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# Human-bottlenose dolphin interactions within wildlife tourism, ocean recreation and fisheries

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## Abstract

Bottlenose dolphins (*Tursiops truncatus* and *Tursiops aduncus*; BND) live in coastal waters, prompting frequent contact with humans. Interaction with BND can be either planned (e.g. swim-with-dolphin experiences) or chance (e.g. BND surfing on boat wakes). These charismatic cetaceans are common in many forms of wildlife tourism, including marine wildlife tours, swim-with-dolphin experiences and hand feeding. BND also interact with humans by chance during ocean recreation activities, such as surfing, swimming and boating. Within fisheries, there is both cooperation and conflict between humans and BND. Through a literature review, this paper highlights the effects such interactions cause to both BND and humans with a focus on wildlife tourism, ocean recreation and fisheries.

## Keywords

dolphins, fisheries, human-wildlife interactions, ocean recreation, wildlife tourism

## Introduction

Bottlenose dolphins (*Tursiops truncatus* [Montagu, 1821] and *Tursiops aduncus* [Ehrenberg, 1832]) (BND) inhabit a large geographical range, spanning coastal and offshore

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habitats from cold-temperate to tropical waters globally.<sup>1</sup> Within coastal waters, BND exist as a complex network of populations and ecotypes, inhabiting diverse environments and displaying high ecological specialisation and behavioural plasticity.<sup>2</sup> The geographical range of BND frequently overlaps with intense coastal anthropogenic activity, which itself varies in intensity and form. Moreover, as charismatic, coastal megafauna, BND are a primary target of marine wildlife tourism.<sup>3</sup> As a result, BND populations and human coastal activities interact in complex and myriad ways, with varying effects on both dolphins and humans.

There is a long history of wildlife interactions between humans and BND due to their coastal habitat ranges and willingness to initiate human contact.<sup>4</sup> Modern-day human-BND interactions have shifted greatly from those of the past. In the 1800's BND were referred to in disgust as 'herring hogs' by Atlantic coast fishers and even hunted up until the 1950's for the oil found in their jaw ducts.<sup>5</sup> Following short-lived attempts at cetacean captivity in the latter half of the 19th century,<sup>6</sup> public interest in BND began in earnest with the opening of *Marine Studios*, the first aquarium to publically display captive BND and permit filming of the animals for entertainment.<sup>7</sup> Research conducted in the early days of cetacean captivity by pioneers such as Ken Norris, drew interest from the public and researchers as the level of BND intelligence and their ability to echolocate were discovered.<sup>8</sup> Interest in dolphin capabilities for military application began during the cold war as the U.S. Office of Naval Research (ONR) began their Navy Marine Mammal Program. It was the research outputs from ONR describing BND intelligence which ultimately led to dolphins becoming a symbol for 1970's environmentalists, successfully shifting public attitudes towards marine conservation and the scaling back of whaling.<sup>9</sup> Increased research efforts, establishments of marine park attractions, and TV shows such as the 1964–1967 *Flipper* influenced the general public to develop empathy towards dolphins, which were generally perceived to be harmless, peaceful animals.<sup>10</sup> As public

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<sup>1</sup>Carwardine, M. *Handbook of Whales, Dolphins and Porpoises*. (Bloomsbury, 2019).

<sup>2</sup>Shane, S. H., Wells, R. S. & Würsig, B. Ecology, Behavior and Social Organization of the Bottlenose Dolphin: A Review. *Mar. Mammal Sci.* **2**, 34–63 (1986). doi:10.1111/j.1748-7692.1986.tb00026.x.

<sup>3</sup>Barney, E. C., Mintzes, J. J. & Yen, C. F. Assessing Knowledge, Attitudes, and Behavior Toward Charismatic Megafauna: The Case of Dolphins. *J. Environ. Educ.* **36**, 41–55 (2005).

<sup>4</sup>Frohoff, T. G. & Packard, J. M. Human Interactions with Free-Ranging and Captive Bottlenose Dolphins. *Anthrozoos* **8**, 44–53 (1995). doi:10.2752/089279395787156527.

<sup>5</sup>Burnett, D. G. A Mind in the Water: The Dolphin as a Beast of Burden. *Orion* **29**, 38–51 (2010).

<sup>6</sup>Corkeron, P. Captivity. in *Encyclopedia of Marine Mammals* 183–188 (Academic Press, 2009). doi:10.1016/B978-0-12-373553-9.00049-3.

<sup>7</sup>Mitman, G. A Ringside Seat in the Making of a Pet Star. in *Reel Nature: America's Romance with Wildlife on Film* (ed. Cronon, W.) 157–179 (1999).

<sup>8</sup>Norris, K. *The Porpoise Watcher: A Naturalist's Experiences with Porpoises and Whales*. (W.W. Norton & Company Inc., 1974).

<sup>9</sup>Colby, J. M. Conscripting Leviathan: Science, Cetaceans, and the Cold War. *Dipl. Hist.* **44**, 466–478 (2020). doi:10.1093/dh/dhaa011.

<sup>10</sup>Mazzoldi, C. et al. From sea monsters to charismatic megafauna: Changes in perception and use of large marine animals. *PLoS One* **14**, e0226810 (2019). doi:10.1371/journal.pone.0226810.

perception of dolphins evolved, so did the human-dolphin relationship as beachgoers began to seek out opportunities to closely interact with BND in their natural habitats.

The form of human-dolphin interactions can range from mutually beneficial to sublethal disturbance for BND populations and even fatalities for both humans and dolphins. Human-wildlife conflict is pervasive throughout marine ecosystems,<sup>11</sup> and may lead to adverse impacts for dolphins and/or humans. However, many interactions are considered neutral for both parties.<sup>12</sup> To illustrate this range of interactive outcomes, we focus on three primary sources of interaction and conflict. Firstly, as a charismatic, curious species, BND are a primary cetacean target of marine wildlife tourism,<sup>13</sup> and provide meaningful experiences for humans, but short-term behavioural disturbance of dolphins may lead to long-term population consequences. Secondly, the interactions between BND and coastal marine recreation are generally neutral but can also lead to direct conflict. Thirdly, coastal fisheries interact with BND in various forms, from deliberate cooperation to the incidental primary driver of dolphin mortality. For each source, the outcome of the interaction may depend on its intensity, spatiotemporal extent, the intention of the interaction (from both human and dolphin perspectives) and the specific BND population. As arguably the most studied cetacean species,<sup>14</sup> each interaction type has been extensively characterised, but key knowledge gaps still remain, particularly regarding the population consequences of disturbance and cumulative effects of multiple interaction types.

## Wildlife tourism

In the past three decades wildlife tourism has moved from a niche activity accessible to few to a mainstream experience, with marine wildlife tourism among the fastest-growing tourism sectors.<sup>15,16,17,18</sup> BND tourism holds particularly wide appeal among the public, in part due to BND being among the most charismatic wildlife.<sup>3</sup> There is also a perception

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<sup>11</sup>Guerra, A. S. Wolves of the Sea: Managing human-wildlife conflict in an increasingly tense ocean. *Mar. Policy* **99**, 369–373 (2019). doi:10.1016/j.marpol.2018.11.002.

