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Letter to the Editor

"Uncertainty remains for white sharks in South Africa, as population stability and redistribution cannot be concluded by Bowlby et al. (2023): "Decline or shifting distribution? a first regional trend assessment for white sharks (*Carcharodon carcharias*) in South Africa"

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ABSTRACT

Bowlby et al. (2023) assessed spatio-temporal trends in South Africa's white shark (*Carcharodon carcharias*) population using a range of different proxies of white shark occurrence. The authors concluded that, despite significant declines in white shark sightings in several historical aggregation sites, the population as a whole has remained relatively stable throughout South Africa since its protection in 1991. The study also suggests a population redistribution eastward, likely driven by natural predator–prey dynamics (i.e., predation and related risk from orcas, *Orcinus orca*). Here, we highlight several issues with the methods and the inferences made in that study and argue that the data, as currently analysed and interpreted, cannot support population stability, or redistribution, of South Africa's white sharks. We also point out that the onset of the decline of white sharks at historical aggregation sites began before the documented appearance of specialist shark-eating orcas (the main alleged cause of the decline put forward in Bowlby et al. 2023). Our concern is that unsupported claims of population stability could jeopardize conservation actions urgently needed for white sharks, if the declines documented at their historical aggregations are representative of the population trend. Below we summarize our arguments.

1. Background

In 1991, South Africa became the first country in the world to protect white sharks (*Carcharodon carcharias*), based on a precautionary approach that recognised the species' ecological and socio-economic importance (Compagno, 1991; Johnson and Kock, 2006). The South African population of white sharks is genetically panmictic, with frequent movement of individuals between aggregation sites (Bonfill et al. 2005, Andreotti et al., 2015, Kock et al. 2022). In recent years, white shark presence has rapidly declined in the Western Cape Province (False Bay, Gansbaai and Mossel Bay), with recorded ecological consequences (Hammerschlag et al., 2019,2022; Towner et al., 2022), and a negative impact on the white shark cage diving industry and the livelihoods depending on this industry. A timeline of related key events is provided in Table 1.

This decline in white sharks sighted in the Western Cape has led to growing concerns among civil society, entrepreneurs, conservationists, and scientists (Braccini et al., 2020). In light of these concerns, Bowlby et al. (2022) modelled different white shark population dynamics in response to multiple levels of anthropogenic mortality (fishing, beach protection programs, etc), which indicated that annual removals of white sharks in the order of 10 s of individuals would substantially limit the potential for population recovery since protection. The average annual white shark removals by the KwaZulu-Natal Sharks Board's (KZNSB) lethal shark control program alone have typically remained higher than these thresholds (an average of 28 white sharks killed per year from 1978 and 2018: Kock *et al.*, 2022). Consequently, even without accounting for unknown removals of white sharks, that are likely occurring across the entire distribution of the white shark population (also outside South African jurisdiction), Bowlby et al. (2022) concluded that known removals of white sharks occurring in South Africa alone, despite protection, would likely be sufficient to drive population abundance decline. In contrast to the results of Bowlby et al. (2022), a newer study by Bowlby et al. (2023) concluded that the white shark population throughout South Africa has been stable since protection in 1991 and has likely redistributed eastwards since 2015. The authors based their claims on the trends derived from combining six different proxies of white shark occurrence: three vessel-based sightings from ecotourism and research operations, one from captures by shore-based recreational anglers and two more from captures by the KZNSB lethal shark control program (nets and drumlines). Here, we highlight key methodological issues, data uncertainty and several contradictions between the results and the conclusions as reported in Bowlby et al. (2023). Thus, while still possible, we argue that as currently presented, the study's findings cannot conclude white shark population stability or its redistribution. We believe highlighting these issues is important given the implications for the conservation management of white sharks in South Africa in light of the localised declines documented at former white shark aggregation sites.

