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Flawed citation practices facilitates the unsubstantiated perception of a global trend toward increased jellyfish blooms

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Title: Flawed citation practices facilitates the unsubstantiated perception of a global trend toward increased jellyfish blooms

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ABSTRACT

Speculation over a global rise in jellyfish populations has become widespread in the scientific literature but until recently the purported 'global increase' had not been tested. Here we present a citation analysis of peer-reviewed literature to track the evolution of the current perception of jellyfish increases and identify key papers involved in its establishment. Trend statements and citation threads were reviewed and arranged in a citation network. Trend statements were assessed according their degree of affirmation and spatial scale and the appropriateness of the citations used to support statements was assessed. Analyses showed 48.9% of publications misinterpreted conclusions of cited sources, with a bias towards claiming jellyfish populations are increasing, with one review having the most influence on the network. Collectively, these disparities resulted in a network based on unsubstantiated statements and citation threads. As a community, we must ensure our statements about scientific findings in general are accurately substantiated and carefully communicated such that incorrect perceptions, as in the case of jellyfish blooms, do not develop in the absence of rigorous testing.

INTRODUCTION

Identifying patterns in nature usually occurs through the accumulation of frequent consistent observations typically involving a synthesis of a large number of scattered scientific reports addressing specific questions, a "development-by-accumulation" of accepted facts and theories (Kuhn, 1975). Generally, the consistency among primary observations will be captured in narrative reviews and eventually in formal meta-analyses. This process of accumulation leads to the establishment of patterns and, once formally tested by the scientific method, theory. The path from primary observations to theory is provided by a network of citations that guide the reader from the final synthesis to the source of individual observations, thereby ensuring that the process is reproducible. This entire process, therefore, critically depends on the quality of the primary observations and on the accuracy of citation practices carrying knowledge across networks of papers (Todd *et al*., 2010). As Dupps (2008) notes citations are "*a form of academic succession, a lineage of ideas and proofs, into which we place our own work*".

Citations are, however, subject to errors of bias and inaccuracy (Dupps, 2008). Mis-citation and publication bias are artefacts of paradigm development across fields. The steep growth of the scientific literature at 7.7% per year for ecological sciences (Andersen *et al.*, 2008) with > 2.2 million papers added to the Web of Knowledge in 2012 alone is now producing a Babelian tower of information challenging the capacity of individual scientists to maintain a solid grasp on literature that underpinned rigorous citation practices in the past. As a result, there is growing concern and evidence that citation practices may be prone to considerable errors of accuracy and bias (Harzing, 2002; Todd *et al*., 2007; 2010).

Following a qualitative study pointing at gross misquotations (Harzing, 1995), Harzing (2002) conducted a pioneering quantitative analysis of citation networks to show that poor citation practices had created the false perception that repatriation rates of foreign workers were high. More recently, Todd *et al.* (2007; 2010) observed high and consistent rates of mis-citation in general ecology and marine biology literatures with only 76.1% and 75.8% of citations respectively clearly supporting the assertions made in each discipline. Errors of accuracy in citation are particularly concerning because

they may have considerable influence on the development of perceptions within a discipline if they are persistent and biased in a particular direction (Harzing, 2002).

A particular case of a perception lacking robust scientific evidence is that of the perceived global increase in jellyfish blooms (Condon *et al.,* 2012). This perception percolated from scientific literature into media reports (Condon *et al*., 2012) and policy statements (e.g. Turley & Boot, 2010) prior to the two meta-analyses that finally tested the hypotheses (Brotz et al. 2012; Condon et al. 2013). These meta-analyses provided evidence of increasing jellyfish blooms in 28 of 45 (i.e. 62%) Large Marine Ecosystems investigated (Brotz *et al*., 2012) and 30% of long-term records of jellyfish abundance (Condon *et al*., 2013), with the latter also indicating that global jellyfish populations undergo multi-decadal cycles. Hence, whereas the hypothesis that jellyfish may be rising globally cannot be rejected, it cannot be fully supported with the data available and the global trend of jellyfish blooms remains inconclusive. Here we examine how the perception that jellyfish blooms are rising, developed in absence of quantitative meta-analysis and solid evidence.

Given that mis-citation is widespread in ecology (Todd *et al*., 2007) we ask here whether chains of citations may have contributed to transforming suggestions that jellyfish blooms 'appear to be rising in some areas' into assertive statements on a 'global rise in jellyfish'. We analysed a network of citations on trends in jellyfish populations to assess the hypothesis that mis-citation practices contributed to the perception that jellyfish blooms were increasing globally in the absence of rigorous analysis supporting the assertion.

METHODS

Classification of statements on jellyfish population trends and citation assessment

All available papers (n=225) published on jellyfish ecology between 1987 and April 2012 (prior to Brotz *et al*., 2012, the first global analysis of jellyfish populations) were collated through an exhaustive search on Google Scholar (GS) and Web of Knowledge (WOK). The search terms used were: "jellyfish" or "jellyfish blooms" or "ctenophore" or "gelatinous zooplankton"; "population" or "abundance" or "distribution"; "change"

or “trend”; “increase” or “increasing” or “rise” or “rising”; “global” or “worldwide” or “regional” or “region”.