<sup>12</sup>Fandel, A. D., Bearzi, M. & Cook, T. C. Effects of Ocean Recreational Users on Coastal Bottlenose Dolphins (*Tursiops truncatus*) in the Santa Monica Bay, California. *Bull. South. Calif. Acad. Sci.* **114**, 63–75 (2015). doi:10.3160/0038-3872-114.2.63.

<sup>13</sup>Samuels, A., Bejder, L., Constantine, R. & Heinrich, S. Swimming with wild cetaceans, with a special focus on the Southern Hemisphere. in *Marine mammals: fisheries, tourism and management issues* 277–303 (2003).

<sup>14</sup>Hill, H. & Lackups, M. Journal Publication Trends Regarding Cetaceans Found in Both Wild and Captive Environments: What do we Study and Where do we Publish? *Int. J. Comp. Psychol.* **23**, 414–534 (2010).

<sup>15</sup>Bruce, B. D. & Bradford, R. W. The effects of shark cage-diving operations on the behaviour and movements of white sharks, *Carcharodon carcharias*, at the Neptune Islands, South Australia. *Mar. Biol.* **160**, 889–907 (2013). doi:10.1007/S00227-012-2142-Z.

<sup>16</sup>Burgin, S. & Hardiman, N. Effects of non-consumptive wildlife-oriented tourism on marine species and prospects for their sustainable management. *J. Environ. Manage.* **151**, 210–220 (2015). doi:10.1016/j.jenvman.2014.12.018.

<sup>17</sup>Curtin, S. Swimming with dolphins: a phenomenological exploration of tourist recollections. *Int. J. Tour. Res.* **8**, 301–315 (2006). doi:10.1002/jtr.577.

<sup>18</sup>O'Connor, S., Campbell, R., Cortez, H. & Knowles, T. *Whale watching worldwide: tourism numbers, expenditures and expanding economic benefits.* <https://www.cabdirect.org/cabdirect/abstract/20093176034> (2009).

amongst participants of BND tourism that the experience improves their own physical and emotional wellbeing,<sup>19</sup> and that the dolphins also enjoy the interaction.<sup>17</sup> The anthropomorphism of BND by participants in wildlife tourism has been explored by other studies, with Freeman and Kreuter,<sup>20</sup> and Smith *et al.*<sup>21</sup> suggesting that humans connect with BND as their playfulness, curiosity and social habits mirror attributes present in humans.<sup>22</sup>

### Tour boats

BND behaviour can change with their proximity to sightseeing boats. BND spend less time resting, socialising and foraging<sup>23,24,25</sup> and engage in increased milling (grouping together) when more tour boats are nearby.<sup>26</sup> This milling behaviour indicates stress as BND will group closer together when they feel threatened.<sup>27</sup> BND may also change their behaviour more when a tour boat is near compared to other vessels, likely due to tour boats following the pod unlike other vessels.<sup>26</sup> Long-term impacts of tour boats on BND have also been observed, with BND populations in Shark Bay, Australia declining by 14.9% over 4.5 years when two boat tours operated in the area compared to a control site where no tours operated.<sup>28</sup> There is competing evidence of the effect of tour boat noise on BND behaviour. It has been shown to interfere with communication between BND and over ride other biologically important sounds in some studies.<sup>29</sup>

<sup>19</sup>Webb, N. L. & Drummond, P. D. The Effect of Swimming with Dolphins on Human Well-Being and Anxiety. *Anthrozoos* **14**, 81–85 (2001). doi:10.2752/089279301786999526.

<sup>20</sup>Freeman, M. M. R. & Kreuter, U. P. *Elephants and whales: resources for whom?* (Gordon and Breach Science Publishers, 1994).

<sup>21</sup>Smith, A., Newsome, D., Lee, D. & Stoeckl, N. *The role of wildlife icons as major tourist attractions: case studies: Monkey Mia dolphins and Hervey Bay whale watching.* <https://researchrepository.murdoch.edu.au/id/eprint/2605/> (2006).

<sup>22</sup>Patroni, J., Newsome, D., Kerr, D., Sumanapala, D. P. & Simpson, G. D. Reflecting on the human dimensions of wild dolphin tourism in marine environments. *Tour. Hosp. Manag.* **25**, 141–160 (2019). doi:10.20867/thm.25.1.8.

<sup>23</sup>Scarpaci, C., Nuggeoda, D. & Corkeron, P. Nature-based Tourism and the Behaviour of Bottlenose Dolphins ‘Tursiops’ Spp. in Port Phillip Bay, Victoria, Australia. *Vic. Nat.* **127**, 64–70 (2010).

<sup>24</sup>Wiener, C. S. Dolphin Tourism and Human Perceptions: Social Considerations to Assessing the Human-Dolphin Interface. in *Animals and Tourism: Understanding Diverse Relationships* 146–162 (Channel View Publications, 2015). doi:10.21832/9781845415051-013.

<sup>25</sup>Christiansen, F., Lusseau, D., Stensland, E. & Berggren, P. Effects of tourist boats on the behaviour of Indo-Pacific bottlenose dolphins off the south coast of Zanzibar. *Endanger. Species Res.* **11**, 91–99 (2010). doi:10.3354/esr00265.

<sup>26</sup>Constantine, R., Brunton, D. H. & Dennis, T. Dolphin-watching tour boats change bottlenose dolphin (*Tursiops truncatus*) behaviour. *Biol. Conserv.* **117**, 299–307 (2004). doi:10.1016/j.biocon.2003.12.009.

<sup>27</sup>Steckenreuter, A., Möller, L. & Harcourt, R. How does Australia’s largest dolphin-watching industry affect the behaviour of a small and resident population of Indo-Pacific bottlenose dolphins? *J. Environ. Manage.* **97**, 14–21 (2012). doi:10.1016/j.jenvman.2011.11.002.

<sup>28</sup>Bejder, L. et al. Decline in Relative Abundance of Bottlenose Dolphins Exposed to Long-Term Disturbance. *Conserv. Biol.* **20**, 1791–1798 (2006). doi:10.1111/j.1523-1739.2006.00540.x.

<sup>29</sup>Luis, A. R., Couchinho, M. N. & dos Santos, M. E. Changes in the acoustic behavior of resident bottlenose dolphins near operating vessels. *Mar. Mammal Sci.* **30**, 1417–1426 (2014). doi:10.1111/mms.12125.

Lusseau<sup>30</sup> found that BND avoid tour boats by increasing dive times. Female BND in particular use this vertical avoidance strategy when boats become intrusive. Nursing mothers change their behaviour, swimming more often when tour ships are nearby,<sup>31</sup> leading to less time for calves to nurse. Stensland and Berggren<sup>31</sup> hypothesise that an increased number of tour boats could cause a shift in habitat for the nursing mothers as they abandon sites where there is heavy tourism-based boat traffic.