2. The proportionality assumption of the time series used to infer abundance trends

The conclusions of Bowlby et al. (2023) appear to be based on an assumption of proportionality among geographically separated time-series (i.e., relative increases and decreases in geographically distinct time-series are comparable), which is subsequently used to infer regional population trends. For instance, the analysis and the conclusion

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Table 1
Timeline of key events related to the white shark population of South Africa, from its protection to the present.

1991	South Africa protects white sharks (Compagno, 1991).
1996	First regional population estimate (pre-protection: January 1989 to December 1993) for South Africa's white sharks: average population size of 1,279 individuals (Cliff et al., 1996).
2004	Second regional population estimate for South Africa's white sharks (post-protection): average population size of 1,953 individuals in 2004 (Tress, 2004). Therefore, an increase in abundance following protection.
2006	The port of Ngqura in Algoa Bay is finalised by 2006 and became operational by 2009. By 2010, it became a critical habitat for sharks and ray in Algoa Bay (Dames et al., 2023).
2009	24 white sharks caught by 4 recreational fishers in Algoa Bay (Dicken and Booth, 2013). This represent the first year in the previous 40 year in which white sharks were caught by recreational anglers in Algoa Bay (Dicken and Booth, 2013).
2010	First local population estimate for white sharks in Mossel Bay (2008 to 2010): a maximum number of 261 individuals were photo-identified in 3 years (Ryklief et al., 2012). 26 white sharks caught by 4 recreational fishers in Algoa Bay (Dicken and Booth, 2013).
2011	Onset of the decline in white shark sightings in False Bay (Hewitt, 2014). First local population estimate for white sharks in Gansbaai (2007 to 2011): a maximum number of 532 individuals were photo-identified in 5 years (Towner et al., 2013). Second local population estimate for white sharks in Gansbaai (2009 to 2011): a maximum number of 426 individuals were photo-identified in 3 years and using 14 nuclear markers, a genetic-based effective population size was calculated at CNe = 333 (Andreotti et al., 2016). 8 white sharks caught by 4 recreational fishers in Algoa Bay (Dicken and Booth, 2013).
2012	Onset of the decline in white shark sightings in Gansbaai (Bowlby et al., 2023). First local population estimate for white sharks in False Bay (2004 to 2012): a maximum number of 303 individuals were photo-identified in 9 years (Hewitt, 2014).
2013	6 white sharks caught by 4 recreational fishers in Algoa Bay (Bowlby et al., 2023).
2014	~12 white sharks caught by 4 recreational fishers in Algoa Bay (derived from Bowlby et al., 2023).
2015	Onset of the decline in white shark sightings in Mossel Bay (Bowlby et al., 2023). First documented predation event on sevengill sharks (*Notorynchus capedianus*) by orcas in False Bay (Engelbrecht et al., 2019). ~6 white sharks caught by 4 recreational fishers in Algoa Bay (derived from Bowlby et al., 2023).
2016	Second documented predation event on sevengill sharks by orcas in False Bay (Engelbrecht et al., 2019). Increase of sightings of orcas along the Western Cape (Towner et al., 2022). ~6 white sharks caught by 4 recreational fishers in Algoa Bay (derived from Bowlby et al., 2023).
2017	First documented predation event on white sharks by orcas in Gansbaai (Towner et al., 2022). Faster decline rate in sightings of white sharks observed in both False Bay and Ganbaai (Bowlby et al., 2023). ~24 white sharks caught by 4 recreational fishers in Algoa Bay (derived from Bowlby et al., 2023).
2018	~30 white sharks caught by 4 recreational fishers in Algoa Bay (derived from Bowlby et al., 2023).
2019	59 white sharks caught by 4 recreational fishers in Algoa Bay (Bowlby et al., 2023).
2023	Only two white sharks sighted in Algoa Bay in 2023 (personal communication by L. Edwards, white shark cage diving operator in Algoa Bay).

