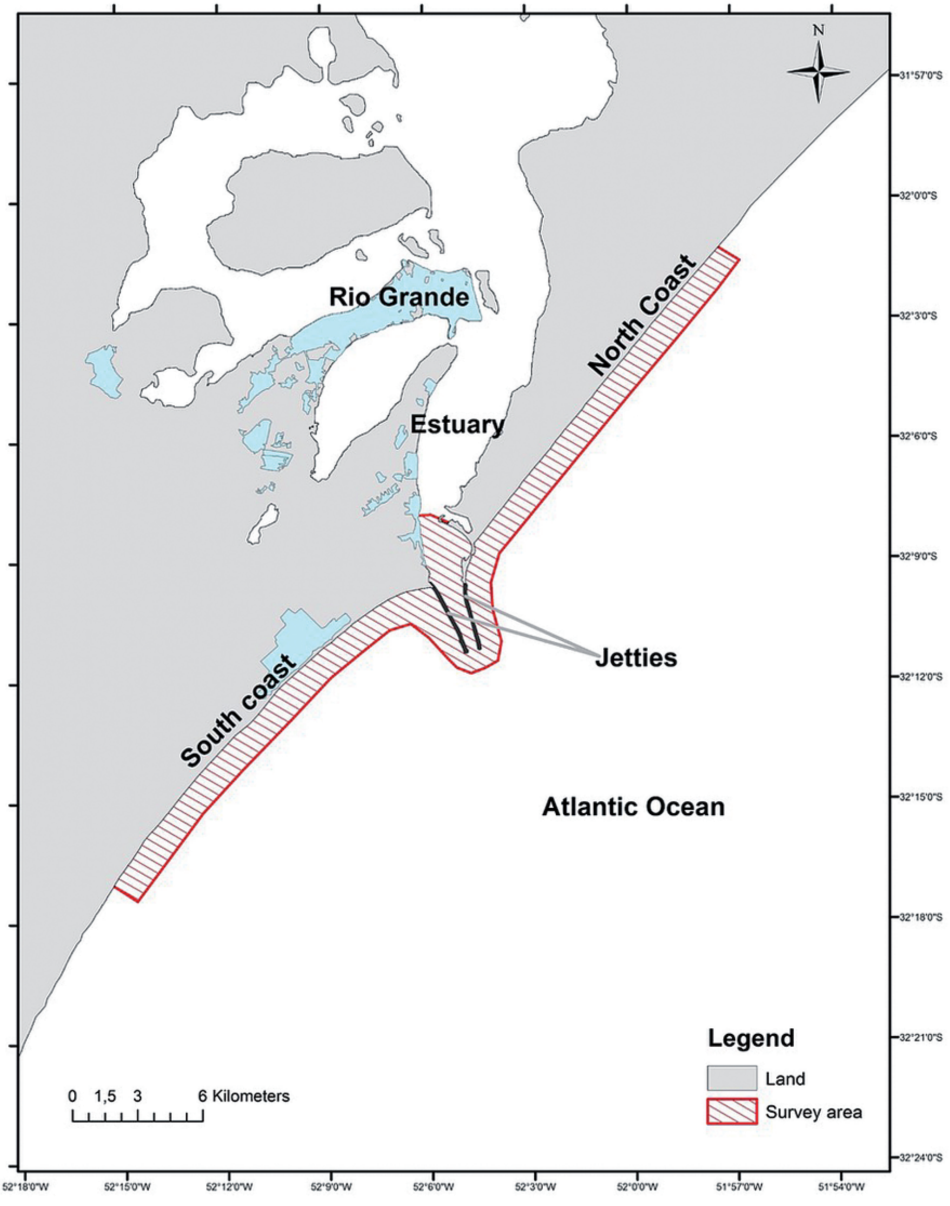


**Fig. 3:** The fishing exclusion area (red crosshatched) was established in 2012 in the final portion of the Patos Lagoon estuary and its adjacent shallow coastal waters, in Southern Brazil.

In this publication, we present an overview of nearly 20 years of research conducted in collaboration with multiple institutions from Brazil, Uruguay and Argentina. Our research follows a stepwise approach to conduct a formal status assessment of Lahille's bottlenose dolphins (*Tursiops gephyreus*) and provides recommendations for conservation actions. Special emphasis is placed on the systematic research and conservation process for the Patos Lagoon Estuary population (PLE).

**Fig. 3:** Lahille's bottlenose dolphins, *Tursiops gephyreus*, socializing, feeding and travelling in the Patos Lagoon estuary and its adjacent coastal waters, in Southern Brazil. Photos: Projeto Botos da Lagoa dos Patos

## Stepwise approach

The conservation process described in this study can be likened to a puzzle, where various pieces of essential information need to be assembled to conduct a thorough assessment of the population's conservation status. The first step involved identifying distinct intraspecific structures, which were considered independent management units, or populations. Subsequently, population-specific life history traits, including age at first reproduction, fecundity, survival rates and other demographic parameters such as abundance and non-natural removal (specifically, bycatch) rates were estimated for the Patos Lagoon Estuary (PLE) population. These data were then utilized as input parameters in Population Viability Analysis (PVA) models, which were developed to evaluate the status of the PLE population and assess the potential impacts of different removal rate scenarios. The approaches employed to accomplish each of these steps are described further below.

### Identification of intraspecific units to conserve

Variations in gene flow can result in the formation of distinct intraspecific units. In the context of conservation, two main types of units are recognized: Evolutionarily Significant Units (ESUs) and Management Units (MUs) (Moritz, 1994). ESUs are concerned with historical population structure, mitochondrial DNA phylogeny and long-term conservation needs. MUs, on the other hand, address current population structure, allele frequencies and short-term management goals. In the Southwest Atlantic Ocean (wSAO), the taxonomy of *Tursiops* dolphins has been a subject of ongoing debate and revision over the past few decades (Costa et al., 2016; Wickert et al., 2016). There is evidence of ecological divergence between an offshore (*T. truncatus*) and a coastal ecotype of common bottlenose dolphins (Committee on Taxonomy, 2019; Costa et al., 2019). Some argue that these two ecotypes exhibit morphological and genetic characteristics indicative of species-level differences (Hohl et al., 2020; Wickert et al., 2016). Offshore dolphins predominantly inhabit waters beyond the continental shelf break (> 150 m depth), while coastal dolphins are restricted to shallow coastal regions from southeastern Brazil (27°S) to central Argentina (43°S), generally staying within 3 km of the coast in waters less than 20 m deep (Simões-Lopes & Fabian, 1999; Di Tullio et al., 2015; Laporta et al., 2016).