### Swim-with experiences

Swimming with BND is one of the most desired dolphin interaction experiences.<sup>22</sup> Wiener<sup>24</sup> hypothesises that swimming with BND is seen as desirable due to the more intimate experience, with participants connecting more emotionally with the animals. These swim-with-dolphin experiences are offered with both BND in captivity and in the wild. Swim experiences with wild dolphins can be organised by a commercial operator on a regulated or unregulated basis or can occur when visitors seek out dolphins whilst performing another activity.<sup>17,32,33</sup>

Swim-with-dolphin experiences have been shown to have direct negative impacts on wild dolphins.<sup>22</sup> The level of impact is influenced by whether the interaction is active, with humans approaching the BND, or passive, with humans waiting for BND to approach.<sup>34</sup> Many of the same negative impacts observed during tour boat interactions with BND also occur as a result of swim-with-dolphin experiences.<sup>32,34,35,36</sup> An example of changed social behaviours was observed by Scarpaci *et al.*,<sup>37</sup> with their study finding whistling increased when swim-with-dolphins tour boats arrived in dolphin habitats. This increased vocalization indicates that group cohesion is impacted when tourists swim with dolphins as BND increase whistling to keep in contact with their pod when stressed.<sup>38</sup>

<sup>30</sup>Lusseau, D. Male and female bottlenose dolphins *Tursiops* spp. have different strategies to avoid interactions with tour boats in Doubtful Sound, New Zealand. *Mar. Ecol. Prog. Ser.* **257**, 267–274 (2003). doi:10.3354/meps257267.

<sup>31</sup>Stensland, E. & Berggren, P. Behavioural changes in female Indo-Pacific bottlenose dolphins in response to boat-based tourism. *Mar. Ecol. Prog. Ser.* **332**, 225–234 (2007). doi:10.3354/meps332225.

<sup>32</sup>Samuels, A., Bejder, L. & Heinrich, S. *A Review of the Literature Pertaining to Swimming with Wild Dolphins*. (2000).

<sup>33</sup>Spradlin, T., Barre, L., Lewandowski, J. & Nitta, E. Too Close for Comfort: Concern About the Growing Trend in Public Interactions with Wild Marine Mammals. *Mar. Mammal Soc. Newsl.* **9**, (2001).

<sup>34</sup>Bearzi, M. Impacts of Marine Mammal Tourism. in *Ecotourism's Promise and Peril: A Biological Evaluation* (eds. Blumstein, D., Geffroy, B., Samia, D. & Bessa, E.) 73–96 (Springer International Publishing, 2017). doi:10.1007/978-3-319-58331-0\_6.

<sup>35</sup>Filby, N. E., Stockin, K. A. & Scarpaci, C. Social science as a vehicle to improve dolphin-swim tour operation compliance? *Mar. Policy* **51**, 40–47 (2015). doi:10.1016/j.marpol.2014.07.010.

<sup>36</sup>Peters, K. J., Parra, G. J., Skuza, P. & Möller, L. First insights into the effects of swim-with-dolphin tourism on the behavior, response, and group structure of southern Australian bottlenose dolphins. *Mar. Mammal Sci.* **29**, 484–497 (2012). doi:10.1111/mms.12003.

<sup>37</sup>Scarpaci, C., Bigger, S. W., Corkeron, P. J. & Nugegoda, D. Bottlenose dolphins (*Tursiops truncatus*) increase whistling in the presence of 'swim-with-dolphin' operations. *J. Cetacean Res. Manag.* **2**, 183–185 (2000).

<sup>38</sup>Esch, H. C., Sayigh, L. S., Blum, J. E. & Wells, R. S. Whistles as potential indicators of stress in bottlenose dolphins (*tursiops truncatus*). *J. Mammal.* **90**, 638–650 (2009). doi:10.1644/08-MAMM-A-069R.1.

Another change in dolphin behaviour observed during swim-with experiences is avoidance. In New Zealand, sensitization occurred as BND increased avoidance behaviour as swim-with-dolphin tourism increased.<sup>39</sup> However, Peters *et al.*,<sup>36</sup> found that BND in the Gulf of St. Vincent, Australia did not mill together or see human swimmers as a threat. They hypothesise that BND in St. Vincent may be less affected by the presence of humans due to comparatively low levels of tourism.

Another issue arising from swim-with-dolphin experiences is the desire of participants to touch the BND.<sup>17,24</sup> This increases the physical risk to both humans and BND, as well as providing the opportunity for transfer of parasites and diseases.<sup>34</sup> Aggressive BND behaviour towards humans is more common and better documented during captive swim-with-dolphin experiences. During captive swim-with-dolphin experiences human participants have been seriously injured as a result of aggressive BND behaviour including ramming, biting and slapping with flukes.<sup>4,40,41,42</sup> Human injuries and deaths can also occur during wild swim-with-dolphin experiences, although these attacks are rare. For wild BND these accounts of injuring swimmers and waders appear to occur in unusual or stressful circumstances, such as inappropriate behaviour by humans,<sup>43</sup> or humans seeking out BND and touching them.<sup>44</sup> The first documented account of a man being killed by a wild BND occurred off the coast of Brazil in 1994, apparently in response to the man tying objects to the flukes of the BND and attempting to force objects into its blowhole.<sup>4</sup> It is hypothesised that this aggressive behaviour towards humans results from BND expecting humans to fulfil social roles usually filled by other BND, and then being frustrated when the expected response does not occur.<sup>4</sup> Whilst such anecdotal evidence exists of humans touching wild BND during swim-with experiences, Wiener,<sup>24</sup> and Patroni,<sup>22</sup> note that there is a lack of detail regarding these interactions, with no research available analysing their impact.

## Feeding dolphins

The provisioning of food to entice wild BND to come into closer contact with wildlife tourism participants is commonly used by tour operators to improve the visitor experience

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<sup>39</sup>Constantine, R. Increased avoidance of swimmers by wild bottlenose dolphins (*Tursiops truncatus*) due to long-term exposure to swim-with-dolphin tourism. *Mar. Mammal Sci.* **17**, 689–702 (2001). doi:10.1111/j.1748-7692.2001.tb01293.x.

<sup>40</sup>10-year-old attacked by dolphins: the dangers of wild animal interactions. *World Animal Protection* <https://www.worldanimalprotection.org/blogs/10-year-old-attacked-dolphins-dangers-wild-animal-interactions> (2019).

<sup>41</sup>Orams, M. B. Historical accounts of human-dolphin interaction and recent developments in wild dolphin based tourism in Australasia. *Tour. Manag.* **18**, 317–326 (1997). doi:10.1016/S0261-5177(96)00022-2.

<sup>42</sup>Holly, J. Trainer attacked by dolphin at Miami Seaquarium. *WSVN 7News* <https://wsvn.com/news/local/trainer-attacked-by-dolphin-at-miami-seaquarium/> (2022).

<sup>43</sup>Lockyer, C. Review of Incidents Involving Wild, Sociable Dolphins, Worldwide. in *The Bottlenose Dolphin* (eds. Leatherwood, S. & Reeves, R.) 337 (Academic Press, Inc., 1990).