The compiled literature was sorted in two stages. First, we searched for statements on jellyfish population trends. Only statements about historical (rather than future) trends in jellyfish populations were included. We included generic statements (i.e. those without a spatial reference) and statements that referred to global or multi-regional spatial scales. Papers with regional/local statements were excluded, unless other papers cited them. An important caveat is that our goal was not to report on any findings of the authors, but to specify trend statements made by authors at global or multi-regional scales. Hence, such statements usually did not stem from the results presented and were often encountered in the introduction or discussion/conclusions section supported by reference to previous research rather than the research presented in the paper being assessed. Because we only assessed papers published prior to the first global analysis of jellyfish populations (Brotz *et al*., 2012), none of the statements found could have been based on a formal global analysis and, therefore, were necessarily supported by inferences made by prior research. Papers making statements that referenced other sources were defined as ‘citing papers’ and papers used to support these statements were ‘cited papers’. Papers that were not available in digital form were scanned and included in the database Sanz-Martín *et al.*, 2016. .

Statements of the citing papers were classified into 5 spatial categories and 6 degrees of affirmation. The spatial categories were: 1) generic (no spatial context provided); 2) global; 3) multiple regions, 4) regional and 5) cannot verify. For analyses, categories 1 and 2 were combined (generic/global) because, whether or not intended by the author, statements that were not framed within a spatial context can be interpreted by others to refer to a generic situation and, therefore, contribute to the perception that increases in jellyfish populations were occurring throughout the world’s oceans. The affirmation degrees were: 1) are or have been increasing; 2) may be or appear to be increasing; 3) equivocal; 4) decreasing; 5) no trend statement and 6) cannot verify. For instance, Brodeur *et al*. (2011) wrote "*Evidence is accumulating that gelatinous zooplankton populations have increased recently in many regions of the world* (Purcell *et al*., 2007; Richardson *et al*., 2009)." This statement was classified as “multiple regions” and “are increasing” (Sanz-Martín *et al.*, 2016.).

When papers contained multiple statements, the paper was categorized using the broadest spatial scale it referred to and its maximum degree of affirmation regarding trends in jellyfish populations. The category of "equivocal" referred to several conditions that included statements that trends were unclear or variable, that there were no representative data or evidence from which to draw conclusions or that some species were increasing whilst others were not.

Citations classified as "cannot verify" referred to entire volumes of conference or workshop proceedings that were cited without identifying individual papers within the volume supporting the claim. Three such volumes, Purcell *et al*. (2001), CIESM (2001) and Dumont *et al*. (2004), have been cited 5, 2, and 1 times, respectively (from 306 citations) (Sanz-Martín *et al.*, 2016.). Some books, despite being correctly cited, could not be included in our study because they cannot be tracked in WOK. Citations of papers written in Chinese, Japanese or Russian with English abstracts in support of statements on jellyfish trends were excluded from the analysis.

Each statement was independently assessed by two of the authors. Whenever the classifications were disputed, a third author was consulted and the statement was discussed until a consensus was reached, thereby providing rigorous quality control of the data set (Sanz-Martín *et al.*, 2016).

The second stage involved assessing the content of the papers cited to support statements on jellyfish population trends. Whereas we excluded regional studies from citing papers, cited papers often comprised regional studies because statements on generic, global and multi-regional trends were actually based on the aggregation of references to regional studies. Appropriateness of each citation was evaluated, following and adapting the method proposed by Todd *et al*. (2007) and a numerical score was assigned. Six categories of appropriateness were assigned one of 3 values to create a quantitative appropriateness score. Categories and values were: 1) supported (score = 0), where the statement was well defined and the cited paper provided explicit support using affirmations in the text or outcomes presented; 2) ambiguous (score = 1), ambiguous affirmations were not inconsistent with the statement but precluded a clear interpretation of the statement. This category was usually assigned when all references

were placed at the end of a sentence instead of after the appropriate phrase within a sentence, thereby preventing unambiguous assessment of which phrase the reference was intended to support; 3) empty citations (score = 1), where the statement in the cited paper referred to by the citing paper was not an outcome of the research presented in the cited paper, but referred to prior research (Harzing, 2002; also called "lazy author syndrome" by Gavras, 2002). These statements were typically found in the introduction and were used to frame the research of the cited paper; 4) selective (score = 1), where a paper was cited despite that paper also having presented information that did not support the statement; 5) cannot verify (score = 1), where a statement was supported by a reference to a volume or conference proceeding, rather than any specific chapter or paper, and 6) unsupported (score = 3), where the citing paper contained no statement that could possibly support the affirmation made in the citing paper. Unsupported statements were assigned the higher value of 3 because the use of references that did not in any way support the statement was considered to reflect a much more serious citation error than those that were cited selectively or ambiguously.

The Todd classification (i.e. the appropriateness assessment) did not necessarily align with the selected statement for the network because the most extreme statement issued in a paper was always selected and a Todd classification could differ from the most extreme statement if the author also issued more moderate or even contrasting statements. As with the statement classifications, every appropriateness assessment was independently assessed by two authors and a third author was consulted if the classifications differed. In case of disagreement between assessors, we generally converged towards a more conservative classification of spatial scale. Out of 159 papers included in the network, the original classifications of spatial scale and degree of affirmation assigned by each assessor differed 17 and 7 times, respectively. Hence, although the classification statements involved a degree of subjective interpretation, this only led to the assignment of categories varying in < 10% of the cases.

