Scientific and Research Advisory Committee Newsletter 24 – April 2024

CONTENTS

Welcome to SRAC Newsletter 24!

In this issue, we highlight our Nature Parks' research for 2022/24. We published 28 papers and supervised 10 high-degree candidates across various levels. Stories include island conservation efforts on post-fox eradication, penguin predation, and diseases impacting eastern barred bandicoots. Seal studies cover diet changes, diseases, ethical research and ways to mitigate bycatch and improve waste practices in fishing boats. Penguin research delves into parenting, resilience, and applied conservation. We also discuss global threats like legacy pollutants and light pollution and our contribution to the State do the Marine Environment Report . Special acknowledgment goes to the massive contribution of our HD candidates and our presentations at the 12th International Penguin Conference in 2023.

Updates on research publications can be found on our website and at the research gate, as well as a map of our external collaborations and students. The Nature Parks' research is guided by a 5-Year Conservation Plan and 30-Year Conservation Vision that details the research we are conducting to protect and enhance Phillip Island's wildlife and its terrestrial and marine environment.

Happy reading!

The Scientific and Research Advisory Committee

Our Scientific and Research Advisory Committee has external scientists who advise the Nature Parks' research activities on scientific issues and research directions. All research is conducted under the guidance and approval of an Animal Ethics Committee and Wildlife Permits issued by the Department of Energy, Environment and Climate Action (DEECA).

A word to our sponsors and partners

We are grateful for the generous support of major research sponsors: the Penguin Foundation, French National Centre for Scientific Research, Telematics Trust, Holsworth Wildlife Research Endowment – Ecological Society of Australia, DEECA – Biodiversity Response Planning and CPAR Grants, Australian Research Council, Bank of Melbourne, Disney Conservation Fund, Australian Marine Mammal Centre and Zoos Victoria.

Terrestrial research

Highlighting the role of community partnerships in island conservation

If conservation depends on people, then community partnerships are the lynchpin to conservation success. The contribution of local knowledge, intellectual capital and volunteer labour not only saves project managers invaluable time and money, it fosters ownership and longevity into conservation initiatives well beyond their projected timeframe. Island communities are socially and culturally diverse and driven by a range of motivations. Hence, if we are to deliver conservation programs at scale, we need to better understand and embed these drivers into program design. This paper presents four contemporary case studies on major populated islands in Australia, including Phillip Island (Millowl), where community collaborations are building the collective impact needed to underpin conservation success. They contain key learnings about community involvement, to help guide managers with future island planning and avoid some pitfalls.

Bryant, S. L., Bower, H., Bower, S., Copley, P. B., Dann, P., Matassoni, D., Sprod, D., and Sutherland, D. R. (2022). Island partnerships building collective impact. *Pacific Conservation Biology* **28**, 303-314. doi: 10.1071/PC21021.

Summerland Estate buyback is just one example of successfully working with community to mitigate threats for wildlife.

Feral cat diet following fox eradication

Following the eradication of foxes from Phillip Island (Millowl), feral cats might be expected to switch prey and target a different array of species. This study compared the diets of 277 feral cat from the 1980s and 1990s with another 415 feral cats from 2016 to 2019. As it turns out, there was no substantial shift in diet before and after fox eradication. Invasive prey (rabbits, black rats and mice) still formed the majority of feral cat diet. Their diet did show seasonal patterns: shearwaters were more prevalent in autumn and winter, whereas invertebrates more prevalent in spring and summer. Males consumed larger prey than females, and feral cats consumed more rabbits when outside conservation reserves compared to within reserves. The eradication of foxes has not led to a notable shift in feral cat diet which may have reduced the conservation benefits of removing foxes.

Rendall, A. R., Sutherland, D. R., Cooke, R., and White, J. G. (2022). Does the foraging ecology of feral cats change after the eradication of foxes? *Biological Invasions* **24**, 1413-1426. doi: 10.1007/s10530-021-02718-x.

Detecting little raven predation of little penguins

Little ravens have emerged as a prominent predator on the clutches of burrow-nesting little penguins on Phillip Island. Non-invasive dietary analysis and identification of penguins in the diet of 'culprit' individual ravens could help focus management. This study tested the feasibility of using non-invasive PCR approaches targeting penguin specific markers to establish whether penguin DNA could be detected in raven faecal samples, potentially enabling the identification of culprit ravens missed by extensive field observation. While this study found metabarcoding unreliable for unambiguous assigning of raven culprit status, it may hold promise complementing observations if consumption via scavenging can be distinguished from direct depredation.

Tan, L. X. L., Gan, H. M., Van Dongen, W. F. D., Dann, P., Sutherland, D. R., and Weston, M. A. (2023). DNA metabarcoding complements but does not replace direct observations of penguin predation by corvids. *Ibis*. doi: 10.1111/ibi.13294.

Impact of a cat borne disease for eastern barred bandicoots

Eastern barred bandicoots are thought to be highly susceptible to disease caused by infection with the protozoan parasite *Toxoplasma gondii*, so the introduction of bandicoots to Phillip Island (Millowl) was a test to see if the disease might prevent their establishment. This study followed 67 bandicoots that were introduced onto the Summerland Peninsula, Phillip Island, where the prevalence of *T. gondii* infection in the feral cat population was known to be very high. Despite expectations, none of the bandicoots positive to being infected by *T. gondii* on any of four testing occasions after release. Survival after release was high, and at least 14 founder bandicoots (21% of founders) were still alive at 500 d after-release. A total of 29 unmarked bandicoots were trapped over the study period, confirming that the bandicoots were successfully reproducing on the island. *Toxoplasma gondii* DNA was not detected by PCR in eight carcasses recovered for necropsy. Body weight, packed cell volume, and total plasma protein were used as measures of individual animal health; population health was inferred from these data. Body weight was significantly associated with trip number, with a general trend of increasing weight after release onto the island. This study showed that eastern barred bandicoots were able to establish a new population despite a probably high environmental load of *T. gondii*.

Adriaanse, K., Lynch, M., Sutherland, D. R., Traub, R., Lowe, J., and Hufschmid, J. (2024). *Toxoplasma gondii* does not inhibit the assisted colonization of eastern barred bandicoots (*Perameles gunnii*) to Phillip Island, Victoria, Australia. *Journal of Wildlife Diseases* **60**, 116-125.

SEALS

Coxiella burnetii in Australian fur seals

The Australian fur seal experiences a high third trimester abortion prevalence. Coxiella burnetii is a well-known cause of abortion in domestic and wildlife species and an important zoonotic pathogen. Third trimester aborted fetuses (n = 46) and full-term placentas (n = 66) were collected on Kanowna Island and Seal Rocks in Bass Strait, south-eastern Australia. The detected prevalence was 40.9% in full-term placentas. This first detection in a marine mammal from the southern hemisphere, highlighting the need to further investigate the potential risks this pathogen poses to Australian fur seals, sympatric marine mammals and persons working with Australian fur seals.

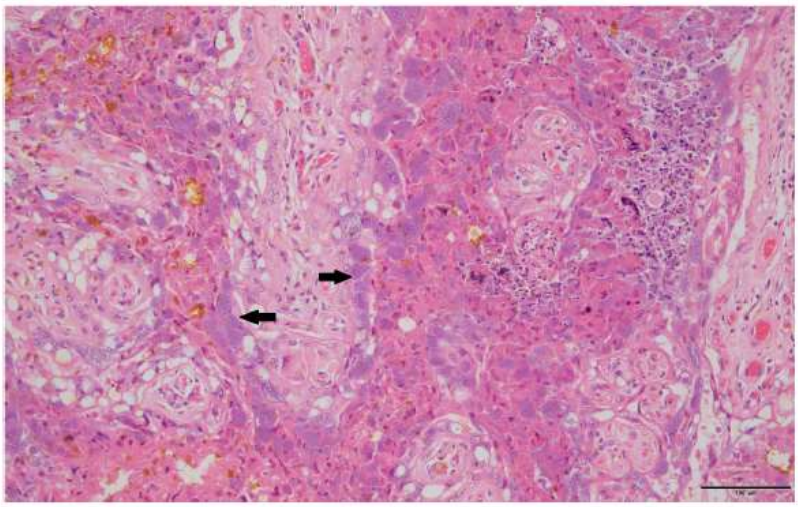


FIGURE 1 | Typical foamy *Coxiella burnetii* cytoplasmic inclusions within the placental trophoblasts are indicated by solid black arrows, 40×, hematoxylin and eosin stain.

Gardner, B.R., Stenos, J., Hufschmid, J., Arnould, J.P.Y., McIntosh, R.R., Tadepalli, M., Tolpinrud, A., Marenda, M., Lynch, M., Stent, A., 2022. An old pathogen in a new environment–implications of *Coxiella burnetii* in Australian Fur Seals (*Arctocephalus pusillus doriferus*). *Frontiers in Marine Science* 9:809075.

Using environmental DNA to identify a zoonotic pathogen

Coxiella burnetii is suspected as a novel pathogen contributing to decreased pup production in Australian fur seals. Soil samples for eDNA analysis were collected from Kanowna Island and Seal Rocks post-pupping with a prevalence of 59.6% at Kanowna Island and 90% at Seal Rocks. eDNA is an effective tool to survey Australian fur seal breeding colonies in the post-pupping period for *C. burnetii* with a higher prevalence at Seal Rocks compared to Kanowna Island. It appears that this is not a terrestrial Australian genotype but rather closely related to genotypes detected in marine mammals in the northern hemisphere.