of a stable population rely heavily on the shortest time-series (Algoa Bay in the Eastern Cape, spanning 2013–2019), obtained from voluntary interviews of four rock-and-surf anglers, who reported an 8-fold increase in white shark captures over four years. This relative increase in shark captures in Algoa Bay appears to offset the decreases in white sharks sighted during boat-based surveys in the Western Cape, suggestive of regional stability, and together with data from shark bites on humans (discussed later), indicative of redistribution from West to East. However, the issue of proportionality (or lack of therefor) is well illustrated when comparing the actual number of white sharks caught in Algoa Bay over the period of relative increase and the numbers of white sharks previously observed in the Western Cape over 15 years. During that period of increased captures in Algoa Bay (2017–2019), the anglers reported capturing a maximum number of 59 white sharks in a single year (some of which could have even been recaptures of the same individuals). In contrast, the Western Cape experienced a relative decrease from an average presence of several hundreds of individual white sharks to less than 10 sightings per year. A previous study in Mossel Bay identified 261 unique individuals between 2008 and 2010 (Ryklief et al., 2012); two population studies done in Gansbaai identified 532 individuals between 2007 and 2011 (Towner et al., 2013) and 426 individuals between 2009 and 2011 (Andreotti et al., 2016); and finally, 303 white shark individuals were identified in False Bay between 2004 and 2012 (Hewitt, 2014). If the entire white shark population was indeed regionally stable and those sharks previously observed in the West had redistributed toward the Eastern Cape, one would have expected the numbers of white sharks in Algoa Bay to be about tenfold higher. In fact, as False Bay, Gansbaai, and more recently Mossel Bay, have had few to no white shark sightings, a larger number of white sharks would be expected in Algoa Bay, namely the core destination of the purported geographical redistribution.

From a modelling point of view, we recognise that trends and magnitudes in observations between the different time-series do not need to be directly related (i.e., a direct decrease at a location does not equate to a direct increase at another location) as 'sightability' from sighting of tourism/research operators (Sightings Per Unit Effort: SPUE) or catchability from angling (Catches Per Unit Effort: CPUE) are inherently different. This is likely the reason for the standardisation among datasets done by Bowlby et al. (2023) in the first place. However, if the assumption of proportionality between indices of occurrence and population is not met (see discussion below), standardising the datasets loses the ability to infer redistribution (e.g., an 80 % reduction from 100 individuals at a location cannot equate to an 80 % increase from 10 individuals at another location). Therefore, the relative increase of white sharks in only one time-series should not be used as argument to conclude a stable population and/or a geographical redistribution.

The lack of this proportional increase in white shark abundance in Algoa Bay based on angler interviews appears to be consistent with a shorter, but more comparable time-series of recent white shark sightings from the only white shark cage diving operation in Algoa Bay. Specifically, between 2020 and 2023, this operator reported an average of 0.9 white sharks per hour around the Bay's only Cape fur colony (a level that is comparable to the lowest levels of sightings reported for False Bay in Bowlby et al., 2023) and in 2023, he only sighted two individual white sharks in total that year (personal communication by L. Edwards, white shark cage diving operator in Algoa Bay). Moreover, this cage diving operator reported seeing only a single white shark above 4 m in length between 2020 and 2023; in contrast white sharks historically seen at the Western Cape sites of False Bay and Gansbaai, prior to their declines, regularly attained sizes greater than 4 m in length (Fallows et al., 2012). Consequently, neither data on abundance of white sharks nor size class distribution in Algoa Bay are comparable with those from False Bay and Ganbsaai. Therefore, the proportional increase in occurrence of white sharks described by Bowlby et al. (2023) in Algoa Bay should not be considered to balance the confirmed local declines in the Western Cape.