Following the previous example to illustrate the process, Brodeur *et al*. (2011) cites Purcell *et al*. (2007) and Richardson *et al*. (2009) in support of a statement that gelatinous zooplankton populations *"are increasing"* at *"multiple regions"* (Sanz-Martín *et al.*, 2016). The citation to Purcell *et al*. (2007) is *"selective"* (score = 1)

because although Purcell *et al*. (2007) reviews cases where populations have increased, she also states *"While speculation is abundant, evidence for sustained increases is lacking"* and *"It is too soon to know whether these recent jellyfish increases will be sustained or the populations will fluctuate with climate as seen for other species"* (Sanz-Martín *et al.*, 2016). The citation to Richardson *et al*. (2009) is *"supported"* (score = 0) because this paper was done in response to claims of increasing jellyfish populations and it states that, *"a picture is now emerging of more severe and frequent outbreaks in many areas"* and it issued no caveats to that statement. Therefore the mis-citing score (defined as the sum of appropriateness scores) of Brodeur *et al*. (2011) is 1 and given that this paper was not cited by other authors in support of jellyfish trends, it does not have a mis-cited score (Sanz-Martín *et al.*, 2016). In contrast, Dong *et al*. (2010) stated *"Over the last decade, a significant increase in jellyfish blooms has been observed worldwide in marine ecosystems and are becoming seen as an indicator of a state shift in pelagic ecosystems* (Arai, 2001; Graham, 2001; Mills, 2001; Purcell, 2005; Purcell *et al.,* 2007; Uye, 2008; Zhang *et al*., 2009; Richardson *et al*., 2009)". This statement was classified as "*are increasing*" and "*global/generic*" because the authors claim it is a "worldwide" phenomenon and the accompanying citations were "*unsupported*" (score = 3 per citation) as none of them carried out a global analysis to achieve this conclusion except Zhang *et al*. (2009), which was excluded because it was written in Chinese and could not be evaluated, and the citation to Richardson *et al*. (2009) that was classified as "*supported*" (score = 0) for the same reason stated for Brodeur *et al*. (2011). The mis-citing score of Dong *et al*. (2010), therefore, is 18, involving 14.3% appropriate and 85.7% inappropriate citations. This paper has only been cited once in support of jellyfish trends and the assessment was "supported" (score = 0), so its mis-cited score is 0 (Sanz-Martín *et al.*, 2016.).

The data set has been archived on the Spanish Research Council database repository (CSIC Digital) with the reference Sanz-Martín et al., 2016.

Citation network and its topological analysis

We used the classification of trend statements, citation threads and citation assessment to build a citation network (Fig. 1). Each node represents a paper with a trend statement

about jellyfish populations classified according to spatial category and degree of affirmation. Links from node *i* to node *j* indicates that paper *i* was cited by paper *j,* thereby representing the information flow in the network, which is directional as, of course, citing papers are published later than those they cite. The colour of nodes indicates the affirmation degree and its shape represents the spatial category of the statement (Fig. 1, Appendix 1 contains a colour-blind friendly network).

The citation network (Fig. 1) allows the evolution of the perception of rising jellyfish to be traced, identifying key papers involved in establishing this notion. Specific properties of the network were analysed to quantify the relevance of each paper (or node) for the optimized flow of citations through the network (Freeman, 1977; Albert & Barabási, 2002): 1) in-degree and out-degree of nodes, which are the number of incoming arrows and outgoing arrow respectively and represent how often paper *i* cites other papers (citing frequency) and how often it is cited by other papers (cited frequency); and 2) betweenness centrality, b_i, that estimates the fraction of all shortest paths connecting any pair of nodes that pass through node *i* (Freeman, 1977). Specific properties of the nodes (or papers) of the network are available in Sanz-Martín *et al.*, 2016. The library Igraph, version 0.7.1, within the statistical software R version 2.13 was used to build and analyse the citation network (Csardi & Nepusz, 2006).

RESULTS

Our search identified 225 papers on jellyfish ecology published between 1987 and April 2012 of which 159 (70.7%) were involved, by citing or being cited, in contributing to the perception of a global jellyfish rise. A total of 51.6% of papers in the network were 'citing only' papers, 27% were 'cited only' papers, and 15.7% of papers were both 'citing & cited' papers. 3.8% of papers claimed jellyfish trend statements, but they were classified as 'neither citing nor cited' papers because they did not support their claims with citations and no other papers cite them. 1.9% of papers were cited papers that could not be verified. The 'citing only' papers and the 'citing & cited' papers contained at least one statement that cited between one and eight papers in support of a statement on jellyfish trends. Seventy-seven per cent of the 'cited only' papers provided statements on jellyfish trends, whereas 23% did not contain any statement on jellyfish trends despite being cited to this end.