<sup>44</sup>Ryan, V. Experience: I was attacked by a dolphin. *The Guardian* (2014).

and levels of satisfaction.<sup>45,46</sup> Habituation of wild BND being hand fed in Shark Bay, Australia has been ongoing since the 1950's with this physical contact during provisioning potentially having increased BND mortality through exposure to human pathogens.<sup>47</sup> Provisioning can also affect reproductive success as calves born to provisioned mothers are more than twice as likely to die in the first year than calves born to non-provisioned females due to reduced parental care for their calves.<sup>48,49</sup> In contrast, other studies have found 100% calf survival even for orphaned calves at some provisioning sites.<sup>50</sup> In this case it was hypothesised that this outcome was achieved due to the isolated location of the site, high-water quality and controlled wildlife tourism management of the area.<sup>50</sup>

Just as BND come to feeding areas, so do their predators. The increased number of sharks frequenting Morton Bay, Australia for hand-outs may cause the frequent attacks on BND.<sup>46</sup> Other risks associated with feeding occur when BND become conditioned to humans<sup>22</sup> as they can approach vessels begging for food, increasing the amount and type of food they eat, as well as their risk of being struck by vessels or entangled in fishing gear.<sup>51,52,53</sup>

## Ocean recreation

Human-dolphin interactions occur regularly in the wild during recreation activities like swimming, sailing and surfing. Illegally feeding BND during these interactions can put dolphins and humans in danger as well as cause nutritional issues for dolphins. Bryant,<sup>54</sup> found that people in the Southeast USA were feeding BND potato chips, marshmallows and other non-suitable foods. In Sarasota Bay, Florida, USA, recreational swimmers and

<sup>45</sup>Bach, L. & Burton, M. Proximity and animal welfare in the context of tourist interactions with habituated dolphins. *J. Sustain. Tour.* **25**, 181–197 (2016). doi:10.1080/09669582.2016.1195835.

<sup>46</sup>Orams, M. B. Feeding wildlife as a tourism attraction: a review of issues and impacts. *Tour. Manag.* **23**, 281–293 (2002). doi:10.1016/S0261-5177(01)00080-2.

<sup>47</sup>Neil, D. T. & Brieze, I. *Wild Dolphin Provisioning at Tangalooma, Moreton Island: An Evaluation*. (1998).

<sup>48</sup>Mann, J., Connor, R. C., Barre, L. M. & Heithaus, M. R. Female reproductive success in bottlenose dolphins (*Tursiops* sp.): life history, habitat, provisioning, and group-size effects. *Behav. Ecol.* **11**, 210–219 (2000). doi:10.1093/beheco/11.2.210.

<sup>49</sup>Foroughirad, V. & Mann, J. Long-term impacts of fish provisioning on the behavior and survival of wild bottlenose dolphins. *Biol. Conserv.* **160**, 242–249 (2013). doi:10.1016/j.biocon.2013.01.001.

<sup>50</sup>Neil, D. T. & Holmes, B. J. Survival of Bottlenose Dolphin (*Tursiops* sp.) Calves at a Wild Dolphin Provisioning Program, Tangalooma, Australia. *Anthrozoos* **21**, 57–69 (2008). doi:10.2752/089279308X274065.

<sup>51</sup>Christiansen, F. et al. Food provisioning increases the risk of injury in a long-lived marine top predator. *R. Soc. Open Sci.* **3**, (2016). doi:10.1098/rsos.160560.

<sup>52</sup>Donaldson, R., Finn, H. & Calver, M. Illegal feeding increases risk of boat-strike and entanglement in Bottlenose Dolphins in Perth, Western Australia. *Pacific Conserv. Biol.* **16**, 157–161 (2010). doi:10.1071/PC100157.

<sup>53</sup>Hazelkorn, R. A., Schulte, B. A. & Cox, T. M. Persistent effects of begging on common bottlenose dolphin (*Tursiops truncatus*) behavior in an estuarine population. *Aquat. Mamm.* **42**, 531–541 (2016). doi:10.1578/AM.42.4.2016.531.

<sup>54</sup>Bryant, L. *Report to Congress on Results of Feeding Wild Dolphins, 1989-1994*. <https://repository.library.noaa.gov/view/noaa/16196> (1994).



boaters feed and touch BND illegally. When questioned, over half of the public were aware these were illegal and potentially harmful activities.<sup>55</sup> In Panama City Beach, Florida, USA, Samuels and Bejder,<sup>56</sup> investigated several wild human-dolphin interactions resulting from food provisioning, that violated the USA Marine Mammal Protection Act (Marine Mammal Protection Act of the United States, 16 U.S.C. 1421h). One juvenile was affected by these interactions to such an extent that he and the humans interacting with him were in danger every 12 min, and 29 min, respectively.<sup>56</sup>

BND feeding habits can be severely impacted through their interaction with recreational fishers. BND depredation is a significant issue in Sarasota Bay, Florida, USA, that is expected to increase with the decline of prey populations, cultural transmission of depredation behaviour and the continued illegal feeding of wild BND by humans.<sup>57</sup> BND depredation increases their risk of serious injury through boat strikes and fishing gear entanglement or ingestion; this degradation of the recreational fishing experience also makes human retaliation more likely.<sup>57</sup> In the Indian River Lagoon, Florida, where BND chase lines, remove hooked fish and beg at recreational fishing boats, there have been several reports of fishing hooks embedded in the mouths of BND.<sup>58</sup> This was also reported in Perth, Australia, where BND conditioned to interact with humans for food were found to engage in 'risky' behaviours that also predisposed them to boat strikes and entanglement.<sup>52</sup> Calves were frequently observed entangled in active or discarded fishing line, comprising more than half of the total observed anthropogenic injuries.<sup>52</sup> Juvenile BND also risk poor development of foraging skills through cultural transmission of depredation behaviour. BND in Sarasota Bay have been observed investing increased time into behaviours energetically conducive to foraging via human interactions; one lineage exhibited patrolling behaviour down three generations.<sup>57</sup> However, BND depredation of recreational fishers is not seen universally. In the north-western Adriatic Sea BND occurrence was reduced near recreational fishing boats, with no evidence found of associated scavenging.<sup>59</sup> This suggests BND depredation may require several influencing factors to become a prevalent issue.

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<sup>55</sup>Cunningham-Smith, P., Colbert, D., ... R. W.-A. & 2006, U. Evaluation of human interactions with a provisioned wild bottlenose dolphin (*Tursiops truncatus*) near Sarasota Bay, Florida, and efforts to curtail the interactions. *Aquat. Mamm.* **32**, 346–356 (2006). doi:10.1578/AM.32.3.2006.346.

<sup>56</sup>Samuels, A. & Bejder, L. Chronic interaction between humans and free-ranging bottlenose dolphins near Panama City Beach, Florida. *J. Cetacean Res. Manag.* **6**, 69–77 (2004).

<sup>57</sup>Powell, J. R. & Wells, R. S. Recreational fishing depredation and associated behaviors involving common bottlenose dolphins (*Tursiops truncatus*) in Sarasota Bay, Florida. *Mar. Mammal Sci.* **27**, 111–129 (2011). doi:10.1111/j.1748-7692.2010.00401.x.