3. Accounting for effort

As noted above, the Algoa Bay time-series from the Eastern Cape, based on angler interviews, is arguably the most influential in Bowlby et al. (2023), as it was the only time-series exhibiting an increase over time. Despite the importance of this time-series, its angling effort was not sufficiently quantified. The authors simply indicated that effort was based on a "*general consistency … in a season of approximately 100 days per year*" without providing any further information. Long-recall biases, with risk of overestimation (Tarrant et al., 1993), as well as prestige biases (Pollock et al., 1994), do not appear to have been even considered in this case. Additionally, changes in angler catch rates would be expected to improve due to changes in catchability over time, not abundance. While the authors recognised that "*external factors such as improved technology, increased skill and/or knowledge of the anglers could affect capture success*", and thus likely to bias abundance estimations, the authors did not show whether they accounted for these biasing effects. This can be highly problematic, because an increase in angler knowledge and improved technology (e.g., increase use of drones used in fishing) can have a substantial impact on catchability and hence on the inferences made from the standardised index (Hunt et al., 2011; Cooke et al., 2021). For example, Winkler et al. (2022) identified a 357 % spike in use of aerial drones in South Africa's recreational fishery since 2016. This increase in use of drone fishing corresponds to the timing of the rapid increase in angler captures of white sharks reported for the Algoa Bay time-series by Bowlby et al. (2023). While there was an obvious rigour in the consideration of effort in all the other time-series in Bowlby et al. (2023), to a level that the authors rightfully considered splitting the time-series of catches by KZNSB lethal shark control program by gear type (even though that could raise some concerns of non-independence, as related to the same geographical area), the effort as described in the Algoa Bay time-series is lacking sufficient details to accounting for changes in catchability or recall bias over time. Without accounting for detailed changes in effort, the possible increased use of aerial drones or changes related to technological advancements, the increases in white sharks captured in Algoa Bay cannot be attributed only to changes in local shark abundance.

4. Are white sharks suddenly appearing in Algoa Bay?

Notwithstanding the issues identified earlier regarding this dataset, the Algoa Bay time series exhibited an 8-fold increase in white shark catches over four years ("*not biologically possible for reproduction alone to account for it*", as indicated in Bowlby et al., 2023). An earlier study by Dicken and Booth (2013) also reported on temporal trends in white sharks catches from Algoa Bay and also derived this information from interviews with four anglers, but from an earlier time-series (2009 to 2012). When considering these earlier data for the same location and methods, the numbers of white sharks caught between 2009 and 2012 reported in Dicken and Booth (2013) were comparable to catches between 2013 and 2019 reported in Bowlby et al. (2023), with averages in the earlier and later time-series documented at 19 and 20 white sharks caught per year, respectively. However, this comparable, but earlier dataset, was not included in the Algoa Bay time-series analysed in Bowlby et al. (2023). It is thus possible that increase in the catches reported for Algoa Bay time-series may not have been as large should the earlier data been integrated into the analysis.

While the hypothesis of a localised increase in white shark presence in the coastal area of Algoa Bay in recent years cannot be discarded (albeit at a scale not comparable to the number of white sharks lost from the Western Cape), we believe this proxy of occurrence should not have been considered without accounting for changes in catchability, inherit biases and other confounding factors. For instance, a study (Dames et al., 2023) presented at the 2023 Southern Africa Shark and Ray Symposium found that the underwater structures associated with construction of a port in Algoa Bay (Port of Ngqura), finalised in 2006, created new habitats that subsequently became an important area for sharks and rays by 2010, a time that also coincided with reported increases in white shark catches by anglers Dicken and Booth, 2013). Similarly, Algoa Bay has also seen the establishment of a complex of marine protected areas (MPAs) during the Algoa Bay time series used in Bowlby et al. (2023) which also could impact white shark presence. For example, using baited remote underwater stereo-videos between 2013 and 2016, Heyns-Veale et al. (2019) reported an increase in catches of commercially important species associated with the Bird Island MPA, established in Algoa Bay in 2004. Thus, it is plausible that the delayed effects of both the nearby port and the MPA, directly or indirectly (through aggregations of prey) also contributed, at least in part, to the rise in white sharks captures reported by anglers in Algoa Bay between 2013 and 2019.