Significant genetic differences have been observed between these ecotypes, with lower diversity observed in coastal dolphins compared to offshore dolphins (Castilho et al., 2015; Costa et al., 2015, 2019; Fruet et al., 2014, 2017; Oliveira et al., 2019). Within each ecotype, genetic differences can also arise due to variations in habitat use and social organization, leading to some degree of reproductive segregation (Fruet et al., 2014; Genoves et al., 2020). Fruet et al. (2014) conducted a study combining analyses of microsatellite loci and mitochondrial DNA control region sequences to investigate the genetic diversity, structure and connectivity of Lahille's bottlenose dolphins in southern Brazil, Uruguay and central Argentina. They found strong and significant genetic differentiation between individuals sampled in southern Brazil – Uruguay and those in Argentinian Patagonia, with limited contemporary gene flow. On a finer scale, moderate differentiation and asymmetric gene flow were detected between five neighboring putative populations in southern Brazil and Uruguay (Fruet et al., 2014). The authors proposed that bottlenose dolphins from Argentina and southern Brazil–Uruguay represent two ESUs, while the latter encompasses five MUs: *i.* Florianópolis (FLN), *ii.* Laguna (LGN), *iii.* Northern Patos Lagoon (NPL), *iv.* Patos Lagoon Estuary (PLE) and *v.* Southern Patos Lagoon/Uruguay (SPL/URU). Further genetic analyses and social network studies of photo-identified individuals inhabiting the PLE and adjacent marine coast confirmed this finer scale structuring, revealing the existence of three distinct social units: estuarine residents, southern coastal residents and northern coastal residents, which displayed low but significant genetic differentiation (Genoves et al., 2018, 2020). Although the objective of this study is to describe the conservation process for Lahille's bottlenose dolphins, particular emphasis will be placed on the PLE social unit (referred to as populations), as it is one of the most extensively studied populations of this species.

## Population-specific parameter estimation

Once intraspecific structuring and the presence of independent management units (populations) are identified, the next step is to estimate population-specific abundance, life history parameters and non-natural removal rates (such as bycatch) to assess the conservation status of the population.

**Abundance:** Studies using mark-recapture methods and photo-identification of individually recognized dolphins in the PLE and its adjacent coastal waters have indicated a relatively large number of Lahille's bottlenose dolphins, with 203 individuals catalogued between 2005 and 2015 (Fruet et al., 2011; Fruet et al., 2015a). However, the PLE population itself is small, with slightly more than 85 individuals. While the population has remained relatively stable, some individuals from this population and the adjacent coastal populations have experienced unnatural mortality due to entanglement in fishing nets over the years (Fruet et al., 2012; Prado et al., 2016; Fruet et al., 2019).

**Survival rates:** Survival rates for different life stages of the PLE population were obtained through mark-recapture models applied to eight years of photo-identification data from 2005 to 2012 (Fruet et al., 2015a). Using Pollock's robust design model (Pollock, 1982), the authors estimated that the annual apparent survival for adult females was 0.97 (95% CI: 0.91–0.99), which was higher than for adult males (0.88, 95% CI: 0.75–0.94) and juveniles (0.83, 95% CI: 0.64–0.93). This difference in survival rates likely contributes to the observed bias in the sex ratio of known adult dolphins, with approximately one male for every two females. The lower survival rates of adult males and juveniles compared to adult females suggest that these age-sex classes are more vulnerable to human-induced mortality, particularly in fisheries. This pattern mirrors the higher mortality rates of juvenile males in the area compared to females.

**Reproduction and reproductive rates:** Reproduction in the Lahille's bottlenose dolphin population is highly seasonal, occurring in spring and summer. Females in the PLE population first reproduce between the ages of 7 and 10, giving birth to calves that are approximately 1 m long at intervals averaging 3.3 yrs (mode = 2 yrs) (Fruet et al., 2015b). The number of female calves born per known mature female was used to estimate a fecundity rate of 0.09. However, since the data on calf presence with their mothers are derived from photo-identified individuals, there is a possibility of undetected births before calf mortality, leading to a downward bias in the estimation. As an alternative approach, fecundity was derived as the reciprocal of the average calving interval (1/3.3 = 0.30). Assuming an even sex ratio at birth, this value is further divided by 2, resulting in a fecundity estimate of 0.15. Limited data from three females with known ages tracked until death suggest evidence of reproductive senescence in this population. These females, aged 40, 44 and at least 40, apparently ceased reproduction 6-8 years before their deaths (Fruet et al., 2015b). They were often observed with other mother-calf pairs, indicating a potential shift in their role from "breeding" to "nursing" individuals at older ages (Wells, 2000), which might be a strategy to increase calf survival and offset the effects of senescence, thus contributing to the long-term viability of the species.

### Assessment of conservation status

While recognizing that multiple stressors, such as pollutants and pathogens, can impact Lahille's bottlenose dolphins, the specific population parameters estimated for the PLE were used to conduct a Population Viability Analysis (PVA) to predict population trajectories under the effects of bycatch removal, considering stochasticity and uncertainty in parameter estimates. Among the various stressors, entanglement in gillnets appears to be the greatest threat to the viability of the PLE population. However, the PVA model results suggest that current bycatch rates have a low effect on the population's viability. The model predicts that in the absence of bycatch, the PLE population would grow at a rate of approximately 3% per year over the next three generations (around 60 years) (Fruet et al., 2021). This optimistic projection is mainly due to the high survival of adult females, as juvenile males are the most affected by bycatch. Nevertheless, the PVA models indicate that even the removal of very few mature females (one every year or two) would significantly increase the likelihood of population decline from its current abundance within three generations. To improve the population's viability, it is crucial to focus on increasing the survival of juveniles and sub-adults, as they are the age group most affected by incidental kills in artisanal gillnet fisheries. It is important to note that while the PVA models provide insights into the potential impacts of bycatch on the population, the interaction and synergistic effects of other stressors, such as pollutants and pathogens, have received limited attention and require further investigation to fully understand their effects on Lahille's bottlenose dolphin populations.

## Conservation strategies and other future direction

To effectively conserve Lahille's bottlenose dolphins in the PLE, a comprehensive conservation plan is needed. This plan should address and monitor various factors including chemical, physical and acoustic pollution, maritime traffic, fishing activities, as well as the dolphins' ecology and dynamics. The influence of environmental, spatial and temporal variables on dolphin distribution and artisanal fishing patterns should be considered.

Research has shown that dolphin distribution in the PLE is likely influenced by the presence of preferred prey or the avoidance of human-related disturbances (Di Tullio et al., 2015). These patterns often coincide with fishing areas. Seasonal variation in fishing effort and distribution influences the risk of dolphin entanglement, which increases during the warm months (November–April). Based on these findings, a fishing exclusion zone was proposed in the lower estuary and along the adjacent marine coast to mitigate entanglement risks. Implementation of such a no-fishing zone, which covers the core area of the PLE, has been established by the Brazilian Environmental Agency, and full compliance is expected to increase survival rates and the long-term viability of the population. Setting conservation goals is crucial for the recovery of the PLE population. If the fishing exclusion zone effectively reduces entanglement rates, there is a substantial chance for the population to increase above 20% of its current size, which has been proposed as a conservation goal. Achieving this goal has the potential to improve habitat quality, increase genetic diversity, enhance connectivity with adjacent populations and improve the population's resilience to environmental changes and potential disease outbreaks.

While progress has been made in regulating gillnet fishing in the PLE, other fishing gear, such as beach seining and beach stake netting, have been used without proper regulation. Incidents of Lahille's bottlenose dolphin mortality and entanglement have been reported in these unregulated fishing activities (Fruet et al., 2019). Enforcement of the fishing exclusion zone and a ban on unregulated fishing gear are necessary to prevent further harm to the population (e.g., Fruet et al., 2021). Additionally, in 2022, a significant strategy for the conservation of Lahille's bottlenose dolphins in the PLE involved declaring them as Natural Heritage by Rio Grande City. This symbolic gesture plays an important role in raising awareness among the local community and fostering a sense of ownership and responsibility. It serves as a foundation for the development of public policies and effective inspection measures.