From the 115 'citing only' and 'citing & cited' (hereafter citing papers) that have contributed to the perception of increasing jellyfish population, 70 papers (60.9%) stated that jellyfish populations are or have been increasing of which 27.2% referred to increases at the global or generic scale, and 34.3% at the scale of multiple regions (Table 1). One in every four citing papers (26.1%) provided a statement indicating that populations may be increasing, of which 11.4% referred to global or generic increases, 14% to increases in multiple regions and 0.9% to possible regional increases (the regional study was included because it was a 'citing & cited' paper) (Table 1). A total of 10.4% of the citing papers stated that trends were equivocal and 2.6% could not be verified (Table 1). Whereas no papers would have had a basis to state that jellyfish are either increasing or decreasing globally since the first global analyses were not available until 2012 (Brotz *et al*., 2012; Condon *et al*., 2013), 27% of the papers contained such a statement and all argued for a global rise in jellyfish (Table 1). Similar inferences however, would have been legitimate for the multi-regional trend statements (34%, Table 1), which often appropriately cited several region-specific papers to support their statement. In our network, 16% of the total evaluated papers (25 out of 159) were 'cited only' studies. As has been shown, most statements focused on increases and neglected the evidence for equivocal and variable trends (12 papers cite 29 other studies in reference to equivocal trends and only 1.3% were inappropriate, Table 1 and Table 3), despite monotonous jellyfish declines being almost as represented as reports of increases (cf. Condon *et al*., 2013).

The cumulative number of citing papers classified as "are increasing" and "may be increasing" displayed a rapid increase, at a rate of 64.1% and 23.8% per year, and papers classified as "equivocal" at a slower rate of 9.7%, from the first papers that discussed possible trends and cited any source (Fig. 2). The first cited paper we found in support of statements on trends in jellyfish populations was Legovic (1987) but it was not until the late 1990s that cited papers started to increase in the literature. The first highly cited paper within the network (which received 18 citations in support of jellyfish population trends) was Brodeur *et al*. (1999), which concluded that in the Bering Sea, "*the biomass of large jellyfish has increased dramatically in the 1990s compared with the previous decade*". This paper attracted considerable attention (Fig. 3, Table 2) and could be considered to have seeded the question of whether jellyfish may

be rising in other areas. This question was subsequently addressed by Mills (2001), which was by far the most influential paper in this citation network (Figs. 1 and 3; Table 2). Mills (2001) triggered a large flux of research on trends in jellyfish populations with other prominent papers in the network of citations including reviews by Brodeur *et al*. (2002), Purcell (2005), Purcell *et al*. (2007) and Richardson *et al*. (2009) (Figs. 1 and 3; Table 2). Despite Mills (2001) being a balanced paper including statements of jellyfish increases (e.g. *"Some blooms appear to be long-term increases in native jellyfish populations"*, Mills, 2001) and decreases (e.g. *"Lest one conclude that the next millennium will feature only increases in jellyfish numbers worldwide, examples are also given in which populations are decreasing in heavily impacted coastal areas",* Mills, 2001), she may have been inadvertently responsible for seeding a chain of inappropriate citations since the title posed the question "*Jellyfish blooms: are populations increasing globally in response to changing ocean conditions?"*, which left it up to the readers to draw their own conclusions and provided grounds for selective and inappropriate citations.

The dominance of Mills (2001) in the network was evident in that it was the most cited paper (54 citations) but also had the highest mis-cited score (= 66), as 85% of the statements supported by reference to Mills (2001) were inappropriate (Fig. 3, Table 2). Specifically, Mills was selectively cited 50% of the time, ambiguously cited 9% of the time, unsupported 10% of the time and supported only 15% of the time. Hence, Mills (2001) was particularly influential in conforming views about jellyfish trends before rigorous, quantitative analyses of the evidence were attempted. The case of Mills (2001) also reflects the difficulties authors had in correctly assigning conclusions to papers that provide ambiguous conclusions.

Five of the eleven most-cited papers in our network were reviews. Of the remaining six papers, which reported primary observations, two papers reported definite regional and multiregional increases (Brodeur *et al*., 1999; Lynam *et al*., 2006), two papers reported possible increases (Brodeur *et al*., 2002; Link & Ford, 2006) and one paper reported equivocal trends (Graham, 2001a) (Fig. 3, Table 2). The top three and the top eleven most-cited papers accumulated a cited frequency of 37% and 59% of all the citations, respectively (Table 2).

Three of the eleven most cited papers also ranked within the ten papers with the highest betweenness centrality, showing their importance in connecting groups of papers with divergent perceptions on the issue and being inappropriately cited on 14% to 85% of occasions (Fig. 3, Table 2). Five of the 11 most cited papers do not cite previous studies regarding global or multi-regional trends in jellyfish populations (i.e. they are 'cited only' papers). Thus, these papers had zero betweenness centrality and they contributed the initiate the perception. Richardson *et al*. (2009) was one of the 11 most cited papers and also had the highest betweenness centrality (*bi* = 199.5) because it connected early views regarding possible trends with more recent research focused on the drivers of those putative trends. Of the citations made by Richardson *et al*. (2009) in support of jellyfish population trends (8 citations) 62.5% were "unsupported" and 37.5% were "supported", having a mis-citing score of 15, the third highest mis-citing score of the network (Sanz-Martín *et al*., 2016). In turn, Richardson *et al*. (2009) was always appropriately cited (100% "supported"), because this paper could be cited as evidence for concern about increases in jellyfish numbers (Fig. 3, Table 2).

Mis-citation was evident in the network (Fig. 1) with 48.9% of the citations being considered inappropriate for the statements they purport to support (Fig. 4, Table 3). The citing papers that had the most inappropriate citations were those that asserted that jellyfish are increasing at both global/generic and multi-regional scales (34.6%, Fig. 4, Table 3) whereas those papers that stated that jellyfish may be increasing at global, generic or multi-regional scales were less prone to poor citation practices (13.1%, Fig. 4, Table 3).