5. Combining different proxies of occurrence into a single model

For each time-series, Bowlby et al. (2023) aggregated all observations into a single annual record. Then each annual record was normalized by the maximum value for any given year to create relative abundance index ranging from 0 to 1. As mentioned before, this step violates the proportionality assumption among time-series and therefore the ability to compare absolute indices of occurrence and, ultimately, to infer a possible population redistribution. Then, the study fitted Generalized Linear or Generalized Additive regression models (GLM or GAM) to all series combined using 'year' as a continuous predictor and assuming a Gamma distribution for the response to evaluate an overall population trend for South Africa. The standardisation of datasets and the following combination of the occurrence proxies into a single GAM spline, while useful for qualitative visualizations, introduces issues of comparability and potentially misleading results in terms of population trend. In fact, such a combined modelling approach of disparate datasets does not account for variability among the differing indices in temporal scales (ranging from 6 to 30 years), collection approach (targeted vs non-targeted efforts), and data type (sightings, catches, angler reports). This could have in part been addressed, for example, through the use of a random term to account for the effect of each index or by separating the modelled time series. Moreover, comparing annually averaged data indices also introduces two pervasive biases: (i) the removal of intra-annual variability which can sometimes explain more of the deviance than annual trends (Cao et al., 2009); and (ii) yearly averaging forces to ignore zero-catch records (typical for rare species such as white sharks), which introduces issues with the use of a Gamma distribution over aggregated data, instead of using for instance a zero-inflated distribution over disaggregated data.

While Bowlby et al. (2023) rightfully acknowledged some of the biases associated with their combined modelling approach (such as the model's inability to account for (i) movement, (ii) changes in observation error in terms of improved experience by anglers, (iii) change in the configurations in KZNSB nets and drumlines, and (iv) the fact that CPUE from small catch numbers, like in KZNSB and Algoa Bay time-series, can impact the reliability of using those indices as proxies for abundance), the quantification of such variability was not accounted for in their models. The overall outcome of the study was ultimately reflected by the coefficient of the smooth term of the model chosen to assess trends which resulted non-significant and, not surprisingly, the combined model was able to explain only 5.4 % of the deviance. Furthermore, when evaluating for potential population redistribution by running correlations between different location-specific indices, results were not only non-significant but often of opposite predictions: "*Locations linked by systematic, directional movement would be expected to have a negative correlation, yet most coefficients were positive*". This reflects the inability of the chosen model to test also for the eastward redistribution hypothesised.

Nevertheless, despite a lack of statistical significance, the authors appeared to infer population trends from a visual interpretation of their findings, reporting that "*the overall fitted trend remained relatively constant over time*" and that "*the population status appears largely unchanged thirty years later*". This last claim is even further extended to a syllogism in the paper: "*For the status of white sharks in South Africa to remain unchanged, the population must have redistributed along the South African coastline*" suggesting that, if the abundance has not changed (given as a fact, despite the published studies and the local declines in white shark occurrence in the Western Cape listed in Table 1), and the trend in catches has increased in Algoa Bay, "*the population must have redistributed along the coastline*". Because of everything mentioned so far, we question such use of those relative proxies of occurrence, lacking proportionality, combining sightings and catches into a simple overall model, without accounting for known biases/issues, to quantify the population abundance trend and to provide evidence of a possible redistribution of the entire South Africa's white shark population toward the Eastern Cape. While it is possible that South Africa's white shark population is stable and/or have redistributed, yet the data, analyses and interpretations presented in Bowlby et al. (2023) do not demonstrate either.