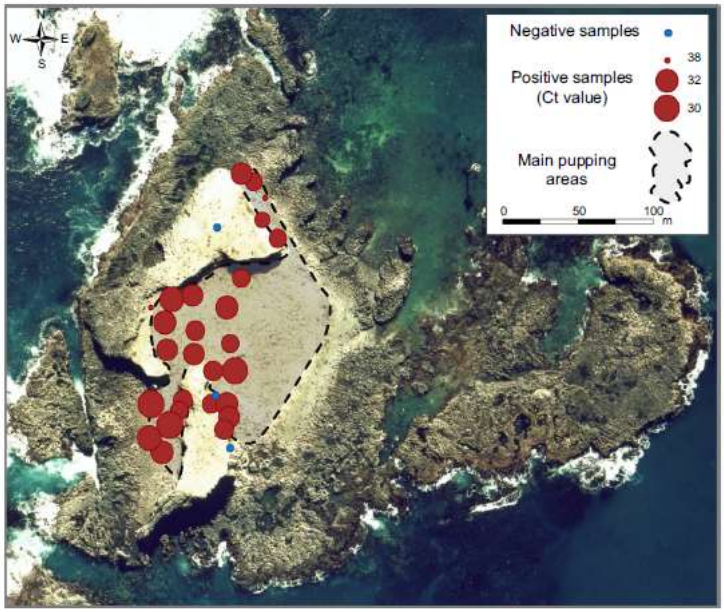


Fig. 4. Seal Rocks post-pupping samples with associated Ct values.

Gardner, B. R., Arnould, J. P. Y., Hufschmid, J., McIntosh, R. R., Fromant, A., Tadepalli, M., and Stenos, J. (2022) Understanding the zoonotic pathogen, *Coxiella burneti* in Australian fur seal breeding colonies through environmental DNA and genotyping. *Wildlife Research*: doi.org/10.1071/WR22136

Australian fur seal diet change in response to the environment

The diet of the Australian fur seal over 17 years (1998-2014) changed in response to the environment. Taxonomically unique prey hard-parts of prey from scats were identified and their frequency of occurrence (FO) used as a proxy for ecosystem change. While 71 different prey were identified, eight were dominant and included redbait until 2005 when jack mackerel increased and pilchard after 2009. Both large-scale and regional processes influenced prey taxa in variable ways. We predict that the diverse and adaptable diet of the Australian fur seal will be advantageous in a rapidly changing ecosystem.

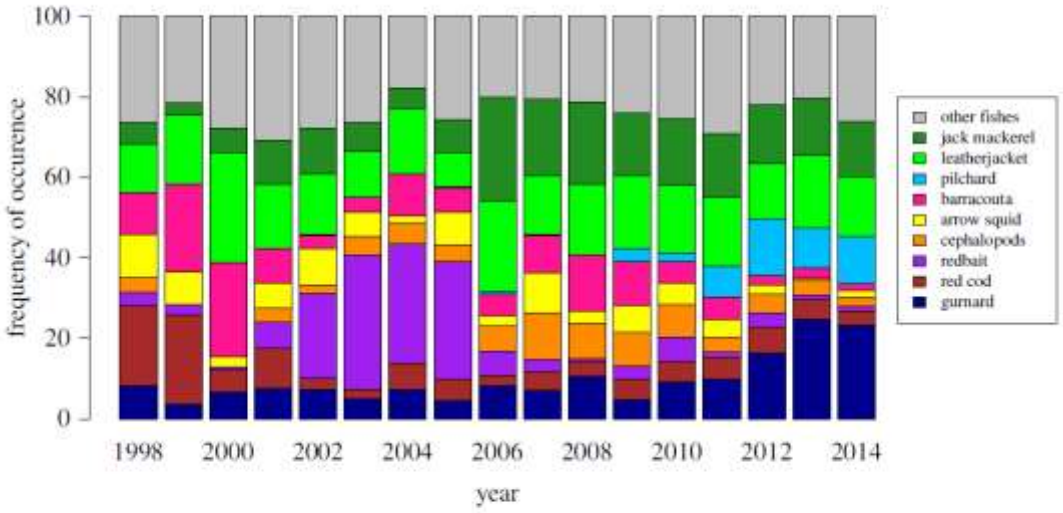


Figure 2. Annual frequency of occurrence (FO) of the nine main prey taxa, other fishes and cephalopods, other than arrow squid (as combined categories) identified in the diet of the Australian fur seal at Seal Rocks, Bass Strait, Australia 1998–2014.

Kliska K., McIntosh, R. R., Jonsen, I., Hume, F., Dann, P., Kirkwood, R., and Harcourt, R. (2022). Environmental correlates of temporal variation in the prey species of Australian fur seals inferred from scat analysis. *Royal Society Open Science 9:211723.*

Predation of little penguins by long-nosed fur seals

Long-nosed fur seal (*Arctocephalus forsteri*) predation of little penguins (*Eudyptula minor*) presents a management challenge and identifying penguin colonies at risk is valuable. Using unique signatures from feathers, stable isotope and trace element techniques successfully identified the source colony of little penguins predated by long-nosed fur seals. The biochemical 'featherprints' from moulted penguins were correctly classified to penguin breeding sites (78%) and broader marine regions (85%); and 46-70% of feathers obtained from fur seal scats originated from penguin sites close to where the scats had been collected. Penguin sites nearby long-nosed fur seal colonies may be most at risk of predation.

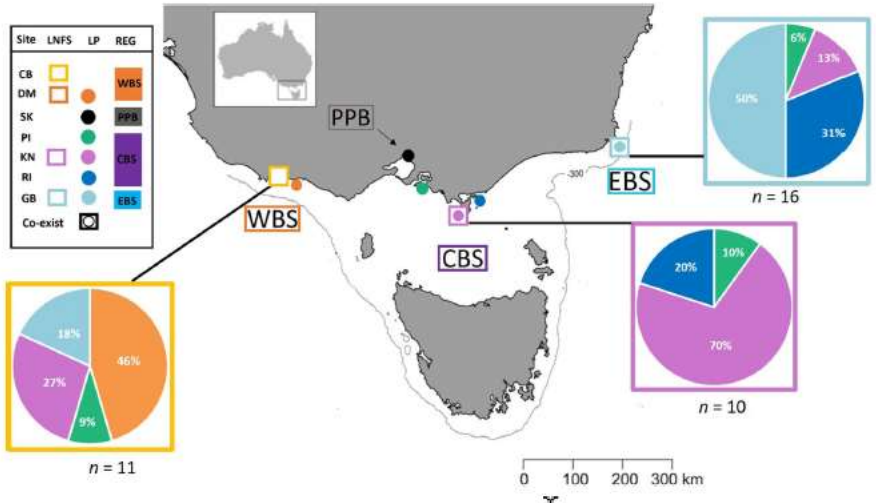


FIGURE 7 | Proportional (%) contribution of source-colonies assigned to little penguin feathers retrieved from scats of long-nosed fur seals. Plots show results of canonical variate analysis of baseline multi-elemental and isotope signatures from penguin colonies sampled across Western (WBS), Central (CBS) and Eastern Bass Strait (EBS), and Pt. Phillip Bay (PPB); Deen Maar Island and Cape Nelson (DM); St. Kilda (SK); Phillip Island (PI); Kanowna Island (KN); Rabbit Island (RI); Gabo Island (GB). Scats of long-nosed fur seals were sampled between October – November 2018.

Reinhold, SL., Goldsworthy, SDG., Arnould, JPY., Gillanders, BM., Connell, S. and McIntosh, RR. (2022). Tracing seal predation back to the source colony of their penguin prey: a trace element and stable isotope analysis. *Frontiers in Marine Science*. 9:813106. doi: 10.3389/fmars.2022.813106.

Ethical research of marine mammals

Marine mammals are distributed throughout the world's oceans. Considered sentinel species of marine ecosystem health because of their high trophic position, they fill important ecological roles in the marine environment. Australia is home to many marine mammals, ranging from coastal species such as fur seals to migratory giants such as whales. Protected in Australian waters under national legislation, any scientific research causing an impact on marine mammals usually requires animal ethics approval. This requirement is to ensure human–wildlife interactions are minimised and animal welfare prioritised. This book chapter describes current best practice for research techniques performed on marine mammals.

Figure 25.2: Long-nosed fur seal (*Arctocephalus forsteri*) with fore-flipper tags and a back-mounted SPLASH tag (Wildlife Computers). Photo by Vincent Antony.

Pirotta, V., McIntosh, R. R., Gray, R. and Lynch, M. J. (2022). Marine Mammals. In "Ethical Wildlife Research in Australia". Eds. Bradley Smith, Helen Waudby and Corinne Alberthsen. CSIRO Publishing. Pp 465-479.

Decline of Australian fur seal populations

Following more than a century of population suppression, partly through on-going harvesting, the Australian fur seals population started to recover in the late 1900s until 2007, when live pup abundance had recovered to approximately 21,400 per year and recovery was expected to continue. However, a species-wide survey in 2013 recorded a 20% decline, to approximately 16,500 live pups, but a range expansion with new colonies formed. Results from the 2017 census provided an estimate of 16,903 live pups, indicating that pup numbers had not recovered. The value of more frequent surveys and potential reasons for the decline are discussed.