DISCUSSION

This network of citations shows that jellyfish demography is a vibrant research field and the rate of papers referring to jellyfish population trends has increased 87.1% per year since 1998, and far exceeds the 7.7% annual increase in the growth rate of scientific literature in ecology (Andersen *et al*., 2009). Examination of the network allows the identification of four stages involved in the development of this perception. First, the report of Brodeur *et al*. (1999) of an increase in jellyfish populations for the Bering Sea followed by the review of Mills (2001), which is by far the most influential paper in this

research topic. Despite the author, Claudia Mills, presenting balanced views in her conference talk at the first Jellyfish Blooms Symposium in 1999 and in the associated paper (Mills 2001), the possibility that jellyfish populations may be increasing was raised. The second stage involved papers that selectively cited the statements in Mills (2001) to assume that jellyfish populations were or may be increasing globally or across multiple regions and moved on to develop the narrative through reviews aimed at identifying the environmental drivers of purported increases (Purcell *et al.*, 2007; Richardson *et al*., 2009). Following a decade of speculation, a third stage developed two quantitative meta-analyses to establish whether increases in jellyfish populations are a global phenomenon (Brotz *et al*., 2012; Condon *et al*., 2013). Interestingly, Brotz *et al*. (2012) and Condon *et al*. (2013), differ in their conclusions despite reporting comparable results. Brotz *et al*. (2012) concluded that evidence for increasing jellyfish blooms was available for 28 of 45 (i.e. 62%) of the Large Marine Ecosystems since 1950, from which 21% showed increases with high certainty. Condon *et al*. (2013) report that 30% (11 of 31) of the long-term records of jellyfish abundance included in their analysis showed a significant increase in jellyfish abundance since 1970. Brotz *et al*. (2012) conclude that "*Jellyfish populations appear to be increasing in the majority of the world's coastal ecosystems and seas*" whereas Condon *et al*. (2013) conclude that "*the perception of a global rise in jellyfish, possibly prompted by more jellyfish blooms in the 1990s, may therefore be best interpreted as part of an oscillation"*. The fourth phase involves the present study, which follows the thread of citations in support of jellyfish trend statements flowing from the quantitative analyses of Brotz *et al.* (2012) and Condon *et al.* (2013) to previous speculative studies because available evidence is still subject to different interpretations. Poor citation practices lends credence to the perception of a global trend toward increased jellyfish blooms which may be less likely once more quantitative data are available and increasing data availability limits the margin for misinterpreting results.

A bias towards the possibility of increasing jellyfish blooms is further illustrated by three cases. First, Jackson *et al*. (2001), a highly cited paper in the context of global impacts in the ocean ecosystem (4,523 cites according to Google Scholar, January 2016) proposed that oceanic degradation resulted, among other consequences, in outbreaks of jellyfish, providing only anecdotal evidence from a single location and study, Newell (1988), to support this claim. Jackson (2008) further concluded in the

abstract that *"synergistic effects… are transforming complex food webs into… simplified… ecosystems with boom and bust cycles of... jellyfish…"* without offering any evidence in the paper to support this statement. Second, Brodeur *et al*. (2002) reported a major increase in jellyfish in the Bering Sea but subsequently reported declines in populations (Brodeur *et al*., 2008). Numerous papers published after Brodeur *et al*. (2008), however, continue to cite Brodeur (2002) as an example of a sustained increase in jellyfish and ignore the later paper showing that jellyfish populations in the Bering Sea are variable. Third, a United Nations Environment Report (Turley & Boot, 2010) and one of the most widely-cited reviews on impacts of ocean acidification (Doney *et al*., 2009; cited 1,602 times in GS, accessed January 2016) cited Attrill *et al*. (2007) to claim a link between ocean acidification and increased jellyfish numbers but both papers did not acknowledge the rebuttal of Attrill *et al*. (2007) by Haddock (2008), the erratum published by Attrill & Edwards (2008) nor the expanded analysis of Attrill *et al*. (2007) by Richardson & Gibbons (2008) that showed no link between acidification and jellyfish populations. Indeed, the misconceptions resulting from mis-citation are even more dangerous when they are contained in papers published in highly influential journals, which provide a platform for those papers to be highly cited. Duarte *et al*. (2015) have argued that poor citation practices are one of the elements that have perpetuated perceptions on ocean calamities, (including rising jellyfish populations) which are contributing to an overly negative perception on the state of the ocean. Our study confirms that that mis-citation facilitated the perception of rising jellyfish populations.

Our analysis suggests that inappropriate citations may have been facilitated by the presence of imprecise or ambiguous language and contradictory statements in papers with variable conclusions. For instance, we determined that 85% of papers referencing Mills (2001) were inappropriate, including 19%, which were unsupported. In this paper Mills poses a question in the title that is not clearly answered in the text and, in searching for answers, the reader might focus on selected sentences thereby choosing to ignore the balanced account of evidence for increases and decreases that Mills (2001) presented throughout her paper (Fig. 3, Table 2). Imprecise and ambiguous language may also introduce uncertainty into our analysis as we assigned statements to one of several categories, implying that authors citing such papers will also find difficulties to constrain the domain of the statement. For instance, Lynam *et al*. (2006) reports

"Jellyfish biomass has increased substantially in several locations worldwide, perhaps as a consequence of fishing (Mills, 2001)" showing that vague statements have facilitated mis-interpretation potentially through greater emphasis on the use of examples showing population increases than those showing declines. Mills (2001) was also cited as evidence of both increasing and decreasing populations but in most cases, increasing examples are discussed first and decreasing examples used as caveats. For instance, Barz & Hirche (2007) stated *"in recent years the abundance of scyphomedusae is increasing in many ecosystems, ... but decreases have also been reported (Dawson et al., 2001; Mills, 2001)"*, where Dawson *et al*. (2001) is the only paper whose maximum degree of affirmation statement was classified as "decreasing" jellyfish trends.