Overall, a comprehensive conservation plan should incorporate strict enforcement of fishing regulations, monitoring of various threats, public awareness campaigns and the involvement of local communities to ensure the long-term viability and conservation of Lahille's bottlenose dolphins in the PLE.

## Integrated conservation approach for the Lahille's Bottlenose dolphin

Given their poor conservation status and the fact that existing threats cannot be immediately addressed, the Lahille's bottlenose dolphin has been selected by the IUCN Species Survival Commission as a priority species for its new Integrated Conservation Planning for Cetaceans initiative. This initiative is actively promoted by IUCN, which recently adopted Motion 079 which "1. URGES the Secretariat and professional societies to promote integration of *in situ* and *ex situ* conservation interventions by applying the One Plan approach, to ensure effective use of all available conservation tools." And "3. ALSO CALLS ON all Members to ensure that 11$^{th}$ hour, last ditch *ex situ* conservation efforts are prevented by proactive and timely application of planning methods, such as the One Plan Approach, and informed by the Guidelines on the Use of *Ex situ* Management for Species Conservation."

The One Plan approach (OPA) to species conservation is the elaboration of management and conservation strategies by all responsible parties and all available resources for all populations of a species, whether inside (*in situ*) or outside (*ex situ*) their natural range. OPA can be seen as a proper response to the conservation challenges of our current times. The experience has shown that it is no longer sufficient to combat the primary threats to save species from extinction. Often species/populations will go extinct before these threats have been eliminated. Therefore, it is inevitable to consider other tools when it comes to species conservation and OPA is certainly the most effective and has been applied successfully in the conservation of many species. It is important to note that

OPA ensures that all *in situ* protection measures are implemented. It also ensures and evaluates the potential benefits, costs, risks and implementation feasibility of all available *ex situ* measures to see how they contribute to the conservation of the species/population (Traylor-Holzer et al., 2018).

In the case of *Tursiops gephyreus*, several basic requirements for protecting this species within the framework of integrated conservation are met. The first and most important component is *in situ* conservation research. There is a considerable number of studies and publications on the species throughout its distribution range, some of which are reviewed in this article, demonstrating that science-based data are available to provide an accurate understanding of the species' threat status (e.g., Fruet et al., 2021). On the other hand, there are various *ex situ* measures that could be considered. Bottlenose dolphins are particularly suitable for integrated species conservation due to the extensive experience gained from managing this species intensively (von Fersen & Miller, in this issue). Captive breeding plays a significant role in this regard. The EAZA Ex-Situ Program (EEP) for the Bottlenose Dolphin (*Tursiops truncatus*), as one example of a coordinated breeding program, has demonstrated successful reproduction of this species in zoo habitats. As of 2021, the EEP comprises 228 individuals housed in 23 different institutions, with approximately 98% of the pedigree known and third-generation animals already born. With a genetic variability of 98.9%, the population is in good health, and it can be assumed that it has achieved self-sustainability. Comparable breeding successes have also been observed with *T. gephyreus*, although these are limited to one institution, the *ex-situ* population at Mundo Marino Zoo in Argentina. A recent publication (Loureiro, 2021) shows that out of 12 calves born in the park, 11 have survived into adulthood, and many are still alive today. This survival rate exceeds that of the wild population. Furthermore, this small population has provided valuable data on the reproductive biology of the species and has laid the foundation for artificial insemination. The breeding success in intensively managed populations of both species underscores the important role of *ex situ* populations as insurance populations and highlights their contribution to research. Much of our knowledge about the sensory, behavioral and veterinary aspects of this species comes from research conducted with animals in human care. The findings from these studies can greatly benefit animals in the wild. Zoos and aquariums that house these animals and run educational programs to raise awareness about species conservation also fulfill an important *ex situ* role. Additionally, these programs in zoos provide excellent opportunities to raise funds for *in situ* species conservation.

Other relevant initiatives may include gene/cell preservation to conserve genetic variation for potential *in vitro* reproduction, followed by reintroduction into the wild in areas with very low abundance or depleted genetic variability. In such cases, it is recommended to obtain ultra-high-quality DNA and RNA for DNA sequencing, genome mapping, assembly and gene annotation.

Estimating range-wide abundance and reproductive rates are among the highest *in situ* research priorities for this subspecies. Assessing the synergistic effects of multiple stressors on vital rate parameters and population viability is strongly recommended. To achieve these goals, the following objectives should be prioritized, especially for populations in proximity to extensive human activities or showing indications of significant inbreeding (e.g., PLE and Laguna populations, respectively):

Identifying the profile of stress-related and reproductive hormones in the dolphins' blubber.

Investigating levels of DNA damage, immune imparity and endocrine disruption through biomarker analysis.

Characterizing the variability of bacterial and fungal composition in the environment, which can aid in assessing the health of bottlenose dolphins.

Identifying and isolating potential bacterial and fungal pathogens specific to Lahille's bottlenose dolphins from water samples and dolphins' skin lesions and determining their antimicrobial susceptibility profile.

Considering a detailed health assessment in specific populations, the capture of a few individuals from the wild should also be considered. The population inhabiting the northern coastal areas of the Buenos Aires Province, Argentina, is suspected to be shrinking and disappearing from some sites (Vermeulen et al., 2017). Therefore, systematic aerial or boat-based surveys are strongly recommended to be conducted in this area throughout all seasons.

## Conclusion

The conservation of Lahille's bottlenose dolphin is of paramount importance due to its low abundance and the presence of human-related threats. The article emphasizes the need to address research gaps and outlines future directions for conservation efforts throughout the species' distribution range. With only approximately 600 individuals remaining, the species is highly vulnerable, and habitat degradation poses a significant risk to its survival. To mitigate these threats and ensure the species' persistence, it is crucial to employ comprehensive conservation strategies. The One Plan Approach framework is highlighted as a promising concept for the conservation of Lahille's bottlenose dolphin. The One Plan Approach emphasizes the integration of *in situ* conservation measures (protecting the species within its natural habitat) and *ex situ* measures (conservation actions outside the natural habitat, such as captive breeding programs or reintroduction efforts). By combining these approaches, the conservation of Lahille's bottlenose dolphin can be strengthened and enhanced. Two articles in this Special Issue authored by von Fersen and Miller, and Taylor et al., discuss the One Plan Approach in more detail. These articles likely provide insights into the practical implementation and effectiveness of this approach for the conservation of Lahille's bottlenose dolphin.

In summary, given the critical status of Lahille's bottlenose dolphin, a comprehensive approach that integrates *in situ* and *ex situ* conservation measures, such as the One Plan Approach, is essential for its survival. Ongoing research and collaborative efforts are crucial to fill knowledge gaps, address human-related threats and ensure the long-term persistence of this species throughout its distribution range.