<sup>58</sup>Durden, W. N. The Harmful Effects of Inadvertently Conditioning a Wild Bottlenose Dolphin (*Tursiops truncatus*) to Interact with Fishing Vessels in the Indian River Lagoon, Florida, USA. *Aquat. Mamm.* **31**, 413–419 (2005). doi:10.1578/AM.31.4.2005.413.

<sup>59</sup>Bonizzoni, S., Furey, N. B. & Bearzi, G. Bottlenose dolphins (*Tursiops truncatus*) in the north-western Adriatic Sea: Spatial distribution and effects of trawling. *Aquat. Conserv. Mar. Freshw. Ecosyst.* **31**, 635–650 (2021). doi:10.1002/aqc.3433.

Generally, the most common human-dolphin interaction involves BND bowriding of anthropogenic waves produced by recreational or commercial ships, as part of their playing behaviour.<sup>17,60</sup> BND also frequently catch natural waves.<sup>61</sup> In Santa Monica Bay, California, USA, surfers were the most common ocean recreation users to interact with BND,<sup>12</sup> with the majority of these by chance interactions causing no change in BND behaviour. Wild BND in the Florida Keys, USA, were seen approaching, swimming near and passing by open water swimmers with limited negative impacts, as they could freely determine when to initiate and terminate the interaction.<sup>4</sup> Conversely, BND in Cardigan Bay, West Wales, United Kingdom had negative responses towards kayaks, swimming away from them 57% of the time.<sup>62</sup> The absence of a motor allows kayaks to approach BND silently, thus causing startle responses where BND retreat up to 200 m from the vessels.<sup>62</sup>

Motorised recreational boating can also negatively impact BND through considerable behavioural changes. In the Galveston Ship Channel the time BND spent socialising and foraging was significantly reduced when boats were present.<sup>63</sup> BND swimming speeds and reorientation rates were found to increase in response to small recreational boats, which may result in BND decreased energy consumption and increased energy expenditure.<sup>63</sup> In regions such as Tampa Bay, Florida, USA, BND are exposed to high levels of boating activity year round. High vessel traffic significantly increases ambient noise levels, causing long-term elevations in BND stress hormones and whistle frequency.<sup>64</sup> Motorised recreational boating also causes direct and significant injuries to BND. In Sarasota, Florida, USA, four BND boat strikes occurred on USA Independence Day weekends between 1983-1996,<sup>65</sup> with unknown long-term health and mortality effects of these injuries. In southern New Caledonia 16.7% of all injuries observed on BND were consequences of propeller hits.<sup>66</sup>

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<sup>60</sup>Paulos, R., Trone, M., Psychology, S. K. I. C. & 2010, U. Play in wild and captive cetaceans. *Int. J. Comp. Psychol.* **23**, 701–722 (2010).

<sup>61</sup>Shane, S. H., Wells, R. S. & Würsig, B. Ecology, Behavior and Social Organization of the Bottlenose Dolphin: A Review. *Mar. Mammal Sci.* **2**, 34–63 (1986). doi:10.1111/j.1748-7692.1986.tb00026.x.

<sup>62</sup>Gregory, P. R. & Rowden, A. A. Behaviour patterns of bottlenose dolphins (*Tursiops truncatus*) relative to tidal state, time-of-day, and boat traffic in Cardigan Bay, West Wales. *Aquat. Conserv. Mar. Freshw. Ecosyst.* **27**, 105–113 (2001).

<sup>63</sup>Piwetz, S. Common bottlenose dolphin (*Tursiops truncatus*) behavior in an active narrow seaport. *PLoS One* **14**, e0211971 (2019). doi:10.1371/journal.pone.0211971.

<sup>64</sup>MacQueeney, M., Collier, M. A. M., Simard, P. & Gowans, S. Characterizing human interactions with bottlenose dolphins (*Tursiops truncatus*) in Tampa Bay. *Hum. Dimens. Wildl.* (2021) doi:10.1080/10871209.2021.1950241.

<sup>65</sup>Wells, R. S. & Scott, M. D. Seasonal incidence of boat strikes on bottlenose dolphins near Sarasota, Florida. *Mar. Mammal Sci.* **13**, 475–480 (1997). doi:10.1111/j.1748-7692.1997.tb00654.x.

<sup>66</sup>Bonneville, C. D., Derville, S., Luksenburg, J. A., Oremus, M. & Garrigue, C. Social Structure, Habitat Use and Injuries of Indo-Pacific Bottlenose Dolphins (*Tursiops aduncus*) Reveal Isolated, Coastal, and Threatened Communities in the South Pacific. *Front. Mar. Sci.* **8**, 52 (2021). doi:10.3389/fmars.2021.606975.

Unfortunately, intentional harm to BND is also a prevalent issue. In the northern Gulf of Mexico alone there has been at least 20 documented gunshot wounds to dolphins, mostly since 2011.<sup>67</sup> Other reported violence in this region includes targeting BND with low-priced and readily available broadhead arrows and explosives.<sup>68</sup>

Though rare, recreational human-dolphin interactions can be dangerous to humans. Conflict can occur when the public chooses to engage wildlife.<sup>69</sup> Humans can be at risk from BND biting during illegal feeding, with three reports of BND biting humans over a 3 year study period in Moreton Bay, Australia.<sup>70</sup> In Brazil in 1994, a lone, sociable male BND killed one swimmer and injured another after they attempted to restrain him.<sup>13</sup> Conversely, miraculous rescues by dolphins have also been reported, such as another lone and sociable BND saving a drowning boy in Norway.<sup>13</sup> Additionally, BND will safely play directly with humans. In Monkey Mia, Australia, BND will play by passing sea grass between themselves and nearby humans.<sup>60</sup>

## Fisheries

### Conflict

Fishing vessels can encounter dolphins, where BND habitat and fishing areas overlap (e.g. the Mediterranean Sea).<sup>71</sup> Propeller and vessel strikes can result in direct or indirect mortality through infection and mutilation.<sup>72,73</sup> In the Mediterranean Sea, BND forage for fish close to fishers' gillnets, causing economic loss to fishers.<sup>71</sup> There is additionally a risk to dolphins: Díaz López,<sup>74</sup> found that juvenile and adult dolphins get caught in gillnets, leading to drowning. Mortality is increased via interactions with fishing nets through ingestion of net fragments, as plastic threads block and/or constrict the digestive

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<sup>67</sup>Vail, C. S. An overview of increasing incidents of bottlenose dolphin harassment in the gulf of Mexico and possible solutions. *Front. Mar. Sci.* **3**, 110 (2016). doi:10.3389/fmars.2016.00110.

<sup>68</sup>Collins, M. K., Carmichael, R. H., Rotstein, D. S., Byrd, J. H. & Deming, A. C. Suspected broadhead arrow injuries in two common bottlenose dolphins (*Tursiops truncatus*) along the Alabama Coast. *Mar. ma* **36**, (2020). doi:10.1111/mms.12667.