The accuracy of citations was not aided by the fact that some influential review papers were often cited indirectly, as shown by the betweenness centrality pattern of the network (i.e. Richardson *et al,* 2009 and Purcell *et al,* 2007). Mills (2001) was clearly the most influential paper in the development of the perception of rising jellyfish populations (54 citations, 17.6% of the 306 citations used in support of trend statements). However, the development of a perception based on a concept introduced in an influential seminal paper, which then is followed by other researchers, is not unusual. In fact, it has been proposed to be the process through which paradigms and even disciplines develop (Krishnan, 2009). Paradigms are not static, but tend to change as science advances through what Thomas Kuhn (1975) called scientific revolutions. A decade after Mills (2001) was published we may be at a point where the perception of rising jellyfish populations (Condon *et al*., 2013) may be shifting. Indeed, Richardson *et al*. (2012) proposed that researchers should move beyond the question of global trends to focus on factors controlling those populations that are certainly increasing by managing the purported anthropogenic drivers of blooms, including eutrophication, overfishing and species translocations.

Todd *et al*. (2010) concluded that *"one in four citations in marine biology papers is inappropriate"*. Our analyses, however, indicate a rate of inappropriate citations (49%) in the literature addressing jellyfish population trends. We also provide evidence of inappropriate citation of papers with variable or ambiguous conclusions, propelling the rapid growth of statements that jellyfish numbers are, or may be, rising globally. We

submit that the reason for differential citation bias for papers asserting or questioning that jellyfish blooms are increasing may be derived from the aversion of the ecological community towards Type II errors or false negatives, as the implications of erroneously concluding that jellyfish blooms are not rising when in fact they might be are higher than the reverse, a concern that has been recently highlighted by Richardson *et al*. (2012). Our results suggest the accumulation of multiple lines of evidence occasionally forms an imprecise framework statement (e.g. assertions of jellyfish increasing globally or generic populations based on "equivocal" and "regional" conclusions) that can be easily propagated. Guidelines to robust citation practices highlight the importance of including the citation immediately after the phrase that calls on it and avoiding the clustering of references at the end of a sentence (Dupps, 2003). This helps clarify which statement each reference supports. It is also important to provide a balanced account of the research question discussed, acknowledge the caveats the authors introduced, and actively search for counter-evidence (Harzing, 2002). However, the onus of avoiding mis-citations also rest on the authors, who should not only ensure they adhere to robust citation practices but that that they too avoid ambiguous statements that may lead to misinterpretations. Catchy, declaratory titles are conducive to misinterpretations as they typically capture only some of the findings reported, which might direct citing readers to focus on the conclusion highlighted in the title. Furthermore, we highlight the importance of adhering to best practices in hypothesis testing enabling strong inferences in science (Platt, 1964). As a community, we must ensure our statements about scientific findings in general are accurately substantiated and carefully communicated, thereby minimizing the possibility of being mis-cited, such that incorrect perceptions, as in the case of jellyfish blooms, do not develop in the absence of rigorous testing and robust evidence.

We are making the database available in Sanz-Martín *et al.*, 2016 to allow readers to challenge the robustness of our analysis by reading the sources cited and decide the extent to which the statements are or not supported by references used, re-classify the statements according to its affirmation degree and spatial scale, and re-run our analysis.

ACKNOWLEDGEMENTS

We are very grateful to P. Casal for sharing his support for the paper and knowledge about jellyfish populations in the early stages of this work and J. Holding for English language. MS-M was funded by Fundación "La Caixa" PhD grants (Spain). RHC was funded by National Science Foundation grant OCE 1030149.

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BIOSKETCH

Marina Sanz-Martín is a PhD student in Marine Science, she studies planktonic primary production and the ecological consequences of changing ocean conditions in the Arctic Ocean; an early version of this study was her master's dissertation. Kylie Pitt, Rob Condon, Cathy Lucas and Carlos Duarte are all members of a NCEAS working group entitled 'Global expansion of jellyfish blooms: magnitude, causes and consequences' (http://www.nceas.ucsb.edu/projects/12479). Charles de Santana is a computer scientist with expertise in computer modelling and complex systems.

TABLES

Affirmation degree	Spatial category	% Citing papers (n)	
Are increasing	Global and generic	27.2 (31)	60.9 (70)
	Multi-regional	34.2 (39)	
May be increasing	Global and generic	11.4 (13)	26.1 (30)
	Multi-regional	14.0 (16)	
	Regional	0.9 (1)	
Equivocal	Global and generic	5.2 (6)	10.4 (12)
	Multi-regional	5.2 (6)	
Cannot verify		2.6 (3)	
Total		100 (115)	

Table 1: Percentage and number in brackets of citing papers that state different trends in jellyfish population. The shaded cell indicates that these statements were impossible based on the literature available prior to April 2012.