## Acknowledgement

We are deeply indebted to the Organization for the Conservation of Latin American Aquatic Mammals – YAQU PACHA (Germany) for the long-standing funding since 2005 that has permitted us to carry on systematic surveys to collect relevant ecological parameters to assess the conservation status of the Patos Lagoon population of Lahille's bottlenose dolphins. This study was partially funded by the Brazilian Long-Term Ecological Research Program (PELD) from CNPq (Proc. Proc. 442206/2020-8), and the Fundação de Amparo à Pesquisa do Estado do Rio Grande do Sul (Proc. 21/2551-0000774-5). The Coordination for the Improvement of Higher Education Personnel (CAPES) provided access to the Portal de Periódicos and financial support through Programa de Excelência Acadêmica – PROEX. CNPq also provided a fellowship to ES PQ 310597/2018-8). We also thank Lauro Barcellos, director of the Oceanographic Museum at the Federal University of Rio Grande-FURG, for the continued logistical support for the Bottlenose Dolphin Project. Colleagues, students and staff from the Marine Megafauna Ecology and Conservation Lab (Ecomega) at FURG helped in many phases of the field and lab work.

## Zusammenfassung

In diesem Artikel wird fast 20 Jahre Forschung beschrieben, die in Zusammenarbeit mit mehreren Institutionen aus Brasilien, Uruguay und Argentinien durchgeführt wurde. Die Ergebnisse führen zu einer detaillierten Bewertung des Status des Lahille Großen Tümmlers (*Tursiops gephyreus*) und zu Maßnahmen zu seiner Erhaltung, wobei der Schwerpunkt auf dem systematischen Forschungs- und Erhaltungsprozess für die Population in der Lagune dos Patos (PLE) liegt. Dieser Artenschutzprozess kann als ein Puzzle betrachtet werden, für das mehrere wichtige Informationen zusammengefügt wurden, um eine angemessene Bewertung des Erhaltungszustands vornehmen zu können. Zunächst wurden intraspezifische Strukturen ermittelt, die als unabhängige Management-Areale betrachtet werden können (im Folgenden als Populationen bezeichnet). Für die PLE wurden dann populationsspezifische Parameter zur Lebensgeschichte, zur Abundanz und zu nicht natürlichen Entnahmeraten (in diesem Fall Beifang) geschätzt. Diese Daten wurden dann in Modelle zur Analyse der Lebensfähigkeit der Populationen (PVA) eingespeist, die entwickelt wurden, um den Status der PLE und die Auswirkungen verschiedener Szenarien für Entnahmeraten zu bewerten. Das Verfangen in Kiemennetzen scheint die größte Bedrohung für dieser Population zu sein. Obwohl die PLE während des gesamten Untersuchungszeitraums stabil zu sein scheint, deuten die PVA-Modelle darauf hin, dass selbst eine geringe Entnahmerate erwachsener Weibchen innerhalb von drei Generationen (etwa 60 Jahren) zu einem erheblichen Rückgang der Population führen kann. Die Unsicherheit der Parameter ändert nichts an der Schlussfolgerung, dass Fischereiverbotszonen erforderlich sind, um das Risiko eines Rückgangs der PLE zu verringern. Wissenschaftliche Gutachten wurden berücksichtigt und es wurde eine Fischereiverbotszone eingerichtet, die das PLE-Kerngebiet abdeckt. Es wird erwartet, dass die vollständige Einhaltung der Verordnung die Überlebensraten und die langfristige Lebensfähigkeit der PLE erhöhen wird. Dennoch wird davon ausgegangen, dass der Lahille Große Tümmler nur in geringem Populationszahlen vorkommt, und einige seiner Populationseinheiten sind nach wie vor kaum bekannt und nicht ausreichend geschützt. Wir haben wichtige Forschungslücken identifiziert und zukünftige Richtungen für die Erhaltung dieser Delfinart in ihrem gesamten Verbreitungsgebiet aufgezeigt.

## References

Bastida, R., Rodríguez, D., Secchi, E.R., & Silva, V.M.F. (2018). Mamiferos Aquaticos da America do Sul e Antartica. Vasquez Mazzini.

Bearzi, G., Notarbartolo-di-Sciara, G., & Politi, E. (1997). Social ecology of bottlenose dolphins in the Kvarneric (Northern Adriatic Sea). Marine Mammal Science, 13(4), 650-668. http://onlinelibrary.wiley.com/doi/10.1111/j.1748-7692.1997.tb00089.x/abstract

Caon, G., & Ott, P. (2004). Populações oceânicas do golfinho-nariz-de-garrafa (*Tursiops truncatus*): foto-identificação e fidelidade no Arquipélago de São Pedro e São Paulo, nordeste do Brasil. 11º Reunión de Trabajo de Especialistas En Mamíferos Acuáticos de América Del Sur y 5º Congreso de La Sociedad Latinoamericana de Especialistas Em Mamíferos Acuáticos, 48.

Castello, H., & Pinedo, M. (1977). Botos da Lagoa dos Patos. Nat Rev Publ Fund Zoobot (Porto Alegre), 2, 46-49.

Castilho, C.S., Pedone-Valdez, F., Bertuol, F., Fruet, P.F., Genoves, R.C., Di Tullio, J.C., Caon, G., Hoffmann, L.S., & Freitas, T.R.O. (2015). Insights about the genetic diversity and population structure of an offshore group of common bottlenose dolphins (*Tursiops truncatus*) in the Mid-Atlantic. Genetics and Molecular Research, 14(2), 3387-3399. https://doi.org/10.4238/2015.April.15.2

Committee on Taxonomy. (2018). List of marine mammal species and subspecies. Society for Marine Mammalogy. Retrieved from https://marinemammalscience.org/, consulted on 29/05/23.

Committee on Taxonomy. (2019). List of marine mammal species and subspecies. Society for Marine Mammalogy. https://marinemammalscience.org/about-us/committees/taxonomy-committee-terms-of-reference/

Costa, A.P.B., Fruet, P., Daura-Jorge, F., Simões-Lopes, P., Ott, P., Valiati, V.H., & Oliveira, L. (2015). Bottlenose dolphin communities from the southern Brazilian coast: do they exchange genes or are they just neighbours? Marine and Freshwater Research, A-J.

Costa, A.P.B., Fruet, P.F., Secchi, E.R., Daura-Jorge, F.G., Simões-Lopes, P.C., Di Tullio, J.C., & Rosel, P.E. (2019). Ecological divergence and speciation in common bottlenose dolphins in the western South Atlantic. Journal of Evolutionary Biology, 34(1), 16-32. https://doi.org/10.1111/jeb.13575

Costa, A.P.B., Rosel, P.E., Daura-Jorge, F.G., & Simões-Lopes, P.C. (2016). Offshore and coastal common bottlenose dolphins of the western South Atlantic face-to-face: What the skull and the spine can tell us. Marine Mammal Science, 32(4), 1433-1457. https://doi.org/10.1111/mms.12342

Di Tullio, J.C., Fruet, P.F., & Secchi, E.R. (2015). Identifying critical areas to reduce bycatch of coastal common bottlenose dolphins *Tursiops truncatus* in artisanal fisheries of the subtropical western South Atlantic. Endangered Species Research, 29(1), 35-50. https://doi.org/10.3354/esr00698

Di Tullio, J.C., Gandra, T.B.R., Zerbini, A.N., & Secchi, E.R. (2016). Diversity and distribution patterns of cetaceans in the subtropical Southwestern Atlantic outer continental shelf and slope. PLoS ONE, 11(5), 1-24. https://doi.org/10.1371/journal.pone.0155841

Flores, P.C., & Fontoura, N.F. (2006). Ecology of marine tucuxi, *Sotalia guianensis*, and bottlenose dolphin, *Tursiops truncatus*, in Baía Norte, Santa Catarina state, southern Brazil. The Latin American Journal of Aquatic Mammals, 5(2), 105-115.