<sup>69</sup>Manfredo, M. J. *Who cares about wildlife?: Social science concepts for exploring human-wildlife relationships and conservation issues*. Springer (Springer US, 2008). doi:10.1007/978-0-387-77040-6.

<sup>70</sup>Orams, M. B. Development and management of a feeding program for wild bottlenose dolphins at Tangalooma, Australia. *Aquat. Mamm.* **21**, 137–147 (1995).

<sup>71</sup>Revuelta, O. et al. Interaction between bottlenose dolphins (*Tursiops truncatus*) and artisanal fisheries in the Valencia region (Spanish Mediterranean Sea). *Ocean Coast. Manag.* **165**, 117–125 (2018). doi:10.1016/j.ocecoaman.2018.08.001.

<sup>72</sup>Dolman, S., Williams-Grey, V., Asmutis-Silvia, R. & Isaac, S. *Vessel collisions and cetaceans: What happens when they don't miss the boat*. (2006).

<sup>73</sup>Leone, A. B., Ferraro, G. B., Boitani, L. & Blasi, M. F. Skin marks in bottlenose dolphins (*Tursiops truncatus*) interacting with artisanal fishery in the central Mediterranean Sea. *PLoS One* **14**, e0211767 (2019). doi:10.1371/journal.pone.0211767.

<sup>74</sup>Díaz López, B. Interactions between Mediterranean bottlenose dolphins (*Tursiops truncatus*) and gillnets off Sardinia, Italy. *ICES J. Mar. Sci.* **63**, 946–951 (2006). doi:10.1016/j.icesjms.2005.06.012.

system.<sup>75</sup> In the Gulf of Guayaquil, off the Peruvian and Ecuadorian coasts, BND are caught in gillnets at an unsustainable rate, seeing mortalities 2-5 times the birth rate.<sup>76</sup> Furthermore, a photo-ID study conducted in the Aeolian Archipelago, Italy, revealed that the most harmful skin lesions were observed on adult male dolphins interacting most frequently with fishing nets.<sup>73</sup> Dolphin entanglement in gillnets happen mostly over the winter months,<sup>77</sup> and occur in other fisheries, such as bottom trawling.<sup>78</sup>

Conflict between fishers and BND occurs when both are targeting the same fish. Whilst BND catch most of their prey in the water column, they opportunistically take fish from nets.<sup>79</sup> Rocklin, *et al.*<sup>79</sup> found that BND in Bonifacio Strait Natural Reserve, France, damaged 12.4% of artisanal nets and 8.3% of the catch. This study also found that the nets attacked had the highest catch per unit effort (CPUE), with damage to nets causing a more serious long-term effect than the loss of catch.<sup>79</sup> In Northern Cyprus fisheries, net damage was found to be six times greater in the presence of BND, with repairs resulting in significant costs.<sup>75</sup> Depredation by BND also occurs in the king mackerel fishery of Florida, USA, with one study finding that up to 20% of commercial mackerel caught are lost due to BND.<sup>80</sup> BND do not usually eat mackerel and thus depredation was hypothesised by Zollett and Read<sup>80</sup> to be exploitation of a new resource: the fishery. Contrarily, in the Gulf of Mexico, Rechimont *et al.*<sup>81</sup> found BND depredation did not directly impact CPUE or catch composition, and that the perceived impact is worse than the reality.

As overfishing of a BND food source is likely decreasing availability in the wild and increasing their interaction with the fishing industry, comprehensive management of fish stocks is vital to reduce BND damage to fishing gear.<sup>75</sup> This is producing a runaway cycle where decreasing fish stocks result in lower catches, and more nets are required to achieve the same catch, so any damage caused by dolphins incurs a greater financial loss. On occasion, fishers will directly kill dolphins due to the impact on their livelihoods.<sup>82</sup> It is important to remember that impacts from Indigenous and artisanal fisheries are much less

<sup>75</sup>Snape, R. T. E. *et al.* Conflict between Dolphins and a Data-Scarce Fishery of the European Union. *Hum. Ecol.* **46**, 423–433 (2018). doi:10.1007/s10745-018-9989-7.

<sup>76</sup>Van Waaerebeek, K. *et al.* Mortality of dolphins and porpoises in coastal fisheries off Peru and southern Ecuador in 1994. *Biol. Conserv.* **81**, 43–49 (1997). doi:10.1016/S0006-3207(96)00152-8.

<sup>77</sup>Kroetz, A. M., Mathers, A. N. & Carlson, J. K. Evaluating protected species bycatch in the U.S. Southeast Gillnet Fishery. *Fish. Res.* **228**, 105573 (2020). doi:10.1016/j.fishres.2020.105573.

<sup>78</sup>Bonanomi, S., Moro, F., Colombelli, A., Pulcinella, J. & Fortuna, C. M. A 14-year time series of marine megafauna bycatch in the Italian midwater pair trawl fishery. *Sci. Data* **2022** *9*, 1–8 (2022). doi:10.1038/s41597-022-01155-2.

<sup>79</sup>Rocklin, D. *et al.* Changes in the catch composition of artisanal fisheries attributable to dolphin depredation in a Mediterranean marine reserve. *ICES J. Mar. Sci.* **66**, 699–707 (2009). doi:10.1093/icesjms/fsp036.

<sup>80</sup>Zollett, E. A.; & Read, A. J. Depredation of catch by bottlenose dolphins (*Tursiops truncatus*) in the Florida king mackerel (*Scomberomorus cavalla*) troll fishery. *Fish. Bull.* **104**, 343–349 (2006).

<sup>81</sup>Rechimont, M. E., Lara-Domínguez, A. L., Morteo, E., Martínez-Serrano, I. & Equihua, M. Depredation by coastal bottlenose dolphins (*Tursiops truncatus*) in the southwestern Gulf of Mexico in relation to fishing techniques. *Aquat. Mamm.* **44**, 469–481 (2018). doi:10.1578/AM.44.5.2018.458.

<sup>82</sup>Bearzi, G. Interactions between cetaceans and fisheries: Mediterranean Sea. in *Cetaceans in the Mediterranean and Black Seas: State of Knowledge and Conservation Strategies* 20 (2002).

than those from industrial efforts. For example in Rudd *et al.*,<sup>83</sup> changes in three (out of four) BND behaviours related to fishing disturbance were caused by commercial fisheries, whereas only one was caused by artisanal fisheries.

## Cooperation

Not all human-dolphin fisheries interactions result in conflict, however. In Laguna, Brazil, fishers and BND work together to catch the same prey: mullet. In this cooperative effort, artisanal fishers can differentiate between dolphin movements to determine the best time to throw their nets.<sup>84,85,86</sup> Dolphins then chase the fish towards fishers' nets, benefitting from this relationship by easily catching leftover, disoriented fish that were not caught by humans. In the 19<sup>th</sup> century, cooperative fishing between dolphins (hypothesised to be BND specifically) and Aboriginals occurred in eastern Australia, later ended by violence from colonizers.<sup>87</sup> In Queensland, Australia, BND currently benefit from discarded by-catch.<sup>88</sup> BND follow fishing vessels and wait for the disposal of unwanted fish, not negatively impacting humans or dolphins.