Network label	Paper	Type of citation	Year	Jounal	Impact Factor	Type	Statements clasification		Appropriateness assessment								
							Spatial category	Affirmation degree	Betweenness centrality	Cited paper				Citing paper			
										Cited frequency (Degree-out)	Mis-cited score	Supported-cited (%)	Inappropiate-cited (%)	Citing frequency (Degree-in)	Mis-citing score	Supported-citing (%)	Inappropiate-citing (%)
1	Mills, 2001	Cited only	2001	Hydrobiologia	2	Review	Multiple regions	Equivocal	0	54	66	14.8	85.2	0	Not Citing	Not Citing	Not Citing
2	Purcell *et al*, 2007	Citing & cited	2007	Marine Ecology Progress Series	2.6	Review	Global or generic	Equivocal	44	21	24	33.3	66.7	1	0	100	0
3	Brodeur *et al*, 1999	Cited only	1999	Fisheries oceanography	2.2	Primary	Regional	Are or have been increasing	0	19	7	84.2	15.8	0	Not Citing	Not Citing	Not Citing
4	Brodeur *et al*, 2002	Citing & Cited	2002	Marine Ecology Progress Series	2.6	Primary	Regional	May be or appear to be increasing	17.5	19	14	57.9	42.1	1	0	100	0
5	Purcell, 2005	Cited only	2005	Journal of the Marine Biological Association of the United Kingdom	1.6	Review	Global or generic	Are or have been increasing	0	16	15	56.2	43.8	0	Not Citing	Not Citing	Not Citing
6	Graham, 2001a	Citing & cited	2001	ICES Journal of Marine Science	2.5	Primary	Multiple regions	Equivocal	7	13	10	69.2	30.8	1	0	100	0
7	Richardson *et al*, 2009	Citing & cited	2009	Trends in Ecology & Evolution	15.4	Review	Global or generic	Are or have been increasing	199.5	13	0	100	0	8	15	37.5	62.5
8	Lynam *et al*, 2006	Citing & cited	2006	Current Biology	9.5	Primary	Multiple regions	Are or have been increasing	5.5	11	6	81.8	18.2	1	1	0	100
9	Arai, 2001	Cited only	2001	Hydrobiologia	2	Review	Global or generic	Equivocal	0	7	8	42.9	57.1	0	Not Citing	Not Citing	Not Citing
10	Link and Ford, 2006	Citing & cited	2006	Marine Ecology Progress Series	2.6	Primary	Multiple regions	May be or appear to be increasing	108	7	3	85.7	14.3	5	1	80	20
11	Mills, 1995	Cited only	1995	Hydrobiologia	2	Review	Multiple regions	May be or appear to be increasing	0	7	2	71.4	28.6	0	Not Citing	Not Citing	Not Citing

Table 2: Summary metrics for the eleven most-cited papers within the network. These papers can be "cited" by others or "citing" other papers in support of jellyfish trend statements. Metrics include: the betweenness centrality, the appropriateness assessment (adapted from Todd *et al.*, 2010), the mis-cited score, the mis-citing score and the results of each appropriateness assessment.

	Inappropriate citations		
Affirmation degree / Spatial scale	% Global and generic (n)	% Multi-regional (n)	% Total (n)
Are increasing	18.6 (57)	16.0 (49)	34.6 (106)
May be increasing	5.9 (18)	7.2 (22)	13.1 (40)
Equivocal	0 (0)	1.3 (4)	1.3 (4)
Decreasing	0 (0)	0 (0)	0 (0)
Total	49 (150 / 306)		

Table 3: Inappropriate citations made to support statements showed in Table 1. The citation was evaluated as inappropriate (unsupported, empty, selective, ambiguous or cannot verify) or appropriate (supported), according to and modified from to Todd *et al.* (2010). The shaded cell indicates that the citations were impossible based on the literature available prior to April 2012.