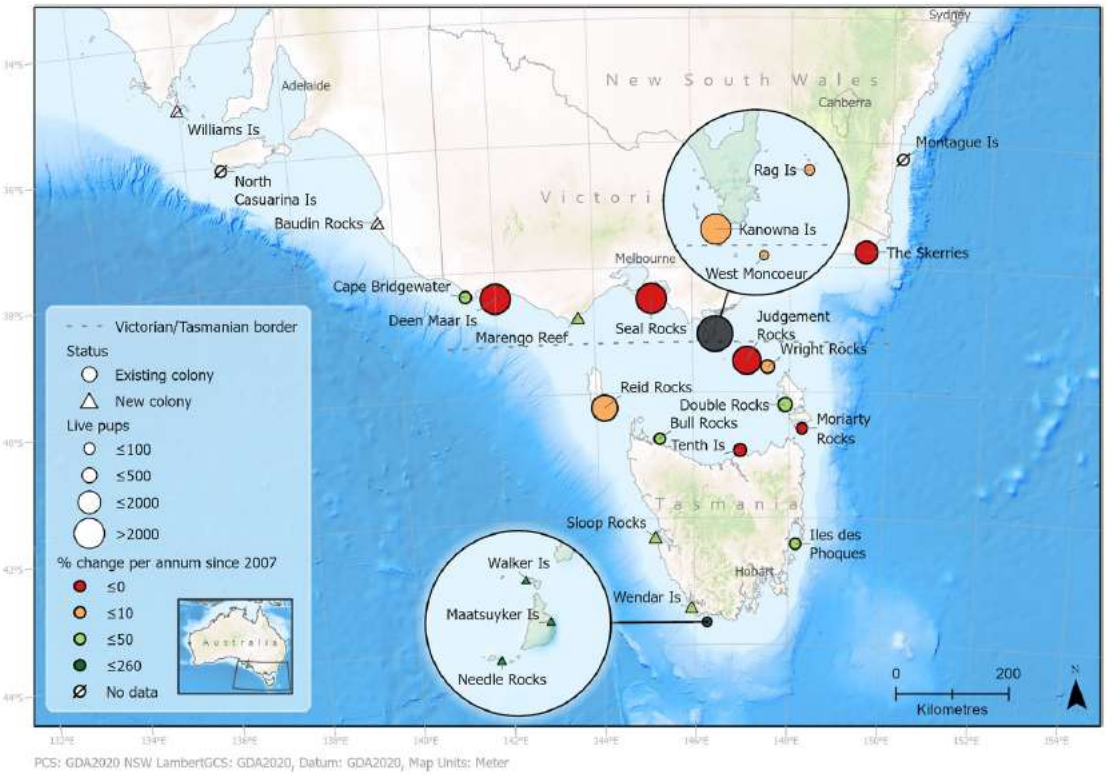


Fig 3. Breeding sites of Australian fur seals indicating the pup abundance and the percentage change in pup abundance per annum between the 2007 and 2017 censuses. The number of live pups is indicated by the size of the shape with larger shapes representing larger pup abundances. The percentage change is indicated by the colour with a scale of red to green indicating negative to positive percent change. Colonies (circles) represent previously identified locations with pups and new colonies (triangles) are those that were identified as having transitioned from a haul-out to a breeding site. Circles of opaque dark grey are extent indicators representing the location of the zoomed detail showing sites in close proximity. The data in this map is from Geoscience Australia [19] and this study.

McIntosh, R. R., Sorrell, K. J., Thalmann, S., Mitchell, T., Gray, R, Schnagl, H., et al. (2022). Sustained reduction in numbers of Australian fur seal pups: implications for future population monitoring. *PLOS ONE*. 2022;17(3): e0265610. doi: 10.1371/journal.pone.0265610.

Effective fisheries bycatch mitigation for Australian sea lions

Populations of the endangered Australian sea lion (*Neophoca cinerea*) off South Australia have been subject to bycatch in a demersal gillnet fishery targeting sharks since the 1960s. A sea lion management strategy was implemented to reduce bycatch with immediate positive impact including ~98% reduction in bycatch mortality from gillnet interactions and an apparent stabilisation of the decline in pup abundances at some impacted breeding sites. There was an almost complete transition in the fishery from gillnets to longlines, and fishing catches returned to pre-management levels. This research provides an important case study which demonstrates how management measures can be effective.

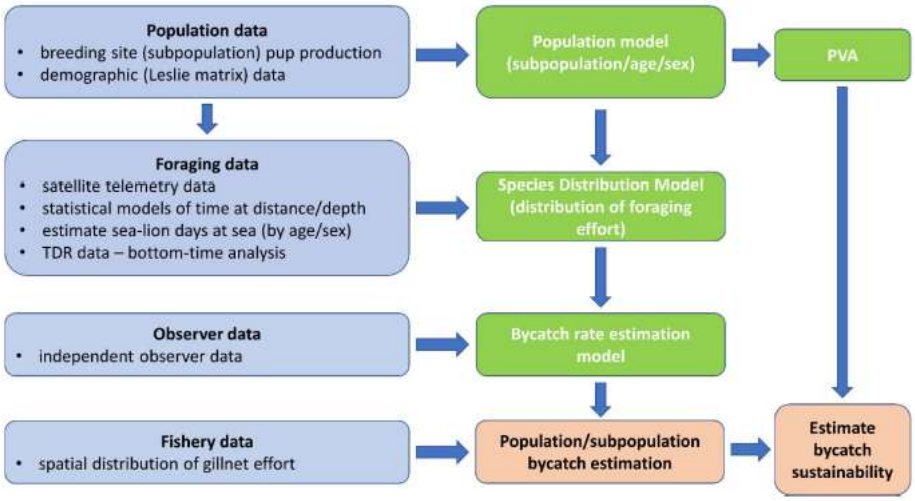


FIGURE 1 | Schematic representation of the various components of data used, and the steps undertaken to develop the suite of models (population, species distribution and bycatch rate estimation models) used to estimate the bycatch mortality of ASL and its impact on population sustainability.

Goldsworthy, Simon D., Page, B., Hamer, D. J., Lowther, A. D., Shaughnessy, P. D., Hindell, M., Burch, P., Costa, D. P., Fowler, S. L., Peters, K., McIntosh, R. R. et al. (2022). Assessment of Australian sea lion bycatch mortality in a gillnet fishery, and implementation and evaluation of an effective mitigation strategy. *Frontiers in Marine Science*. 9:799102. doi: 10.3389/fmars.2022.799102.

Antibiotic resistant bacteria in Australian seals

The rapid emergence of antimicrobial resistance (AMR) is a major concern for wildlife and ecosystem health globally. AMR have become indicators of anthropogenic pollution due to their greater association with humans. Three species of seal were tested across southern Australia. Positive detections were associated with Australian fur seal and Australian sea lion pups, but not long-nosed fur seal pups. Genes conferring resistance to four antibiotic classes were identified. Results highlight the extent of AMR pollution in the marine environment. As AMR determinants are frequently associated with bacterial pathogens, their occurrence suggests that these pinniped species are vulnerable to potential health risks.

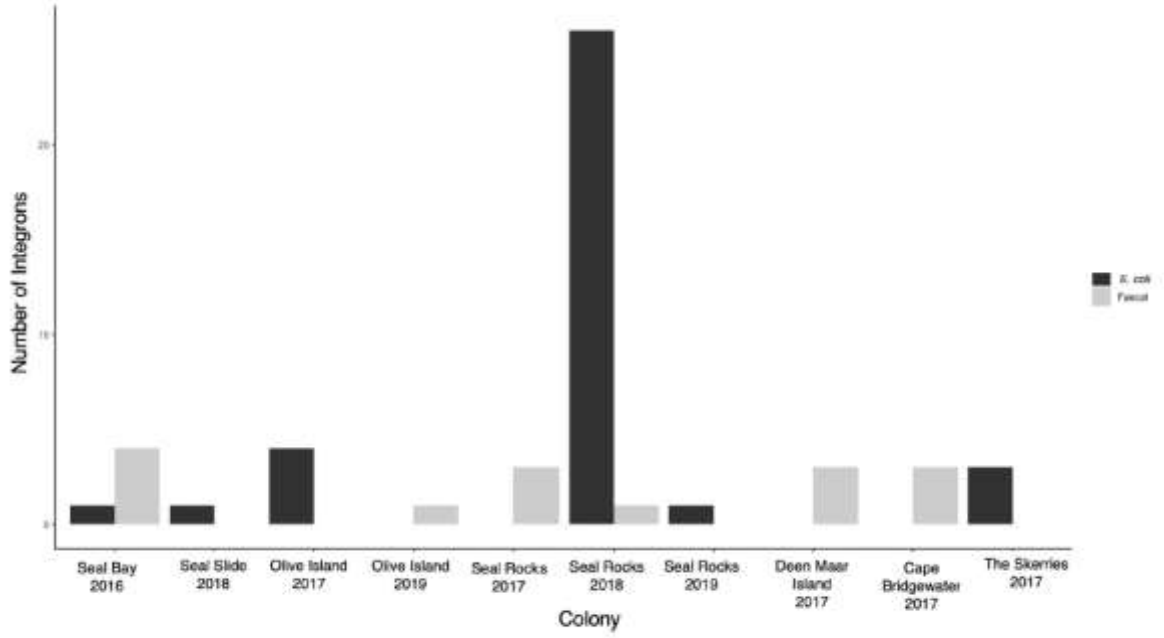


Fig 2. Graph of class 1 integrons detected in pinniped pups. Total number of class 1 integrons detected in faecal and *E. coli* isolate DNA in pups at each colony where integrons were detected during each breeding season sampled.

Fulham, M., Gray, R., McIntosh, R. R., McDougal, F., and Power, M. (2022). Carriage of antibiotic resistant bacteria in endangered and declining Australian pinniped pups. *PLoS ONE* 17(1): e0258978. doi.org/10.1371/journal.pone.0258978.

Improving waste practices on active fishing boats

Here, we describe and evaluate the "bins on boats" project undertaken in Victoria, Australia, which aimed to reduce marine pollution that causes entanglement among Australian fur seals on the Victorian coastline of Bass Strait. This program represents a successful case study in how conservation managers, industry, government, and researchers can collaborate to achieve conservation outcomes. It also demonstrates the value of taking a behavioural approach to the design of program interventions and represents an all-too-rare occurrence of program evaluation.