Dolphins known to interact with fishers have more localized ranges, as the need to forage further afield is lessened by the success they have with fishers.<sup>85</sup> This relationship is crucial for the fishers' livelihoods, as mullet are caught for commercial sale and are the primary income source for many families.<sup>89</sup> It has also been shown to increase calf survival by providing feeding mothers with an abundant source of prey.<sup>90</sup> In northwest Spain, BND have been observed to show a homophilic preference for others within their population that utilise the same foraging strategy.<sup>91</sup> Over time, this could lead to a divergence from a single dolphin population into two with distinct feeding strategies:

<sup>83</sup>Rudd, L. E. et al. The effect of commercial and artisanal fishing practices on the behavioral budget of bottlenose dolphins off the coast of Montenegro, South Adriatic Sea. *Mar. Mammal Sci.* (2022) doi:10.1111/MMS.12913.

<sup>84</sup>Peterson, D., Hanazaki, N. & Simões-Lopes, P. C. Natural resource appropriation in cooperative artisanal fishing between fishermen and dolphins (*Tursiops truncatus*) in Laguna, Brazil. *Ocean Coast. Manag.* **51**, 469–475 (2008). doi:10.1016/j.ocecoaman.2008.04.003.

<sup>85</sup>Cantor, M., Simões-Lopes, P. C. & Daura-Jorge, F. G. Spatial consequences for dolphins specialized in foraging with fishermen. *Anim. Behav.* **139**, 19–27 (2018). doi:10.1016/j.anbehav.2018.03.002.

<sup>86</sup>Agrelo, M. et al. Spatial behavioural response of coastal bottlenose dolphins to habitat disturbance in southern Brazil. *Aquat. Conserv. Mar. Freshw. Ecosyst.* **29**, 1949–1958 (2019). doi:10.1002/aqc.3188.

<sup>87</sup>Neil, D. T. Cooperative fishing interactions between Aboriginal Australians and dolphins in eastern Australia. *Anthrozoos* **15**, 3–18 (2002). doi:10.2752/089279302786992694.

<sup>88</sup>Chilvers, B. L. & Corkeron, P. J. Trawling and bottlenose dolphins' social structure. *Proc. R. Soc. B* **268**, 1901–1905 (2001). doi:10.1098/rspb.2001.1732.

<sup>89</sup>Pryor, K. & Lindbergh, J. A Dolphin-Human Fishing Cooperative in Brazil. *Mar. Mammal Sci.* **6**, 77–82 (1990). doi:10.1111/j.1748-7692.1990.tb00228.x.

<sup>90</sup>Bezamat, C. et al. Reproductive parameters and factors influencing calf survival of bottlenose dolphins that engage in a unique foraging cooperation with fishermen. *Mar. Biol.* **167**, 5 (2020). doi:10.1007/s00227-019-3611-4.

<sup>91</sup>Methion, S. & Díaz López, B. Individual foraging variation drives social organization in bottlenose dolphins. *Behav. Ecol.* **31**, 97–106 (2020). doi:10.1093/beheco/arz160.

“cooperatives” and “non-cooperatives”.<sup>86</sup> This may also impact other social processes outside of a feeding context.<sup>92</sup>

## Discussion

Interactions between humans and BND vary in their form, intention, intensity and outcome. The deliberate interactions involved in marine wildlife tourism, driven by a demand for meaningful experiences for humans, can result in detrimental behavioural reactions for BND and, at high cumulative exposure, cause long-term consequences for bioenergetics and even population dynamics. Within wider coastal recreation, the form of interactions is more variable and difficult to regulate, sometimes resulting in severe negative consequences for individual humans and dolphins. Interactions within coastal fisheries can have the most extreme consequences for BND, ranging from increases in food availability through deliberate cooperation to unsustainable levels of dolphin mortality due to indiscriminate bycatch. For each type of interaction, the outcome depends on geographical area and BND population identity.

In addition, the outcomes of interactions may be determined by the form and extent of regulation of the human activity. For example, BND-watching activities are frequently managed by codes of conduct, providing either voluntary guidelines or enforced rules for vessel behaviour around dolphins. Whilst there is evidence that such measures can limit behavioural disturbance for other cetacean species,<sup>93,94</sup> this has not been determined for BND and levels of compliance vary.<sup>95</sup> Compliance of BND-watching tour boats were assessed in Southwest Florida in 2019, with results showing that tour captains violated an average of 44% of NOAA mammal viewing guidelines.<sup>96</sup> The sustainable management of dolphin-watching tourism in developing countries poses further challenges, with the rapid growth of the industry often meaning local people lack the capacity, framework and institutions to manage the industry sustainably.<sup>97</sup> Meanwhile, management solutions for controversial activities such as feeding and swimming with dolphins should be considered

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<sup>92</sup>Machado, A. M. S. et al. Homophily around specialized foraging underlies dolphin social preferences. *Biol. Lett.* **15**, (2019). doi:10.1098/rsbl.2018.0909.

<sup>93</sup>De Fatima Filla, G. & De Araujo Monteiro-Filho, E. L. Monitoring tourism schooners observing estuarine dolphins (*Sotalia guianensis*) in the Estuarine Complex of Cananéia, south-east Brazil. *Aquat. Conserv. Mar. Freshw. Ecosyst.* **19**, 772–778 (2009). doi:10.1002/aqc.1034.

<sup>94</sup>Magalhaes, S. et al. Short-term reactions of sperm whales (*Physeter macrocephalus*) to whale-watching vessels in the Azores. *Aquat. Mamm.* **28**, 267–274 (2002).

<sup>95</sup>Allen, S., Smith, H., Waples, K. & Harcourt R. The voluntary code of conduct for dolphin watching in Port Stephens, Australia: Is self-regulation an effective management tool? *J. Cetacean Res. Manag.* **9**, 159–166 (2007).

<sup>96</sup>Hooper, L. K., Moore, R. B. T., Boucquey, N., Mchugh, K. A. & Fuentes, M. M. P. B. Compliance of dolphin ecotours to marine mammal viewing guidelines. *J. Sustain. Tour.* (2021) doi:10.1080/09669582.2021.1900206.