Fruet, P.F., Daura-Jorge, F.G., Möller, L.M., Genoves, R.C., & Secchi, E.R. (2015a). Abundance and demography of bottlenose dolphins inhabiting a subtropical estuary in the Southwestern Atlantic Ocean. Journal of Mammalogy, 96(2), 332-343. https://doi.org/10.1093/jmammal/gyv035

Fruet, P.F., Genoves, R.C., Möller, L.M., Botta, S., & Secchi, E.R. (2015b). Using mark-recapture and stranding data to estimate reproductive traits in female bottlenose dolphins (*Tursiops truncatus*) of the Southwestern Atlantic Ocean. Marine Biology, 162(3), 661-673. https://doi.org/10.1007/s00227-015-2613-0

Fruet, P.F., Kinas, P.G., Da Silva, K., Di Tullio, J.C., Monteiro, D.S., Dalla Rosa, L., Estima, S.C., & Secchi, E.R. (2010). Temporal trends in mortality and effects of by-catch on common bottlenose dolphins, *Tursiops truncatus*, in southern Brazil. Journal of the Marine Biological Association of the United Kingdom, 98(8), 1-12. https://doi.org/10.1017/S0025315410001888

Fruet, P.F., Möller, L.M., & Secchi, E.R. (2021). Dynamics and Viability of a Small, Estuarine-Resident Population of Lahille's Bottlenose Dolphins From Southern Brazil. Frontiers in Marine Science, 7(January), 1-13. https://doi.org/10.3389/fmars.2020.593474

Fruet, P.F., Prado, J., Genoves, R.C., Di Tullio, J.C., & Secchi, E.R. (2019). Preliminary evidences suggest that the establishment of a bottlenose dolphin protection area in southern Brazil is failing against the reduction of bycatch. Paper presented during the Annual Scientific Committee Meeting of the International Whaling Commission. May 2019, Bled, Slovenia.

Fruet, P.F., Secchi, E.R., Daura-Jorge, F., Vermeulen, E., Flores, P.A.C., Simões-Lopes, P.C., Genoves, R.C., Laporta, P., Di Tullio, J.C., Freitas, T.R.O., Dalla Rosa, L., Valiati, V.H., Beheregaray, L.B., Möller, L.M., & Dalla Rosa, L. (2014). Remarkably low genetic diversity and strong population structure in common bottlenose dolphins (*Tursiops truncatus*) from coastal waters of the Southwestern Atlantic Ocean. Conservation Genetics, 15(4), 879–895. https://doi.org/10.1007/s10592-014-0586-z

Fruet, P.F., Secchi, E.R., Di Tullio, J.C., & Kinas, P.G. (2011). Abundance of bottlenose dolphins, *Tursiops truncatus* (Cetacea: Delphinidae), inhabiting the Patos Lagoon estuary, southern Brazil: implications for conservation. Zoologia (Curitiba, Impresso), 28(1), 23-30. https://doi.org/10.1590/S1984-46702011000100004

Fruet, P.F., Secchi, E.R., Di Tullio, J.C., Simões-Lopes, P.C., Daura-Jorge, F., Costa, A.P., Vermeulen, E., Flores, P.A.C., Genoves, R.C., Laporta, P., Beheregaray, L.B., & Möller, L.M. (2017). Genetic divergence between two phenotypically distinct bottlenose dolphin ecotypes suggests separate evolutionary trajectories. Ecology and Evolution, July, 1-13. https://doi.org/10.1002/ece3.3335

Fruet, P.F., Zappes, C.A., Bisi, T.L., Simões-Lopes, P.C., Laporta, P., Loureiro, J.D., & Flores, P.A.C. (2016). Report of the Working Group on Interactions between Humans and Tursiops truncatus in the Southwest Atlantic Ocean. Latin American Journal of Aquatic Mammals 11(1-2): 79-98. http://dx.doi.org/10.5597/lajam00218

Genoves, R.C., Fruet, P.F., Botta, S., Beheregaray, L.B., Möller, L.M., & Secchi, E.R. (2020). Fine-scale genetic structure in Lahille's bottlenose dolphins (Tursiops truncatus gephyreus) is associated with social structure and feeding ecology. Marine Biology, 167(3/34). https://doi.org/10.1007/s00227-019-3638-6

Genoves, R.C., Fruet, P.F., Di Tullio, J.C., Möller, L.M., & Secchi, E.R. (2018). Spatiotemporal use predicts social partitioning of bottlenose dolphins with strong home range overlap. Ecology and Evolution, 8(24), ece3.4681. https://doi.org/10.1002/ece3.4681

Gowans, S., Würsig, B., & Karczmarski, L. (2007). The social structure and strategies of delphinids: predictions based on an ecological framework. Advances in Marine Biology, 53(07), 195-294. https://doi.org/10.1016/S0065-2881(07)53003-8

Haase, P. A., & Schneider, K. (2001). Birth demographics of bottlenose dolphins, *Tursiops truncatus*, in Doubtful Sound, Fiordland, New Zealand – Preliminary findings. New Zealand Journal of Marine and Freshwater Research, 35(4), 675-680. https://doi.org/10.1080/00288330.2001.9517034

Hoffmann, L.S. (2004). Um estudo de longa duração de um grupo costeiro de golfinhos *Tursiops truncatus* (Montagu, 1821) (Cetacea, Delphinidae) no sul do Brasil: Aspectos de sua biologia e bioacústica. Ph.D. Thesis. Universidade Federal do Rio Grande do Sul.

Hohl, L.S.L., Sicuro, F.L., Wickert, J.C., Moreno, I.B., Rocha-Barbosa, O., & Barreto, A.S. (2020). Skull morphology of bottlenose dolphins from different ocean populations with emphasis on South America. Journal of Morphology, 281(6), 564-577. https://doi.org/10.1002/jmor.21121

IWC (International Whaling Commission). 2019. Page 49 on the Report of the Scientific Committee. Journal of Cetacean Research and Management 20, 1-78.

IWC (International Whaling Commission). 2021. Page 88 on the Report of the Scientific Committee. Journal of Cetacean Research and Management (Suppl.) 22, 1-65.

IWC (International Whaling Commission). 2022. Page 123 on the Report of the Scientific Committee. Journal of Cetacean Research and Management (Suppl.) 23, 1-171.

Klatsky, L.J., Wells, R.S., & Sweeney, J.C. (2007). Offshore bottlenose dolphins (Tursiops truncatus): Movement and dive behavior near the Bermuda Pedestal. Journal of Mammalogy, 88(1), 59–66. http://www.asmjournals.org/doi/full/10.1644/05-MAMM-A-365R1.1

Laporta, P., Martins, C.C.A., Lodi, L., Domit, C., Vermeulen, E., & Di Tullio, J.C. (2016). Report of the Working Group on Habitat Use of Tursiops truncatus in the Southwest Atlantic Ocean. Latin American Journal of Aquatic Mammals, 11(1-2), 47-61. https://doi.org/http://dx.doi.org/10.5597/lajam00215

Laporta, P., & Dimitriadis, C. (2004). Occurencia y comportamiento de *Tursiops truncatus* en Cerro Verde, Rocha, Uruguay: casualidad o residencia. 11ª Reunión de Trabajo de Expertos Em Mamíferos Acuáticos de América Del Sur, Setembro 11-19, 137.