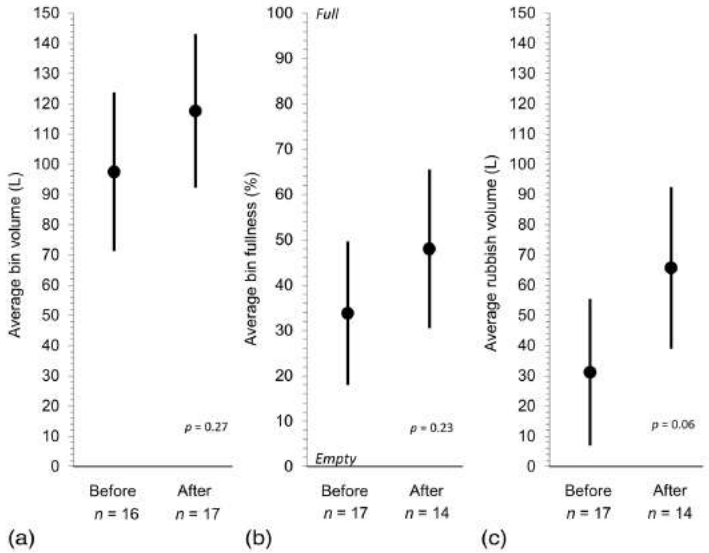


FIGURE 2 Observations made of commercial fishing vessels before and after the program: Average bin volume per vessel (a); average bin fullness per vessel (b); and average rubbish volume per vessel (c), including 95% confidence intervals (CIs). All measures were greater after the program, resulting in an approximate doubling of the average volume of rubbish observed being returned to port for disposal. CIs were calculated and figures plotted using the exploratory software for confidence intervals (Cumming, 2016)

Kusmanoff, A. M., McIntosh, R. R., Boag, S. and Bekessy S. A. (2022). 'Bins on Boats', a behaviourally-based intervention to curb marine pollution in Bass Strait, Australia. *Conservation Science and Practice*. 2022:e12659, doi: 10.1111/csp2.12659.

PENGUINS

Parenthood: age, selection, and foraging evolution on breeding little penguins

Reproductive success in little penguins follows a fascinating age pattern, peaking in middle age before declining in old age. We explored three potential mechanisms driving this trend: selection, constraint, and restraint. Using a comprehensive dataset spanning 19 years and over 450 individuals, we untangled the within- and among-individual effects of age on breeding success. While all mechanisms played a role, within-individual changes were more influential, with middle-aged birds showing peak performance. Interestingly, factors like foraging efficiency, breeding timing, and mate fidelity contributed significantly to these age-related variations. Our findings shed light on the complex dynamics of reproductive success with age in little penguins.

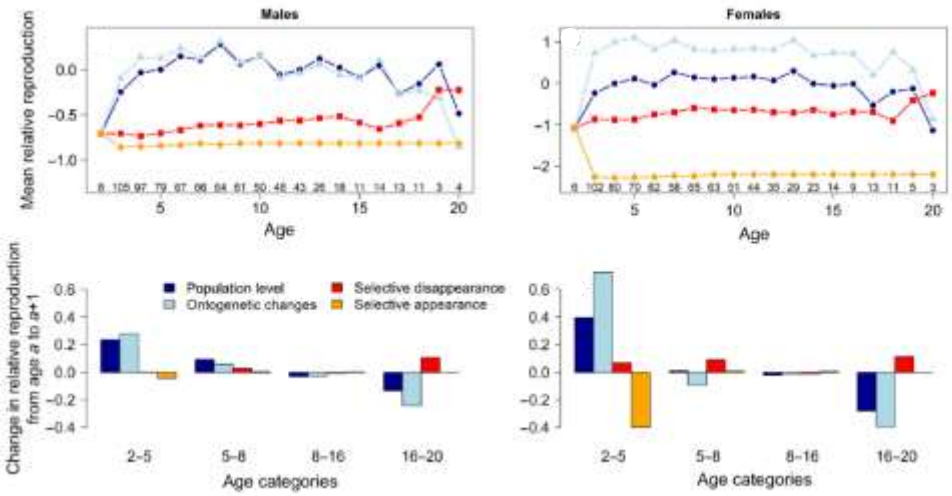
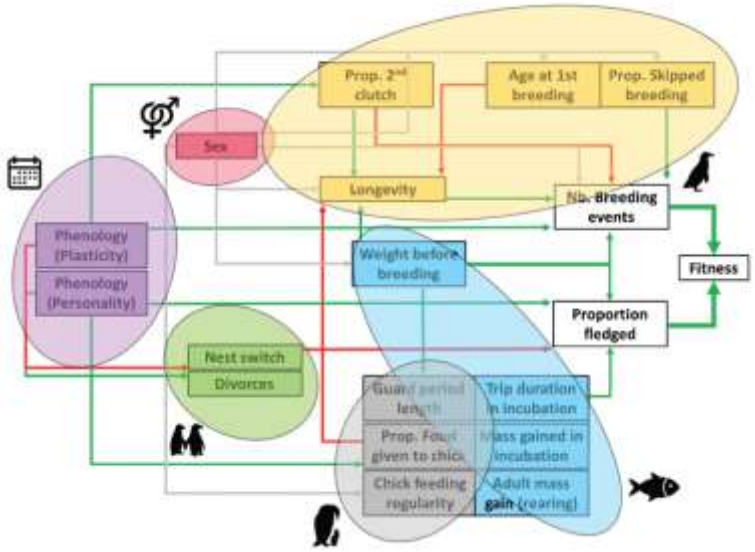


Figure illustrates population trends across different ages. Dark blue denotes observed data, while light blue represents ontogenetic development, red indicates selective disappearance, and orange signifies selective appearance. It provides insights into demographic patterns and reproductive behaviours across various age groups.

Saraux, C. and A. Chiaradia (2022). Age-related breeding success in little penguins: a result of selection and ontogenetic changes in foraging and phenology. *Ecological Monographs* 92(1): e1495.

Breeding success secrets: unravelling individual fitness mysteries

Individual fitness in little penguins is influenced by various factors such as individual quality, energy allocation, and environmental randomness. By studying 18 life-history traits in 162 penguins over their lifespan, we found that fitness varied greatly among individuals. Those with better quality, breeding earlier, and foraging more efficiently exhibited higher fitness. While stochasticity, quality, and trade-offs all played a role, individual quality drove most of the variability. Penguins breeding early and foraging well showed higher fitness, raising questions about the selection process behind these traits. Understanding why some excel in foraging and breeding early remains a key area for investigation.

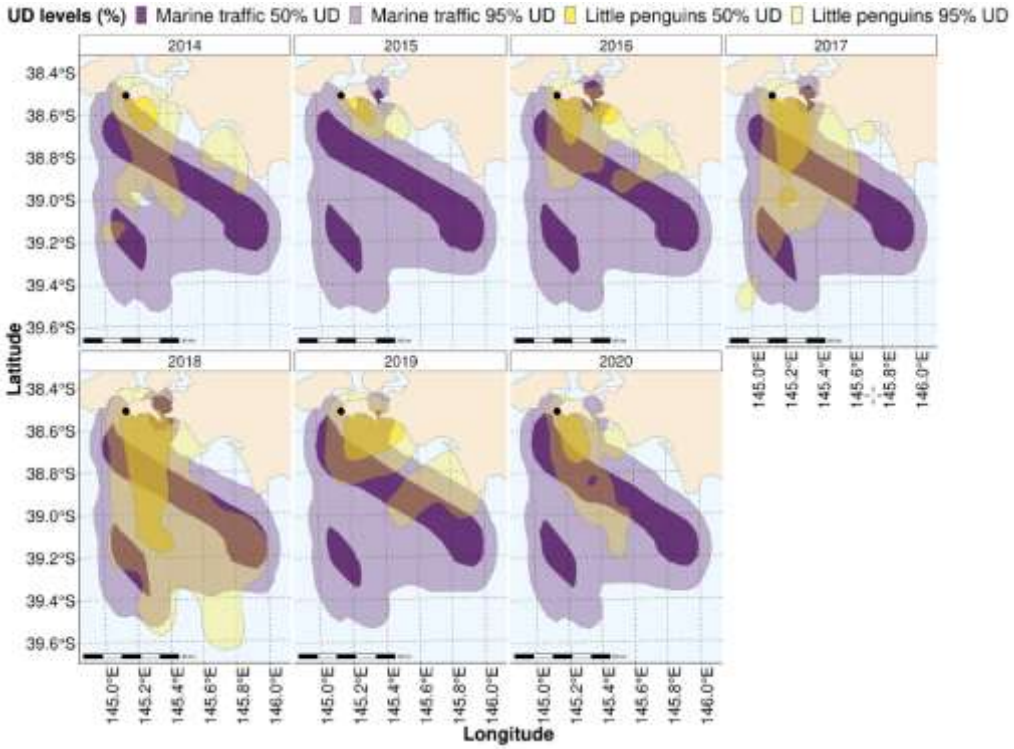


Theoretical path modelling showing relations between foraging, chick investment, breeding behaviour, longevity, phenology, mating behaviour, and sex. Negative associations indicated by red arrows, positive by green. It focuses on breeding success and fitness influenced by these factors.

Joly, N., A. Chiaradia, J.-Y. Georges and C. Saraux (2023). Unpacking the Lifelong Secrets of Little Penguins: Individual Quality, Energy Allocation, and Stochasticity in Defining Fitness. *Evolution*. https://doi.org/10.1093/evolut/qpad126

Penguin resilience at navigating anthropause

Amidst COVID-19, reduced human activity (anthropause) was expected to benefit marine ecosystems. We analysed 11 breeding seasons of little penguins, expecting changes due to decreased tourism and shipping. Surprisingly, tourism absence had no impact on penguins, and maritime traffic remained unchanged. While environmental fluctuations affected breeding behaviour, short-term anthropause had minimal impact. We detected a negative effect on the foraging efficiency in years of increased marine traffic. Our long-term data highlighted the resilience of penguins to pandemic-related disruptions, emphasizing the greater influence of environmental changes on their behaviour.