6. Shark-human interactions and orca-driven white shark population redistribution

In an effort to evaluate evidence of a potential white shark population redistribution toward the Eastern Cape post-2015, Bowlby et al. (2023) further examined shark-human interaction (i.e., shark bites on humans) trends by region, reporting an eastward shift in those incidents over time. However, previous studies have reported a lack of association between human-shark interactions and white shark abundance alone (Bruce and Bradford 2012; Dicken and Booth, 2013), especially when the low frequency of incidents hampers the ability to statistically identify differences (Huveneers et al., 2024). Additionally, evidence from South Africa (Kock and Johnson, 2006) and elsewhere (Ferretti et al., 2015) suggests that human risk of white shark interaction is largely driven by the number of human water users, not shark abundance. In fact, a major issue of using frequency of shark-human interactions to investigate spatio-temporal variations in shark abundance is the assumption that the number of human water user has been stable or varied at the relatively same rate in different regions over the years. Given that tourism has more than doubled in South Africa between 2005 and 2019 (Statistics South Africa, 2019), it is unlikely that the frequency of human water users has been unchanged or varied at the same rate in the different regions, especially given differences in socio-economic realities of the Western and Eastern Cape. Accordingly, without accounting for the variation in water users in both space and time (as done in other studies, see Ferretti et al. 2015), trends in human-shark interactions should not be used as a proxy for patterns of shark population abundance over space and time. Regardless, Bowlby et al. (2023) reported a roughly similar number of white shark related incidents for the Western Cape and the Eastern Cape Provinces during the last eight years of data, despite concluding an eastward shift.

Notwithstanding the above issues, Bowlby et al. (2023) recognised that when evaluating trends in human-shark bites "*such small numbers complicate robust statistical evaluation. As such, we did not fit a model to the annual number of incidents to assess trends*", and yet they fit a graphical loess smooth trend line in the plots of Figure 3, which is suggestive of a trend, and used this "*general pattern*" of shark-human interactions to infer a relationship with occurrence patterns of white sharks, and ultimately to conclude the abundance trend of an entire population over three decades. So, despite reporting in the article that "*there was no evidence of a geographic pattern or a corresponding increase in the total number of incidents over time in the Eastern Cape or KZN regions*", the study still states that "*Movement and redistribution cannot be ignored when monitoring changes in relative abundance from localised indices, particularly in light of the geographic pattern in white shark incidents*".

Bowlby et al. (2003) further hypothesized that the cause of this white shark redistribution eastward, as evidenced by the alleged shift in shark-human interactions, was driven by new predation risk for white sharks posed by specialized shark-eating orcas in the Western Cape. Nevertheless, Bowlby et al. (2023) noted the first documented occurrence of orca predation on white sharks in the Western Cape was in 2017, yet their reported eastward shift in shark-human interactions began in the early 2000 s, almost 15 years earlier than its alleged cause.

We note that if a redistribution of the entire white shark population eastward had occurred, an increase in capture rates of white sharks in the KZN nets and drumlines should have also been detected, as KZN spans the known eastern range extent of white shark distribution in South Africa. Instead, catches of white sharks in nets decreased from 2010 onward and the standardised captures of drumlines in the period from 2015 to 2021 were much lower than between 2007 and 2012.

That said, we cannot rule out that a population redistribution eastward or to other areas not considered in Bowlby et al. (2023) (e.g., oceanic environments, coastal Mozambique channel, or even further north) may be occurring, but additional data is needed to conclude either. As for now, we fail to see evidence of an increase occurrence of white shark in the Eastern Cape in comparable numbers and of comparable size ranges as previously found at their historical aggregation sites in the Western Cape.

While we agree that orcas have likely influenced white shark numbers and behaviours, and at least temporarily displaced many from their historical aggregation sites, the data as currently presented, do not suggest that orcas are the primary driver of the declines in white shark observed in the Western Cape. As noted above, the onset of white shark declines in False Bay (2012/13), Gansbaai (2013/14), and Mossel Bay (2015), as depicted in Figure 2 of Bowlby et al. (2023), pre-dates the first appearances of those orcas in False Bay and in Gansbaai in 2015, and in Mossel Bay only in 2017: i.e., the alleged cause cannot appear two years later than its effect.