Loureiro, J.D., Migliorisi, A.L., Loureiro, J.P., Rodríguez Heredia, S., Rebollo, J., Álvarez, K.C., Morón, S., & Nuñez Favre, R. (2021). Breeding program in rehabilitated bottlenose dolphins (*Tursiops truncatus gephyreus*) from the Southwestern Atlantic Ocean. Zoo Biology, 40(3), 208-217. doi: 10.1002/zoo.21592. Epub 2021 Feb 19. PMID: 33606298.

Moritz, C. (1994). Defining "Evolutionarily significant units" for conservation. Trends in Ecology & Evolution, 9, 373-375. https://doi.org/10.1016/0169-5347(94)90057-4

Oliveira, L.R., Fraga, L.D., Ott, P.H., Siciliano, S., Lopes, F., Almeida, R., Wickert, J.C., Milmann, L., Danilewicz, D., Emin-Lima, N.R., Meirelles, A.C., Luz, V., Do Nascimento, L.F., De Thoisy, B., Tavares, M., Zerbini, A.N., Baumgarten, M., Valiati, V.H., & Bonatto, S.L. (2019). Population structure, phylogeography, and genetic diversity of the common bottlenose dolphin in the tropical and subtropical southwestern Atlantic Ocean. Journal of Mammalogy, 100(2), 564-577. https://doi.org/10.1093/jmammal/gyz065

Pinedo, M. (1986). Mortalidade de *Pontoporia blainvillei*, *Tursiops gephyreus*, *Otaria flavescens* e *Arctocephalus australis* na costa do Rio Grande do Sul, Brasil, 1976-1983. Primeira Reunión de Trabajo de Expertos Em Mamíferos Acuáticos de América Del Sur, 187-199.

Pollock, K.H. (1982). A Capture-Recapture Design Robust to Unequal Probability of Capture. The Journal of Wildlife Management, 46(3), 752-757.

Prado, J.H.F., Mattos, P.H., Silva, K.G., & Secchi, E.R. (2016). Long-term seasonal and interannual patterns of marine mammal strandings in subtropical western South Atlantic. PLoS ONE, 11(1), 1-23. https://doi.org/10.1371/journal.pone.0146339

Quérouil, S., Silva, M.A., Freitas, L., Prieto, R., Magalhães, S., Dinis, A., Alves, F., Matos, J.A., Mendonça, D., Hammond, P.S., & Santos, R.S. (2007). High gene flow in oceanic bottlenose dolphins (*Tursiops truncatus*) of the North Atlantic. Conservation Genetics, 8(6), 1405-1419. https://doi.org/10.1007/s10592-007-9291-5

Reeves, R.R. (2003). Dolphins, whales, and porpoises: 2002-2010 conservation action plan for the world's cetaceans. World Conservation Union.

Righetti, B.P.H., Daura-jorge, F.G., Mattos, J.J., Siebert, M.N., Bezamat, C., Fruet, P.F., Genoves, R.C., Taniguchi, S., Da Silva, J., Montone, R.C., Simões-Lopes, P.C., Bainy, A.C.D., & Lüchmann, K.H. (2019). Biochemical and molecular biomarkers in integument biopsies of free-ranging coastal bottlenose dolphins from southern Brazil. Chemosphere, 225, 139-149. https://doi.org/10.1016/j.chemosphere.2019.02.179

Secchi, E.R. (ed.) (2002). Special Issue on the Biology and Conservation of Franciscana. The Latin American Journal of Aquatic Mammals (special issue 1), 1-192.

Simões-Lopes, P.C.C., & Fabian, M.E.E. (1999). Reidence patterns and site fidelity in bottlenose dolphins, *Tursiops truncatus* (Montagu) (Cetacea, Delphinidae) off Southern Brazil. Revista Brasileira de Zoologia, 16(4), 1017-1024. https://doi.org/10.1590/S0101-81751999000400012

Traylor-Holzer, K., Leus, K., Byers, O., Minter, B.A., Maienschein, J., & Collins, J.P. (2018). Integrating ex situ management options as part of a one plan approach to species conservation. The Ark and beyond: The Evolution of Zoo and Aquarium Conservation, 129141.

Van Bressem, M.F., Flach, L., Reyes, J.C., Skontorp, M.E., Santos, M., Viddi, F., Félix, F., Lodi, L., & van Waerebeek, K. (2015). Latin American Journal of Aquatic Mammals Epidemiological characteristics of skin disorders in cetaceans from South American waters Marie-Françoise Van Bressem. Latin American Journal of Aquatic Mammals, 10(1), 20–32. https://doi.org/10.5597/lajam00190

Vermeulen, E., Bastida, R., Berninsone, L.G., Bordino, P., Failla, M., Fruet, P.F., Harris, G., Iñíguez, M., Marchesi, M.C., Petracci, P., Reyes, L., Sironi, M., & Bräger, S. (2017). A review on the distribution, abundance, residency, survival and population structure of coastal bottlenose dolphins in Argentina. Latin American Journal of Aquatic Mammals, 12(1-2), 2-16. https://doi.org/10.5597/00233

Vermeulen, E., & Cammareri, A. (2009). Residency Patterns, Abundance, and Social Composition of Bottlenose Dolphins (*Tursiops truncatus*) in Bahía San Antonio, Patagonia, Argentina. Aquatic Mammals, 35(3), 378-385. https://doi.org/10.1578/AM.35.3.2009.378

Vermeulen, E., Fruet, P.F., Costa, A.P.B., Coscarella, M., & Laporta, P. (2019). *Tursiops truncatus* ssp. *gephyreus*, Lahille's Bottlenose Dolphin. The IUCN Red List of Threatened Species.

Wells, R.S., Scott, M., & Irvine, A. (1987). The social structure of freeranging bottlenose dolphins. In H. Genoways (Ed.), Current Mammalogy Vol. 1 (pp. 247-305). New York: Plenum Press.

Wells, R.S. (2000) Reproduction in wild bottlenose dolphins: overview of patterns observed during a long-term study. In D. Duffield, & T. Robeck (Eds), Report of the bottlenose dolphins reproduction workshop, June 3-6 (pp. 57-74). Silver Springs, MD.

Wells, R. S., & Scott, M. D. (2009) Common bottlenose dolphin (Tursiops truncatus). Pp 249-255 in: Encyclopedia of marine mammals, 2nd ed. (Perrin, W.F., Würsig, B., & Thewissen, J.G.M., eds). Elsevier, San Diego.

Wickert, J.C., Von Eye, S.M., Oliveira, L.R., & Moreno, I.B. (2016). Revalidation of *Tursiops gephyreus* Lahille, 1908 (Cetartiodactyla: Delphinidae) from the southwestern Atlantic Ocean. Journal of Mammalogy, 97(6), 1728-1737. https://doi.org/10.1093/jmammal/gyw139

Wilson, D. R. B. (1995). The ecology of bottlenose dolphins in the Moray Firth, Scotland: a population at the northern extreme of the species' range. University of Alberdeen.