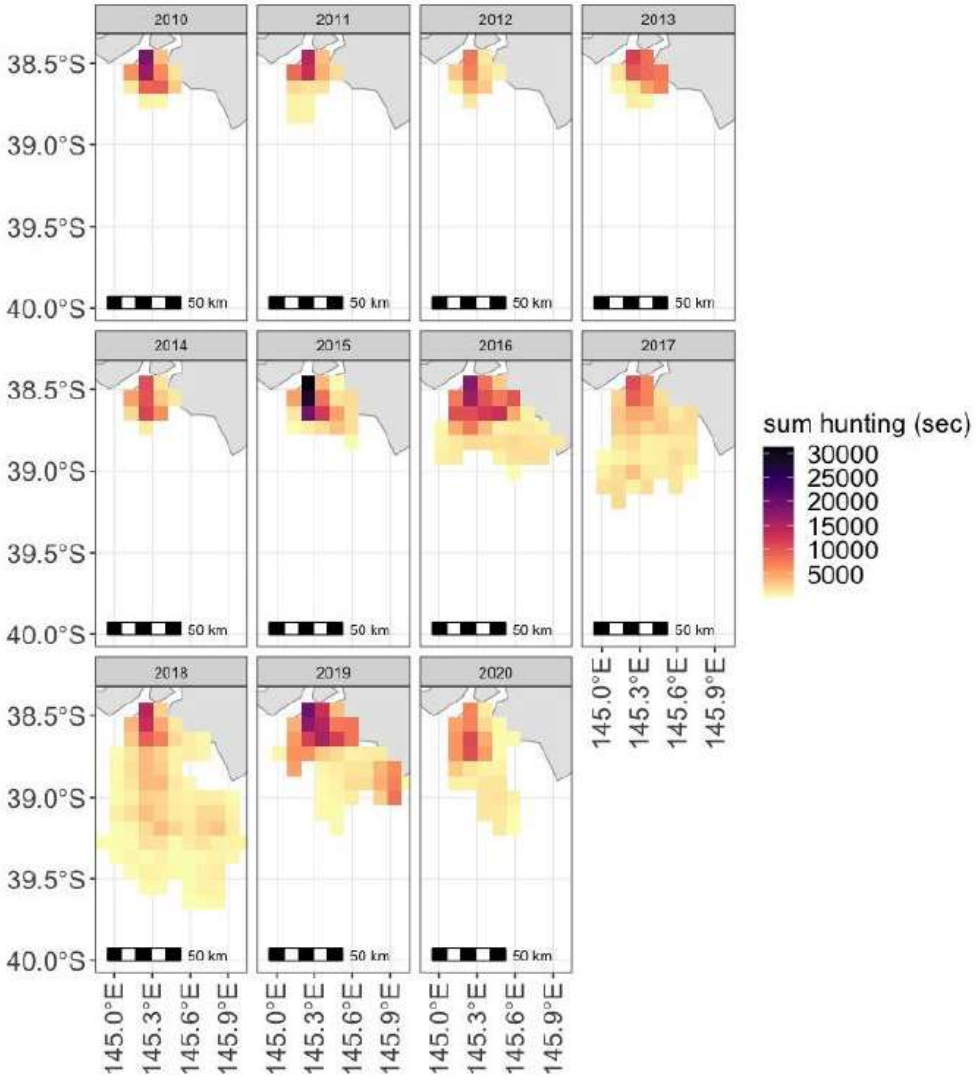
The overlap of the spatial distribution of penguins (yellow) in relation to marine traffic (purple)

Dupuis, B., A. Kato, N. Joly, C. Saraux, Y. Ropert-Coudert, A. Chiaradia and M. Chimienti (2023). COVID-related anthropause highlights the impact of marine traffic but not of tourism on breeding little penguins. *Biological Conservation* 287: 110323.

Dupuis, B., A. Kato, N. Joly, C. Saraux, Y. Ropert-Coudert, A. Chiaradia and M. Chimienti (2023). No impact of COVID-related anthropause on breeding little penguins. *BioRxiv*: 2023.2006.2030.547199.

Penguin guiding Marine Spatial Planning

Protected areas are vital for ecosystem preservation amidst global change. Bio-logging technology aids species monitoring and conservation efforts. Using GPS-accelerometer data, we studied little penguins at Phillip Island, uncovering insights into their foraging behaviour. Penguins adapt hunting strategies based on environmental conditions, emphasising the importance of such data for conservation planning. Our findings offer valuable information for future marine spatial planning, especially in the face of climate change. Integration of high-resolution data into conservation programs is recommended for effective planning and adaptation strategies.

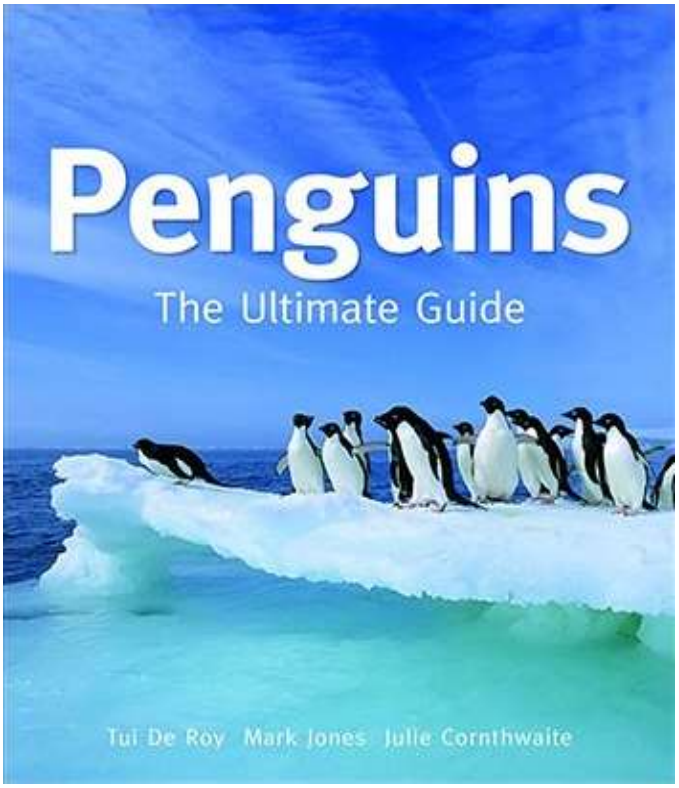


Total time spent hunting, obtained from GPS-accelerometer datasets, performed by 604 Little penguin across eleven breeding seasons. Rasters are at 10x10 Km resolution.

Chimienti, M., A. Chiaradia, B. Dupuis, N. Joly, C. Saraux, Y. Ropert-Coudert and A. Kato (2023). Decoding Ten Years of Little Penguin Foraging: Bio-Logging Reveals Foraging Patterns with Implications for Climate Change Mitigation and Marine Spatial Planning. *BioRxiv*: 2023.2010.2014.562344.

Smallest penguins face big challenges

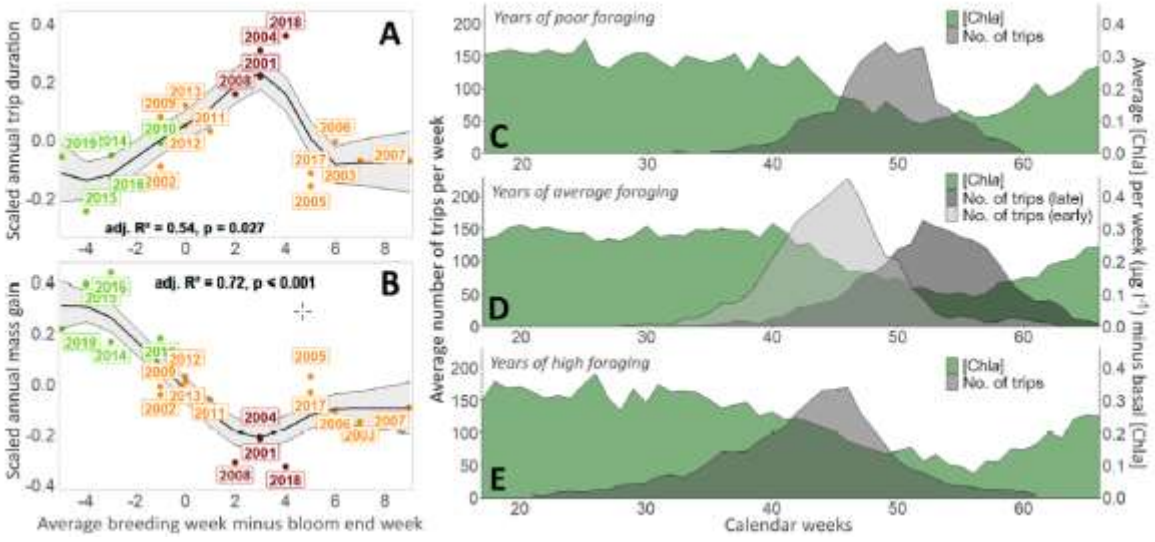
Little penguins, reliant on sardines, faced unprecedented challenges with the near-total collapse of sardine schools along the south Australian coast. Despite this, they showed resilience, adapting hunting strategies and targeting higher trophic level prey. They maintained breeding success and displayed remarkable individual traits. While conservation efforts have aided local populations, global threats like climate change and El Niño persist. Little penguins, the smallest of all penguins, navigate a changing world, facing significant challenges with their small size.



Chiaradia, A. (2022). Little blues: smallest penguins face big challenges. Book chapter in Penguins: The Ultimate Guide. T. De Roy, M. Jones and J. Cornthwaite, Princeton University Press.

How environment shapes little penguin foraging success

Foraging behaviours of little penguins were studied over 19 years, 400 individuals and >45,000 foraging trips to reveal seasonal variability with marked but inconsistent patterns. Inter-annually, foraging performance fell into three groups: low, average, and good, with post-guarding low performance linked to reduced breeding success. Environmental factors influencing foraging included currents, waves, tides, and prey availability, with waves and currents having a primary impact. Synchrony between penguin phenology and primary production cycles explained inter-annual foraging performance variations, underscoring the significance of seabird breeding phenology in understanding the environmental drivers of foraging behaviour in this climate change hotspot.