<sup>97</sup>Beasley, I., Bejder, L. & Marsh, H. Cetacean-watching in developing countries: A case study from the Mekong river. in *Whale-watching: Sustainable Tourism and Ecological Management*, (eds. Higham, J., Bejder L & Williams R) vol. 9780521195973 307–322 (Cambridge University Press, 2014).

on a case-by-case basis.<sup>98,99</sup> The demand for such experiences, in addition to the prevalence of inappropriate behaviours such as touching wild dolphins, including BND, may be limited through education and increased awareness.<sup>100,101</sup> Beyond limiting its own negative impacts, education within marine wildlife tourism can positively impact wildlife conservation through raising awareness and garnering support for conservation efforts.<sup>98</sup>

Within coastal fisheries, both the economic impacts of dolphins on artisanal and commercial fisheries and the incidence of dolphin bycatch can be limited by gear modifications.<sup>102</sup> These may include the addition of deterring wires<sup>80</sup> and acoustic deterrent devices.<sup>103</sup> However, there is reluctance from fishing communities; in Brazil, local fishers believe more rigorous laws should be enacted to prevent mortality of dolphins in gillnets, but they are concerned that certain measures, such as acoustic alarms, will decrease their fish catch.<sup>104</sup> In these situations, smaller gillnets and altered positioning can prevent dolphin entanglement.<sup>105</sup>

Creating marine protected areas (MPA) can also be used to limit the potential negative impacts of all forms of direct disturbance on marine mammals, and are often suggested as a management strategy to protect BND populations susceptible to disturbance.<sup>106,107,108</sup> However, to date, benefits of MPAs to BND at a population level have not been

<sup>98</sup>Lima, I. de & Green, R. *Wildlife Tourism, Environmental Learning and Ethical Encounters*. Springer (2017). doi:10.1007/978-3-319-55574-4\_5.

<sup>99</sup>Stamation, K. A., Croft, D. B., Shaughnessy, P. D., Waples, K. A. & Briggs, S. V. Educational and Conservation Value of Whale Watching. *Tour. Mar. Environ.* **4**, 41–55 (2007).

<sup>100</sup>Orams, M. B. & Hill, G. J. E. Controlling the Ecotourist in a Wild Dolphin Feeding Program: Is Education the Answer? *J. Environ. Educ.* **29**, 33–38 (1998). doi:10.1080/00958969809599116.

<sup>101</sup>Zeppel, H. Education and Conservation Benefits of Marine Wildlife Tours: Developing Free-Choice Learning Experiences. *J. Environ. Educ.* **39**, 3–18 (2008). doi:10.3200/JOEE.39.3.3-18.

<sup>102</sup>Hamilton, S. & Baker, G. B. Technical mitigation to reduce marine mammal bycatch and entanglement in commercial fishing gear: lessons learnt and future directions. *Rev. Fish Biol. Fish.* **29**, 223–247 (2019). doi:10.1007/s11160-019-09550-6.

<sup>103</sup>Leeney, R. H. et al. Effects of pingers on the behaviour of bottlenose dolphins. *J. Mar. Biol. Assoc. United Kingdom* **87**, 129–133 (2007). doi:10.1017/S0025315407054677.

<sup>104</sup>Zappes, C. A., Simões-Lopes, P. C., Andriolo, A. & Di Benedetto, A. P. M. Traditional knowledge identifies causes of bycatch on bottlenose dolphins (*Tursiops truncatus* Montagu 1821): An ethnobiological approach. *Ocean Coast. Manag.* **120**, 160–169 (2016). doi:10.1016/j.ocecoaman.2015.12.006.

<sup>105</sup>Zappes, C. et al. Comparison of local knowledge about the bottlenose dolphin (*Tursiops truncatus* Montagu, 1821) in the Southwest Atlantic Ocean: New research needed to develop conservation management strategies. *Ocean Coast. Manag.* **98**, 120–129 (2014). doi:10.1016/j.ocecoaman.2014.06.014.

<sup>106</sup>Currey, R. J. C., Dawson, S. M., Slooten, E. & Lusseau, D. Survival rates for a declining population of bottlenose dolphins in Doubtful Sound, New Zealand: An information theoretic approach to assessing the role of human impacts. *Aquat. Conserv. Mar. Freshw. Ecosyst.* **19**, 658–670 (2009). doi:10.1002/aqc.1015.

<sup>107</sup>Pulcini, M., Pace, D. S., La Manna, G., Triossi, F. & Fortuna, C. M. Distribution and abundance estimates of bottlenose dolphins (*Tursiops truncatus*) around Lampedusa Island (Sicily Channel, Italy): implications for their management. *J. Mar. Biol. Assoc. United Kingdom* **94**, 1175–1184 (2014). doi:10.1017/S0025315413000842.

<sup>108</sup>La Manna, G., Ronchetti, F., Sarà, G., Ruiui, A. & Ceccherelli, G. Common Bottlenose Dolphin Protection and Sustainable Boating: Species Distribution Modeling for Effective Coastal Planning. *Front. Mar. Sci.* **7**, 955 (2020). doi:10.3389/fmars.2020.542648.

demonstrated.<sup>109,110</sup> MPAs may be insufficient for wide-ranging marine megafauna,<sup>111</sup> poorly planned, displace sources of disturbance to surrounding areas and create a false illusion of protection.<sup>112</sup> In addition, in impoverished areas, managers must realize that local communities will perceive wildlife management as a luxury.<sup>113</sup> Locally managed marine areas represent a potential solution,<sup>114</sup> but their effectiveness has not yet been determined for cetaceans.

Whilst human-BND interactions have been extensively described, several key knowledge gaps remain, which may hinder future management and conservation efforts. Firstly, individual interactions do not exist in isolation. Coastal areas may be subject to a large number of human activities, including the three discussed in this review in addition to port construction, large-scale shipping traffic, renewable energy development, oil and gas exploration and many more.<sup>115,116</sup> BND may interact with multiple sources of human disturbance, whose effects could amplify or suppress each other,<sup>117</sup> but this has not yet been determined. Secondly, the population consequences of disturbance are poorly categorised. Given sufficient levels of exposure and intensity, short-term behavioural responses may impact bioenergetics and population dynamics. However, there is a lack of empirical evidence to support this theory for cetaceans,<sup>118</sup> including BND. Finally, there is little information on the measured benefits of management practices in improving human-dolphin interactions, hindering evidence-based conservation.

As a charismatic, coastal and intelligent cetacean, BND are subject to extensive interactions with a variety of human activities. Within wildlife tourism, recreation and fisheries, interactions can range from cooperative, to neutral, to detrimental. For BND, such interactions may have lethal or sublethal consequences which can lead to population-level impacts. For humans, interactions, particularly in a marine tourism setting, often lead to positive experiences. To

<sup>109</sup>Adameczak, S., Kemper, C. & Tomo, I. Strandings of dolphins in the Adelaide Dolphin Sanctuary, South Australia. *J. Cetacean Res. Manag.* **19**, 105–111 (2019).

<sup>110</sup>Cheney, B. et al. Long-term trends in the use of a protected area by small cetaceans in relation to changes in population status. *Glob. Ecol. Conserv.* **2**, 118–128 (2014). doi:10.1016/j.gecco.2014.08.010.

<sup>111</sup>Woodroffe, R., Thirgood, S. & Rabinowitz, A. *People and Wildlife, Conflict or Co-existence?* (2005).

<sup>112</sup>Agardy, T., di Sciara, G. N. & Christie, P. Mind the gap: Addressing the shortcomings of marine protected areas through large scale marine spatial planning. *Mar. Policy* **35**, 226–232 (2011). doi:10.1016/j.marpol.2010.10.006.

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facilitate less detrimental interactions, improve the human-dolphin relationship and promote public awareness, future research should directly measure the effectiveness of management and conservation measures. Moreover, as a bi-directional relationship, the development of such measures should consider the potential impacts on both humans and dolphins.

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