Würsig, B., & Würsig, M. (1979). Behavior and Ecology of the Bottlenose dolphin, *Tursiops truncatus*, in the South Atlantic. Fishery Bulletin, 77(2), 399-412. http://fishbull.noaa.gov/77-2/wursig.pdf

# DER ZOOLOGISCHE GARTEN

## THE ZOOLOGICAL GARDEN

**Zeitschrift für die gesamte Tiergärtnerei (Neue Folge)**
**Offizielles Organ des Verbands der Zoologischen Gärten – VdZ**
**Organ of the World Association of Zoos and Aquariums – WAZA**

DER ZOOLOGISCHE GARTEN ist eine internationale, wissenschaftliche Zeitschrift, die allen die Tiergärtnerei (im weitesten Sinne) betreffenden Originalarbeiten offensteht. Neben größeren Abhandlungen werden Kurzmitteilungen und Nachrichten aus Zoologischen Gärten aufgenommen.

DER ZOOLOGISCHE GARTEN is and international scientific journal which is open to all original papers concerning zoo biology and related topics. In addition to larger scientific contributions, we accept short notes and news from zoological gardens.

### Abonnement/Subscription

□ Ich abonniere DER ZOOLOGISCHE GARTEN ab 2023 (2 Ausgaben pro Jahr) zum Preis von 32 €/Jahr (Deutschland) bzw. 36 €/Jahr (außerhalb Deutschlands).
Der Abonnementpreis ist im Voraus zu entrichten und enthält die Versandkosten. Die schriftliche Kündigung ist zum Jahresende möglich.

□ I subscribe to DER ZOOLOGISCHE GARTEN as of 2023 (2 issues per year) for the price of 32 €/year (Germany) or 36 €/year (outside Germany)
The subscription has to be paid in advance and includes shipping; it may be cancelled in writing at the end of each year.

Name: ______________________________________________________________________
Lieferanschrift/
Ship To Address:
______________________________________________________________________
Rechnungsanschrift, falls abweichend
Bill To Address, if different:
______________________________________________________________________

Ort/Place______________________________Datum/Date_____________________________

Unterschrift/Signature:_____________________________________________________

Bankeinzug/SEPA: ja___yes___/nein___no___ (please tick), bei „ja“ bitte ausfüllen/if „yes“ please fill in

**SEPA-Mandat für Abonnement DER ZOOLOGISCHE GARTEN/**
**SEPA Direct Debit Mandate for DER ZOOLOGISCHE GARTEN**

IBAN: ________________________________________ BIC:__________________________

Bank Name:____________________________________________________________________

Bitte ausschneiden oder kopieren und senden an/Please clip or copy and send to:

Verlag Natur & Wissenschaft
Harro Hieronimus
Dompfaffweg 53
D-42659 Solingen
E-Mail: info@verlagnw.de

DER ZOOLOGISCHE GARTEN
THE ZOOLOGICAL GARDEN

| Hinweise für Autoren | Instruction for authors |
|---|---|
| DER ZOOLOGISCHE GARTEN ist eine fachübergreifende wissenschaftliche Zeitschrift für die gesamte Tiergärtnerei. Zur Veröffentlichung angenommen werden Manuskripte, die im weitesten Sinne dazu beitragen, die Kenntnisse über die Tierhaltung in Zoologischen Gärten zu erweitern. Hierzu gehören neben wissenschaftlichen Originalbeiträgen auch Kurzmitteilungen über bemerkenswerte Beobachtungen und Nachrichten aus dem Umfeld zoologischer Einrichtungen sowie Buchbesprechungen (siehe „Aims and Scope“). Manuskripte sind einzureichen an editor@koelnerzoo.de.<br><br>Manuskripte sind in deutscher oder englischer Sprache zu verfassen. Texte sind unformatiert und als Fließtext in gängiger Schriftart (Arial, Calibri oder Times New Roman) als Worddokument einzureichen. Ihr Aufbau sollte folgendermaßen strukturiert sein: Titel in deutscher und englischer Sprache mit Kennzeichnung für die Redaktion, ob britisches (UK) oder amerikanisches Englisch (US) verwendet wird; Kurzübersicht mit maximal 45 Zeichen, Vor- und Nachnamen sowie Forschungsstätten und Adressen sämtlicher Autoren; Anzahl der Abbildungen und Tabellen; Zusammenfassung und englisches Abstract (sofern der Artikel in Deutsch verfasst wurde); 3-5 Keywords in der Sprache, in der der Artikel verfasst wird; Einleitung; Hauptteil des Manuskripts (mögliche, aber nicht notwendige Gliederung, z. B.: Material und Methoden, Ergebnisse und Diskussion); Danksagung; Literatur; Zusammenfassung; Abbildungslegenden; Tabellen einschließlich ihrer Titel.<br><br>Alle Abbildungen (einschließlich Bilder und Grafiken) sowie Tabellen sind fortlaufend zu nummerieren. Im Text ist an passenden Stellen auf jede Abbildung und Tabelle | DER ZOOLOGISCHE GARTEN is a multidisciplinary scientific journal publishing articles about zoo biology and related topics. We accept manuscripts for publication which will help to increase the knowledge of animal husbandry in zoological gardens. In addition to original scientific contributions this also includes short notes on remarkable observations and news from zoological institutions as well as book reviews (see “Aims and Scope”). Please send manuscripts by e-mail to editor@koelnerzoo.de.<br><br>All manuscripts must be written in German or English. Texts have to be submitted as Word documents, unformatted and as continuous text in common fonts (Arial, Calibri or Times New Roman) with the following structure: title in German or English (for English texts, please indicate for the editorial staff whether British (UK) or American (US) English is used); short title in the main language with a maximum of 45 characters; first name, surname as well as affiliated institutions and addresses of each author; e-mail address of the corresponding author; number of figures and tables; abstract in English and also in German (if the article was written in English); 3-5 keywords in the language in which the article is written; introduction; main part of the text (e.g. material and methods, results and discussion); acknowledgement; summary; references; figure captions; tables with headings.<br><br>All figures (including images and charts) and tables have to be numbered consecutively. Please check that all figures and tables have been cited in the text. Example: [Fig. 1] or [Tab. 2] etc.<br><br>Figure legends and table titles should be comprehensive but brief. Captions in texts |

hinzuweisen. Beispiel: [Abb. 1] oder [ Tab. 2] etc. Die Legenden der Abbildungen und die Überschriften der Tabellen sollen informativ, komplett aber kurz sein. Die Bildunterschriften in Manuskripten, die in deutscher Sprache eingereicht werden, sind in Deutsch und Englisch anzugeben. Zu allen Abbildungen (d. h. Bilder, Grafiken etc.) muss der Fotograf bzw. die Quelle angegeben werden. Beispiel: Abb. 1: Text. Foto: T.B. Pagel. Oder Abb. 1: Text. Quelle: Archiv Kölner Zoo.