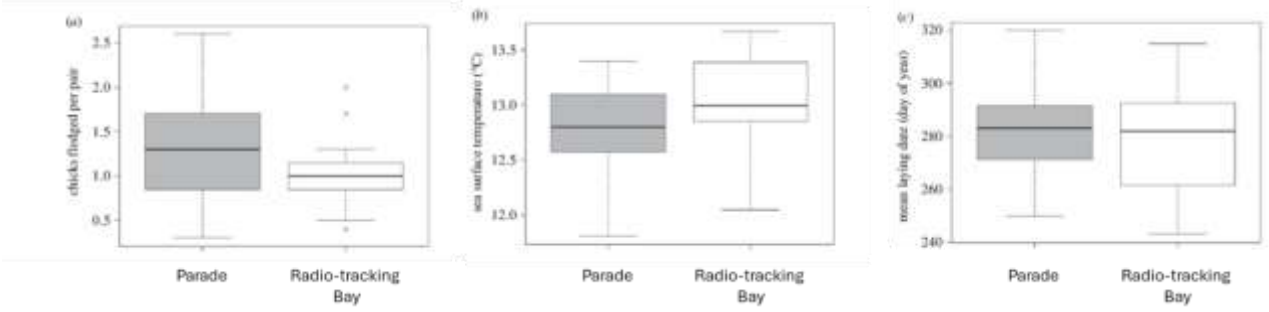


Figures show the synchronisation of little penguin foraging with primary production affects annual trip duration and mass gain. Graphs show trends with coloured points indicating foraging cluster quality. Weekly Chl-a concentration and trip density are also compared among clusters, with a distinction between early and very late breeding based on trip duration and mass gain.

Joly, N. B., A. Chiaradia, J. Y. Georges and C. Saraux (2022). Environmental effects on foraging performance in little penguins: a matter of phenology and short-term variability. *Marine Ecology Progress Series* 692: 151-168.

Exploring sub-colony differences in foraging and reproductive success

In the dynamic world of seabird ecology, understanding variations in foraging and reproductive success at different spatial scales remains a crucial challenge. Investigating little penguins at Phillip Island during breeding seasons revealed intriguing differences between nearby sub-colonies. While one sub-colony exhibited lower foraging success during certain breeding stages, the pattern reversed in others. Moreover, spanning over more than 10 years, data analysis showcased a negative relationship between reproductive success and sea surface temperature. These findings underscore the nuanced responses of seabird populations to environmental pressures, urging tailored conservation strategies at the sub-colony level to ensure the long-term survival.

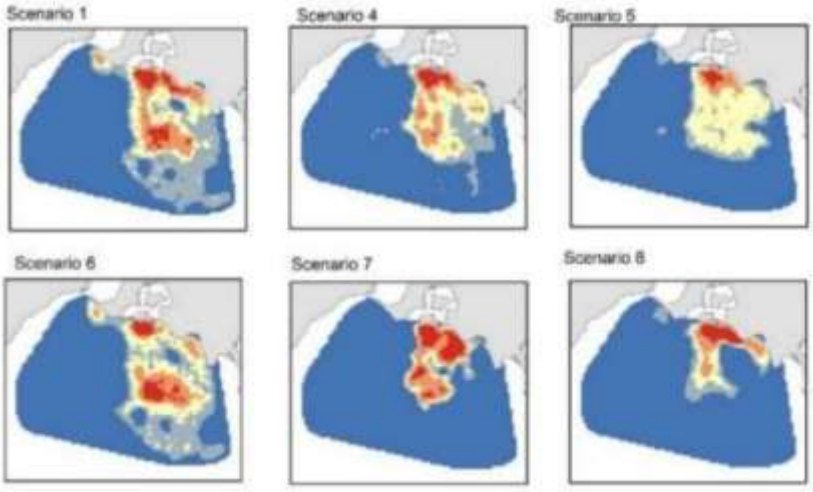


Boxplots compare (a) chicks fledged per adult pair, (b) sea surface temperature at foraging sites, and (c) mean egg-laying date showing differences between the two sub-colonies. Data span 2004–2018, with grey for Penguin Parade and white for Radio-tracking Bay.

Pulvirenti, J., R. D. Reina and A. Chiaradia (2023). Exploring sub-colony differences in foraging and reproductive success: the influence of environmental conditions on a central place foraging seabird. *Royal Society Open Science* 10(6): 220362.

Integrating animal tracking data into spatial conservation prioritisation

Understanding the marine habits of air-breathing breeding animals is vital for their conservation. Focusing on little penguins from Phillip Island, this study used tracking data to pinpoint key foraging areas during breeding. Analysing long-term data from sub-colonies and breeding stages, the study identified breeding success levels and explored specific habitats. Using Marxan, a conservation planning tool, it proposed static and dynamic spatial-temporal scenarios for protection based on kernel utilisation distributions (KUDs). The dynamic approach, more efficient and acceptable to stakeholders, highlighted core regions at sea for safeguarding. This research underscores the importance of comprehensive data in conservation planning and marine spatial prioritisation.



Selection frequencies for scenarios that capture different levels of detail in temporal dynamics of little penguin foraging ranges at Phillip Island

Venegas-Li, R., A. Chiaradia, H. Schinagl, A. Kato, Y. Ropert-Coudert, H. Possingham and R. D. Reina (2023). Integrating animal tracking data into spatial conservation prioritisation for seabirds during their breeding season. *BioRxiv*: 2023.2012.2014.571606.

SHEARWATERS

Disease surveillance for migrating shearwaters

Across the globe, there is an ongoing and profound impact of high pathogenicity avian influenza (HPAI) H5N1 on wildlife and poultry. The only continent that the virus has yet to arrive on is Australia. This study reports on the continued absence of HPAI and antibodies against lineage 2.3.4.4b HPAI from October – December 2023, in migratory birds shortly after their arrival in Australia. More than 230 short-tailed shearwaters, *Ardenna tenuirostris*, were tested on Phillip Island in both 2022 and 2023 as part of the surveillance study. Given the ever-changing phenotype of this virus, worldwide studies on the occurrence, or here absence of the virus, are of critical importance to understand the virus' dispersal and incursion risk and development of response strategies.

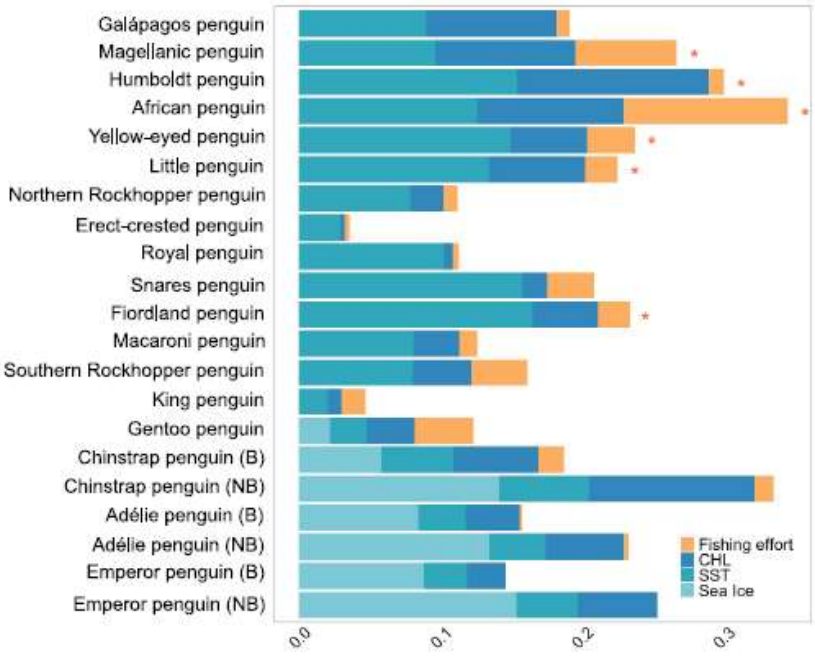
Short-tailed shearwaters returning to Phillip Island after their southerly migration.

Wille, M., Atkinson, R., Barr, I. G., Burgoyne, C., Bond, A. L., Boyle, D., Christie, M., Dewar, M., Douglas, T., Fitzwater, T., Hassell, C., Jessop, R., Klaassen, H., Lavers, J. L., Leung, K. K.-S., Ringma, J., Sutherland, D. R., and Klaassen, M. (2024). Long-Distance Avian Migrants Fail to Bring 2.3.4.4b HPAI H5N1 Into Australia for a Second Year in a Row. *Influenza and Other Respiratory Viruses* **18**, e13281. doi: 10.1111/irv.13281.

Local research to Regional and Global impact

Climate and human stressors on global penguin hotspots

Penguins serve as iconic ambassadors for Southern Hemisphere conservation. Yet, a comprehensive analysis of their multiple threats is lacking. Combining penguin occurrence data with climate-driven changes, industrial fisheries, and human disturbances, we assessed their impacts. We revealed spatially varying pressures, with Humboldt, African, and chinstrap penguins facing the most strain. The areas with the greatest impacts for penguins are the coast of Perú, the Patagonian Shelf, the Benguela region, and the Australian and New Zealand coasts. By distinguishing between climate and human stressors, we identify opportunities for local management to mitigate cumulative impacts. We called for coordinated efforts to gather data on underrepresented species like the northern rockhopper, erected-crested and Snares penguins.



Bar plots showing the cumulative index impact within each penguin hotspot. Asterisks (*) indicate species that have night lights, a proxy for human disturbance, present in their hotspots.

Gimeno, M., J. Giménez, A. Chiaradia, L. S. Davis, P. J. Seddon, Y. Ropert-Coudert, R. R. Reisinger, M. Coll and F. Ramírez (2024). Climate and human stressors on global penguin hotspots: Current assessments for future conservation. *Global Change Biology* 30(1): e17143.