7. Conservation and management implications

The findings of Bowlby et al. (2023) have important management and conservation implications. As the conservation of a natural resource requires a management plan, not only to prevent exploitation and destruction, but also to prevent its neglect, in light of the issues raised above and the uncertainty presented in Bowlby et al. (2023), it is important to consider how the conclusions of the study are being communicated to the public and the media, and the consequent conservation implications. The general narrative being communicated is that the documented declines of white sharks seen at former hotspots are not due to an overall population decline, but to a redistribution eastward to flee predation from orcas. For example, the title of a popular article in Nature.com (https://www.nature.com/articles/d44148-023–00224-x) reads: "*Orcas blamed for missing great white sharks*," with the main text stating "*These findings, published in Ecological Indicators, confirm that the white shark population is moving eastwards inside its historic home range, rather than dying out*." Notably, the authors of Bowlby et al. (2023), in a popular article, (https://theconversation.com/south-africas-great-white-sharks-are-changing-locations-they-need-to-be-monitored-for-beach-safety-and-conservation-212211) affirms that South Africa's white shark population is not in decline but "*migrating to survive*" and that "*The stable population of white sharks is reassuring*". Such narrative creates an avenue for relaxation of management prioritisation and associated conservation mitigation actions for white sharks in South Africa. This is particularly concerning if the declines in relative abundance of white sharks documented at their historical aggregation sites were instead indicative of a declining population.

8. Issues regarding the open science approach

A final concern relates to data availability and reproducibility. Open science is considered beneficial as it allows increasing faith in scientific work (Allen and Mehler, 2019). We note that as part of an effort aimed at addressing some of the analytical issues outlined above and further investigating whether the population of white sharks in South Africa might be indeed stable, we sought access to evaluate the raw data which was indicated in Bowlby et al. (2023) as "available on request" - part of the publishing journal's open access data requirements. Following multiple requests, we received a data sharing agreement, legally restricting the use of the data, which included prohibiting the "disclosure of information" and "the retention of data", subject to "legal actions", thus undermining the whole essence of both the principle of scientific reproducibility and the open science approach. We were thus unable to re-analyse the data under such restrictions.

Concluding remarks and future directions

Because of the violation of the assumption of index-population proportionality, the issues around variability among and within a time-series, the lack of statistical support for the model, and the interpretations of the results, we do not believe the data, as currently reported, provide evidence of a stable white shark population in South Africa, nor of its redistribution. In contrast, while the spatial distribution of some individual sharks may have changed, likely impacted by orcas after 2017, we believe that the concurrent declines shown in Bowlby et al. (2023) both in the West (False Bay and Gansbaai) and in the East (KZN region), as well as the reduction in sightings of large mature individuals, might be more consistent with the hypothesis of a population decline contracting from the edges of its distribution. This hypothesis is further substantiated by Bowlby et al. (2023) when they confirm that "*the mean size of female white sharks caught in the KZNSB bather protection program has declined… indicative of a population under pressure*".

Therefore, while more data is needed to understand the population status of South Africa's white sharks, we suggest a precautionary approach to be taken in light of concurrent local declines documented at historical aggregation sites, historical and current levels of known removals occurring in the KZNSB lethal shark control program, as well as the reduction in sightings of large mature individuals currently being observed. We believe that, while the need for a precautionary approach to white shark conservation could be worryingly undermined by the inferences made by Bowlby et al. (2023) and the message conveyed to the media, and ultimately to the South African government, such suggested line of action is in accordance with "*scientifically based management and consistent with a Precautionary Approach*" per the South African Department of Forestry Fisheries and Environment's National Plan of Action for Sharks (DAFF, 2013). An approach also shared by previous government's strategies both in South Africa and worldwide which, in presence of knowledge gaps and uncertainty, decided to err on the side of precaution (Compagno, 1991; Woolaston and Hamman, 2015).

CRediT authorship contribution statement

Enrico Gennari: Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Conceptualization. **Neil Hammerschlag:** Writing – review & editing, Conceptualization. **Sara Andreotti:** Writing – review & editing, Conceptualization. **Chris Fallows:** Writing – review & editing. **Monique Fallows:** Writing – review & editing. **Matias Braccini:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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Author contributions

Enrico Gennari, Sara Andreotti and Neil Hammerschlag conceptualised the manuscript. The first draft of the manuscript was written by Enrico Gennari and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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