Die Bilder und Grafiken müssen unabhängig vom Text als eigenständiges Dokument eingereicht werden, wenn möglich in digitaler Form. Empfohlene Speicherformate sind TIFF, JPEG, EPS und PDF. Grafiken werden auch als Excel-Dateien angenommen. Die Abbildungen müssen als Farb- oder Graustufenbilder eine Druckauflösung von 300 dpi aufweisen. Bitmap-Grafiken benötigen für den Druck eine Auflösung von 600-1200 dpi. Im Titel sind wissenschaftliche Artnamen komplett mit Autor und Beschreibungsdatum anzugeben. Gattungsname und Artepitheton sind bei ihrer Erstnennung im Text auszuschreiben. Im Folgenden wird der Gattungsname durch den ersten Buchstaben abgekürzt. Artnamen und Gattungsbezeichnungen werden kursiv geschrieben.

Im Text müssen Autoren an entsprechenden Passagen in chronologischer Abfolge zitiert werden: Mayr (2003); Darwin & Wallace (2007)

Wenn mehrere Autoren in Klammern eingefügt zitiert werden, sind sie durch ein Semikolon voneinander zu trennen, z.B. (Wilson, 2001; Flemming & Gould, 2010). Sofern auf verschiedene Veröffentlichungen eines Autors im selben Jahr verwiesen wird, sollte dies so erfolgen: (Morgan 2003a, b; Wallace et al., 2013a, b). Wenn mehrere Autoren in Klammern eingefügt zitiert werden, sind sie durch ein Semikolon voneinander zu trennen,

submitted in German must be in German and English.

Example:
Fig. 1: Text. Photo: T.B. Pagel. or
Fig. 1: Text. Source: Archive Cologne Zoo.

Please submit images and charts as separate files, if possible in digital form. Recommended storage formats are TIFF, JPEG, EPS and PDF. Charts are also accepted as Excel files. Printing in journal quality requires color or grayscale images with resolutions of 300 dpi. Bitmap graphics require a resolution of 600-1200 dpi for printing.

Please indicate the photographer or source for all figures (i.e. pictures, graphics, etc.). Indicate scientific species names in the title completely with author and date. Binominal species names in the text should appear with the complete generic name when first mentioned. Thereafter, abbreviate the generic name with its first letter. All genus and species group names must be in italics. In-text citations to literature must be in chronological order, i.e. author‘s surname followed by the year of publication: Mayr (2003); Darwin & Wallace (2007); if a publication has more than two authors, cite first authors as e.g. Wallace et al. (2013), with all authors listed in the references. If more than one publication is cited in parenthesis, please separate the names by a semicolon, e.g. (Wilson, 2001; Flemming & Gould, 2010). If reference is made to more than one paper by the same author published in the same year, this should be indicated as follows: (Morgan, 2003a, b; Wallace et. al, 2013 a, 2013 b).

Please list the cited publications in the reference section alphabetically by author’s name according to the following examples:

Journals or magazines:

z.B. (Wilson, 2001; Flemming & Gould, 2010; Mayer et al., 2013). Sofern auf verschiedene Veröffentlichungen eines Autors im selben Jahr verwiesen wird, sollte dies so erfolgen: (Morgan 2003a, b; Wallace et al., 2013a, b).

Die zitierten Publikationen sind am Ende des Artikels geordnet nach der alphabetischen Reihenfolge der Autoren aufzuführen. Die Literaturverweise sind nach folgendem Schema anzufertigen:

Zeitschriften:

Der Titel von Zeitschriften ist immer ganz auszuschreiben, aber nicht in Kapitälchen anzugeben.

Backhaus, D., & Frädrich, H. (1965). Experiences keeping various species of Ungulates together at Frankfurt Zoo. International Zoo Yearbook, 5, 14-24.

Bücher:

Fowler, M.E., & Miller, R.E. (2003). Zoo and wild animal medicine. (5th ed.). Philadelphia: W.B. Saunders & Co.

Kapitel aus Büchern:

Folch, A. (1992). Family Apterygidae (Kiwis). In J. del Hoyo, A. Elliott, & J. Sargatal (Eds), Handbook of the Birds of the World. Vol. 1. Ostrich to Ducks (pp. 104-110). Barcelona: Lynx Edicions.

An Stelle eines Honorars steht den Autoren ein PDF-Dokument ihres Betrages kostenlos zur Verfügung. Sonderdrucke können gegen Rechnung bezogen werden.

The title of journals or magazines must always be written out in full but not in small caps:

Backhaus, D., & Frädrich, H. (1965). Experiences keeping various species of Ungulates together at Frankfurt Zoo. International Zoo Yearbook, 5, 14-24.

Books:

Fowler, M.E., & Miller, R.E. (2003). Zoo and wild animal medicine. (5th ed.). Philadelphia: W.B. Saunders & Co.

Book chapter citations:

Folch, A. (1992). Family Apterygidae (Kiwis). In J. del Hoyo, A. Elliott, & J. Sargatal (Eds), Handbook of the Birds of the World. Vol. 1. Ostrich to Ducks (pp. 104-110). Barcelona: Lynx Edicions.

Instead of a gage, the authors will receive a PDF file of the article free of charge. Offprints will be available on request and invoice.

## Impressum

# DER ZOOLOGISCHE GARTEN

## THE ZOOLOGICAL GARDEN

**AG Zoologischer Garten Köln**
Editorial Board:
DER ZOOLOGISCHE GARTEN/THE ZOOLOGICAL GARDEN
Riehler Str. 173
50735 Köln
Deutschland/Germany

**Verband der Zoologischen Gärten (VdZ) e.V.**
**Association of Zoological Gardens**
Bundespressehaus (Büro 4109)
Schiffbauerdamm 40
10117 Berlin
Deutschland/Germany

**Weltzooverband (WAZA)**
**World Association of Zoos and Aquariums**
WAZA Executive Office
Carrer de Roger de Llúria, 2, 2-2
08010 Barcelona
Spanien/Spain

**Hinweise für Autoren** findet man auf den letzten Seiten des Heftes.
**Rezensionsexemplare** senden Sie bitte direkt an die Anschrift der AG Zoologischer Garten Köln (siehe oben).

**Instructions for Authors** can be found on the last pages of each issue.
**Books for review:** Please send books for review directly to the address of AG Zoologischer Garten Köln (see above).



**Satz und Druck/Typesetting and Printing:**
Verlag Natur & Wissenschaft Harro Hieronimus
Dompfaffweg 53
42659 Solingen

**Umschlagseite/Cover:**

October 18, 2017, the first vaquita (*Phocoena sinus*) caught during the Vaquita Conservation,Protection & Recovery project. © VaquitaCPR

18. Oktober 2017, der erste gefangene Vaquita (*Phocoena sinus*) im Rahmen des Vaquita Conservation, Protection & Recovery Projekts. © VaquitaCPR

VNW

# DER ZOOLOGISCHE GARTEN

THE ZOOLOGICAL GARDEN

Volume 91
Issue 2 · 2023
ISSN 0044-5169

## Contents/Inhalt



**Die Publikationen sind frei zugänglich unter www.vdz-zoos.org**
**The published articles are open access at www.vdz-zoos.org**

**Bibliographiert/Indiziert in – Abstracted/Indexed in**
Biological Abstracts; BIOSIS database; CAB Abstracts database; Fisheries Review; Key Word Index of Wildlife Research; NISC – National Information Services Corporation; Protozoological Abstracts; Referativnyi Zhurnal; Wildlife & Ecology Studies Worldwide; Wildlife Review (Fort Collins); Zoological Record.