Fur seal trends for the State of the Environment Report

Current conservation state and trends were presented as a marine index for the State of the Environment report. Three pinniped species, the Australian fur seal, long-nosed fur seal and Australian sea lion were included. Current information regarding a species description, their pressures and issues of importance, and current state and trends were provided as well as a discussion of each species resilience. Uncertainties, knowledge gaps, management opportunities and outlook for each species were highlighted. Australian fur seals were classified for 2021 as poor assessment grade with a deteriorating trend, long-nosed fur seals as a good grade with improving trend and the Australian sea lion as very poor grade with deteriorating trend. This process will be repeated every three years as an indicator for the health of the pinniped population of Australia and the ecosystem.

Assessment summary (see example assessment summary and key to grades for state, trend and confidence provided) for the Australian fur seal.

Year	Assessment grade		Confidence		Comparability with 2016 assessment
	Grade	Trend	Grade	Trend	
2021	Poor	Deteriorating	**Somewhat adequate:** Adequate high-quality evidence **or** high level of consensus	**Somewhat adequate:** Adequate high-quality evidence **or** high level of consensus	**Somewhat comparable:** Grade and trend are somewhat comparable to the previous assessment
2016	Good	Unclear	Limited evidence or limited consensus	Limited evidence or limited consensus	Grade and trend are somewhat comparable to the 2011 assessment

McIntosh, R. R. (2021). State and Trend Assessment: pinnipeds. State of the Environment 2021 Marine Expert Assessments. 17 pp.

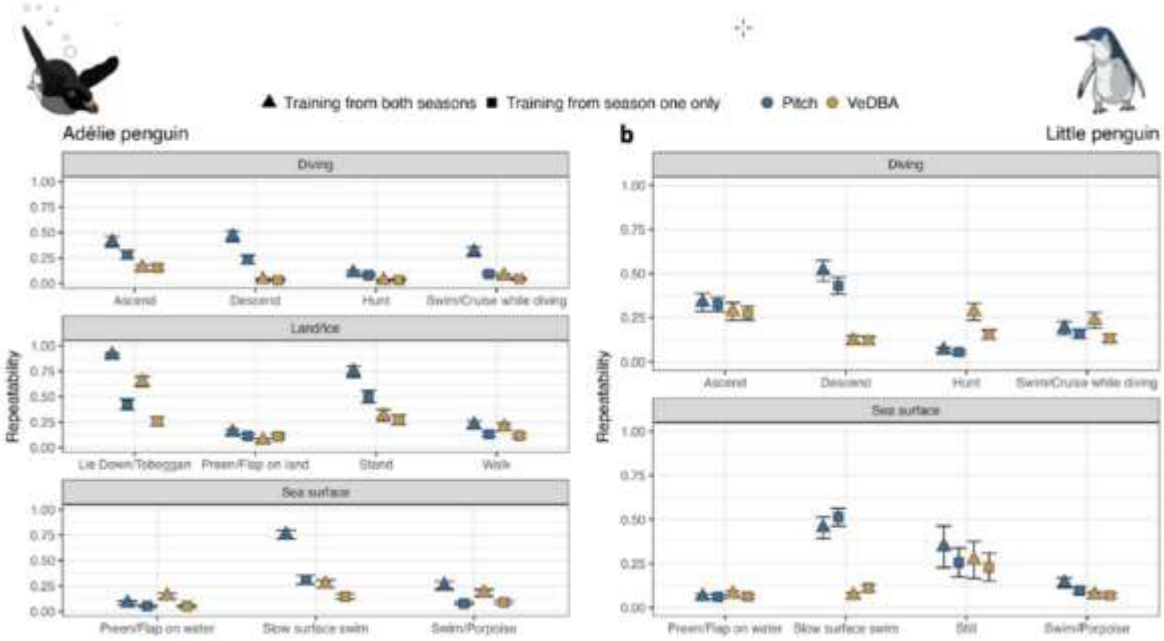
State of the Marine and Coastal Environment 2021 Report (published December 2021)

Nature Parks featured prominently across two volumes of the report, with two case studies showcasing success stories from Phillip Island. Penguins serve as key indicators, particularly in assessing the impact of light pollution, which has become a new environmental indicator based on research conducted on Phillip Island. Phillip Island research highlights efforts to mitigate light pollution's impact on wildlife. Our research also proves valuable in assessing regional pollution, with studies revealing entanglement issues among Australian fur seals and establishing baseline data on persistent organic pollutants in little penguins and short-tailed shearwaters.

Interpreting penguin behaviour using machine learning

Animal-borne bio-loggers generates vast and intricate datasets, challenging to analyse. We assessed AI tools' performance on increasingly voluminous and dimensional datasets, considering inter-individual variability. By integrating unsupervised and supervised machine learning, we predicted behaviours in two penguin species. The agreement between approaches exceeded 80%, with minimal differences in energy expenditure

estimates. Outliers, however, revealed confusion in similar behaviours. Our findings caution against upscaling predictions from large datasets, as accuracy may diminish. Researchers should exercise caution when extrapolating behaviour and energy expenditure estimates, ensuring robust analyses of bio-logging data to avoid inaccuracies.

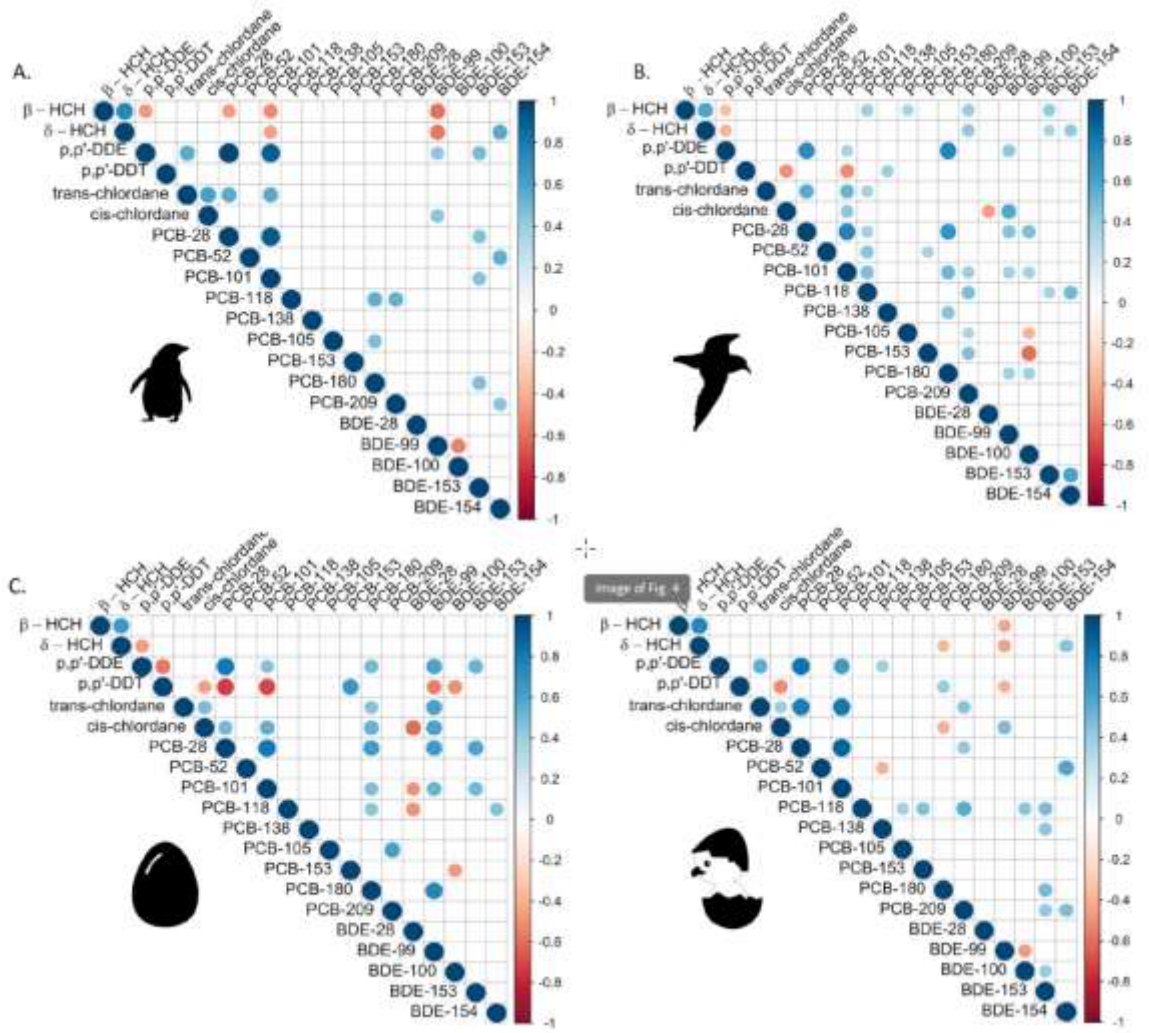


Agreement between training (blue) and predicted (yellow) for diving parameters

Chimienti, M., A. Kato, O. Hicks, F. Angelier, M. Beaulieu, J. Ouled-Cheikh, C. Marciau, T. Raclot, M. Tucker, D. M. Wisniewska, A. Chiaradia and Y. Ropert-Coudert (2022). The role of individual variability on the predictive performance of machine learning applied to large bio-logging datasets. *Scientific Reports* 12(1): 19737.

Legacy pollutants in a pristine environment

Persistent organic pollutants (POPs) pose a global threat, yet Antarctic seabirds' data is limited, leaving critical gaps. Blood samples offer snapshots of contamination but have been underused in Antarctica. This study unveils legacy POP levels (PCBs, OCPs, PBDEs) and novel NBFRs in five Antarctic seabird species. Adélie penguins exhibit high ∑PCB levels, emphasizing persistent contamination despite bans. Trace levels of PBDEs and NBFRs are detected, akin to Arctic seabirds. These findings bridge crucial gaps in Antarctic POP studies, vital for understanding and mitigating legacy contamination's impact on this pristine environment.

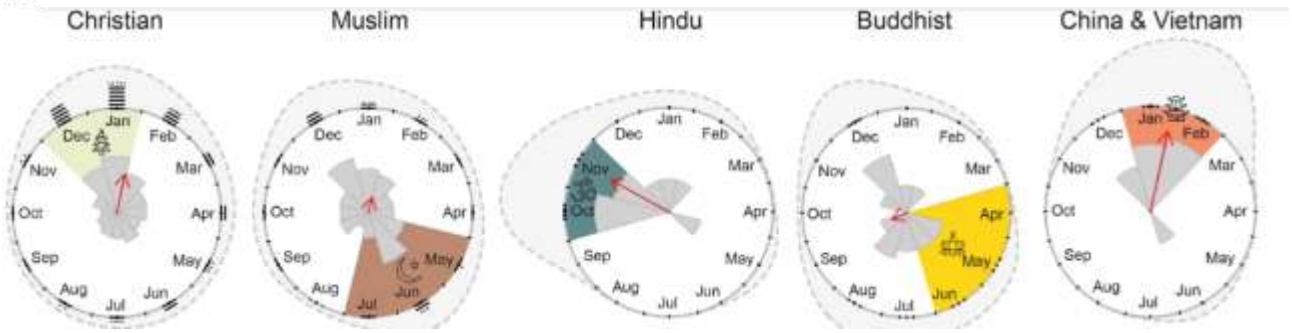


Rank correlations among contaminants in different groups of penguins and petrels. Blank squares signify insignificant correlations (P > 0.05). Positive correlations are blue, negative are red. Stronger correlations are darker/larger dots.

Lewis, P. J., A. Lashko, A. Chiaradia, G. Allinson, J. Shimeta and L. Emmerson (2022). New and legacy persistent organic pollutants (POPs) in breeding seabirds from the East Antarctic. *Environmental Pollution* 309: 119734.

Large-scale human celebrations increase global light pollution

Human cultural behaviours tied to artificial light usage shape global patterns of light pollution, impacting nocturnal ecosystems. By analysing global night lights data from 2014 to 2019, we found that cultural festivities and religious celebrations drive peaks in urban nighttime light intensity. For instance, Christmas lights illuminate Christian countries during December and January, while Muslim and Hindu countries glow during Ramadan and Karthika Masam. In contrast, Buddhist countries, lacking such festivities, exhibit more uniform light patterns. Understanding these cultural influences is crucial to mitigate the adverse effects of increasing light pollution on global nighttime ecology.



Night light monthly patterns per country and major cultural celebrations. Mean annual peak in night light per country according to their major cultural contexts.

Ramírez, F., Y. Cordón, D. García, A. Rodríguez, M. Coll, L. S. Davis, A. Chiaradia and J. L. Carrasco (2023). Large-scale human celebrations increase global light pollution. *People and Nature* DOI: 10.1002/pan3.10520.

Theses completed in 2022/24

Dupuis, B. (2023) The effect of anthropause caused by Covid-19 lockdown on little penguins. (MSc, Ecole Normale Superieure de Lyon, France. André Chiaradia, Yan Ropert-Coudert, Akiko Kato & Marianna Chimienti.)

Eketone, T. A. M. (2022) Long-nosed potoroo and eastern barred bandicoot activity and habitat use in relation to feral cat reduction on French Island , Victoria. Honours Thesis. (Deakin University.)

Gardner, Brett (2024). Surveillance for *Mycoplasma* and *Brucella* as potential etiological agents of abortion in Australian fur seals (*Arcocephalus pusillus doriferus*) in Victoria. PhD Candidate, University of Melbourne. Co-supervised by Dr Jasmin Hufschmid, Dr Marc Marenda, Dr Glenn Browning and Dr Andrew Stent (University of Melbourne), Dr John Arnould (Deakin University) and Dr Michael Lynch (Zoos Victoria).

Heward, M. (2022) The fate of rehabilitated orphaned common brushtail (*Trichosurus vulpecula*) & ringtail possums (*Pseudocheirus peregrinus*). Honours Thesis. (Deakin University: Burwood.)

Joly, N. (2024) Effects of environmental conditions on foraging performance of inshore seabirds (PhD, Universitate de Strasbourg. André Chiaradia, Claire Saraux & Jean-Yves Georges)

Moore E.R (2022). Impacts of marine heatwaves on the foraging and reproductive ecology of little penguins (Honours, Monash University, André Chiaradia & Richard Reina)

Pattison N. (2022). Mitigating anthropogenic light pollution: ecological implications and strategies for sustainable lighting (third year, University of Melbourne, André Chiaradia & Théresa Jones)

Petch, H. D. M. (2022) A Genetic Perspective on the Persistence of Eastern Barred Bandicoot on the Island Reserves of Churchill and Phillip Islands. Masters Thesis. (The University of Melbourne: Parkville.)

Reinhold, Sarah-Lena (2023). Shifting cultural-ecological baselines in the recovery of long-nosed fur seals and inquiry of the predator-prey relationship with little penguins. PhD Candidate, University of Adelaide. Co-supervised by Prof. Simon Goldsworthy (SARDI – Aquatic Sciences) and Prof Sean Connell (Adelaide University).

Williams, K. (2022) Ecology of the long-nosed potoroo (*Potorous tridactylus*) on French Island, Victoria. Honours Thesis. (Deakin University.)

11th International Penguin Conference (IPC)

Nature Parks have a strong presence at the 11IPC with 17 papers showcasing the little penguin research at Phillip Island. They are all related to the study of little penguins and their survival in changing environmental conditions. Some focus on specific factors affecting the penguins, such as increasing ocean temperatures and the effects of rivers on foraging ecology. Others explore new techniques for studying penguin behaviour, such as transponders and weighbridges. The COVID-19 pandemic did not significantly impact little penguins'

behaviour during breeding. Using fauna grids may help prevent penguin mortality, and bio-logger insights can assist with marine spatial planning. Studies also examine the individual quality, energy allocation, early growth effects on life-history traits and expansion of the penguin population to new sites. Finally, there are initiatives to promote global efforts towards the conservation of penguins in the face of climate change and human impacts.

1) Surviving the Heat: increasing ocean temperature and shifting breeding patterns of little penguins by the 22nd Century

   Andre Chiaradia, Catriona McCallum, Eleanor Moore, Leanne Nguyen, and Richard Reina

2) Penguin Monitoring 2.0: How Transponders and Weighbridges Revolutionised the Way We Study Penguins

   Andre Chiaradia, Ross Holmberg and Kean Maizels

3) Waddling to Success: Using Little Penguins as a Model for Business Strategy

   Jessica McKelson

4) Prey-mediated environmental effects on little penguins: using a sailing drone to monitor the marine ecosystem

   Claire Saraux, Lilia Guillet, Jonas Hentati-Sundberg and Andre Chiaradia

5) Tracing seal predation back to the source colony of their penguin prey: a trace element and stable isotope analysis.

   Sarah-Lena Reinhold, Simon D. Goldsworthy, John P.Y. Arnould, Bronwyn M. Gillanders, Sean D. Connell, Rebecca R. McIntosh

6) COVID-related anthropause did not affect little penguins' behaviour during breeding

   Ben Dupuis, Akiko Kato, Nicolas Joly., Claire Saraux , Yan Ropert-Coudert, Andre Chiaradia and Marianna Chimienti

7) Ten years of little penguin foraging in the Bass Strait: insights from Bio-loggers to assist Marine Spatial Planning

   Marianna Chimienti, Yan Ropert-Coudert, Benjamin Dupuis, Nicolas Joly, Claire Saraux, Andre Chiaradia and Akiko Kato2

8) Unpacking the Lifelong Secrets of Little Penguins: Individual Quality, Energy Allocation, and Stochasticity in Defining Fitness

   Nicolas Joly, Andre Chiaradia, Jean-Yves Georges and Claire Saraux

9) Chasing the fish with little penguins: spatial and temporal variability in relation to environmental conditions

   Lilia Guillet, Benjamin Dupuis, Nicolas Joly, Marianna Chimienti, Akiko Kato, Yan Ropert-Coudert, Jonas Hentati Sundberg, Andre Chiaradia, Claire Saraux

10) Fast vs. Slow: Investigating the Effects of Early Growth on Little Penguins' Life-History Traits

    Justine Wintz, Nicolas Joly, Stéphanie Jenouvrier, Andre Chiaradia, Claire Saraux

11) Using fauna grids to prevent penguin mortality

    Leanne Renwick, Andre Chiaradia, Ross Holmberg, Damian Prendergast

12) The Fall and Rise of the Little Penguin on Phillip Island, Australia.

    Paula Wasiak, Leanne Renwick & Meagan Tucker

13) Effects of rivers on seabird foraging ecology

    Julia Morais, Andre Chiaradia, Richard Reina

14) The hotter, the worse: Little penguin population responses to increasing ocean temperatures in New Zealand.

    Francisco Ramírez, Míriam Gimeno, Philippa Agnew, Thomas Mattern, Richard Reina, Phil Seddon, Kerry-Jayne Wilson, Andre Chiaradia,

15) Safe Operating Space for Penguins (SOS Penguins)" initiative: a global effort towards the IUCN-Penguin Specialist Group vision of "penguins in perpetuity"

    Zuzana Zajková, Yan Ropert-Coudert, Andre Chiaradia, Phil Seddon, Francisco Ramírez

16) Climate and human impacts on global penguin hotspots; current assessments for future conservation

    Míriam Gimeno, Joan Giménez, Andre Chiaradia, Lloyd S. Davis, Phil Seddon, Yan Ropert-Coudert, Marta Coll, Francisco Ramírez

17) IUCN SSC Penguin Specialist Group – member feedback and way forward

    Waller L.J., Garcia Borboroglu P., Boersma P.D., Bost C., Chiaradia A., Dewar M., Ellis S., Schneider T., Seddon P.J., Simeone A., Trathan P.N., Wienecke B.