FIGURE LEGENDS

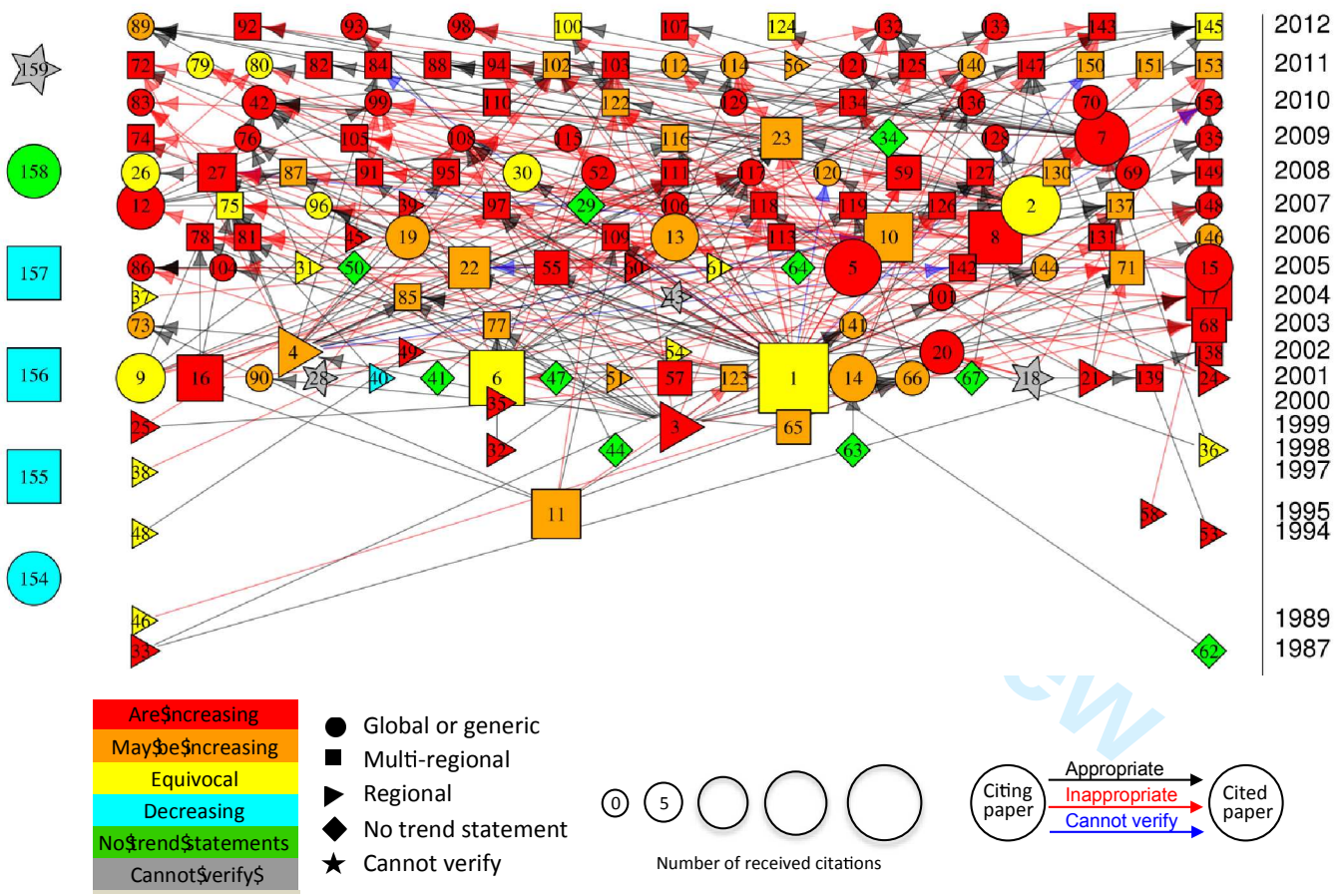
Figure 1. Chronological network of citation threads regarding jellyfish population trends. Nodes represent papers, their size and their numerical label represent the frequency at which they have been cited by other papers in the network, their shape represents the spatial category and their colors represent the affirmation degree stated in support of jellyfish trends. Arrows represent the appropriateness assessment of the citations. Data set available in Sanz-Martín *et al*., 2016

Figure 2. Cumulative number of citing papers containing different statements on jellyfish population trends (a)

Figure 3. The eleven papers most often cited to support jellyfish trend statements: citation assessment (adapted from Todd *et al.*, 2010) and number of received citations.

Figure 4. Citation appropriateness results (adapted from Todd *et al.*, 2007) for jellyfish population trends statements.

FIGURES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Appropriate
Inappropriate
Cannot verify

Figure 1

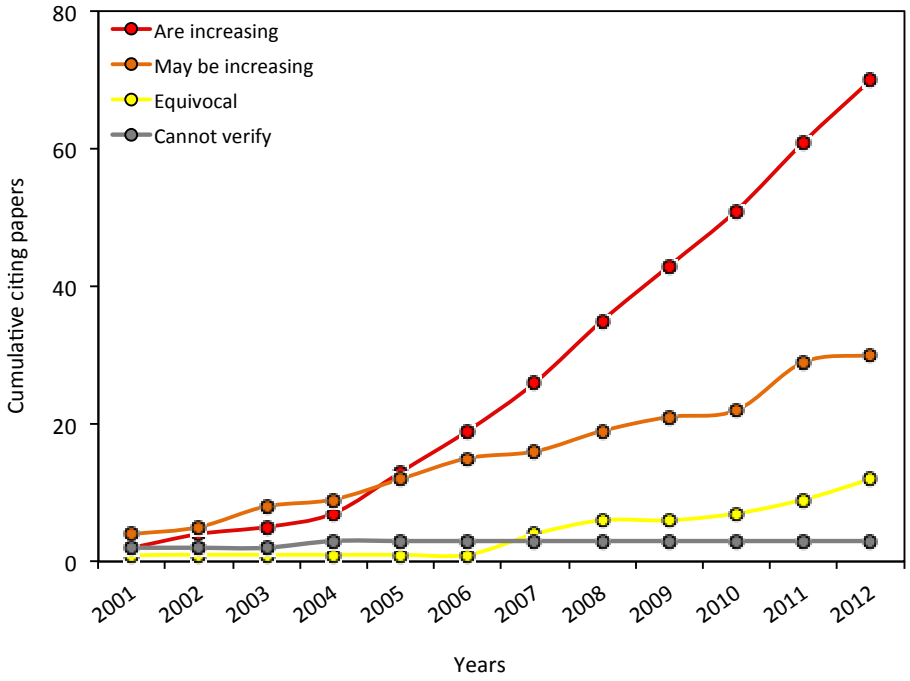


Figure 2

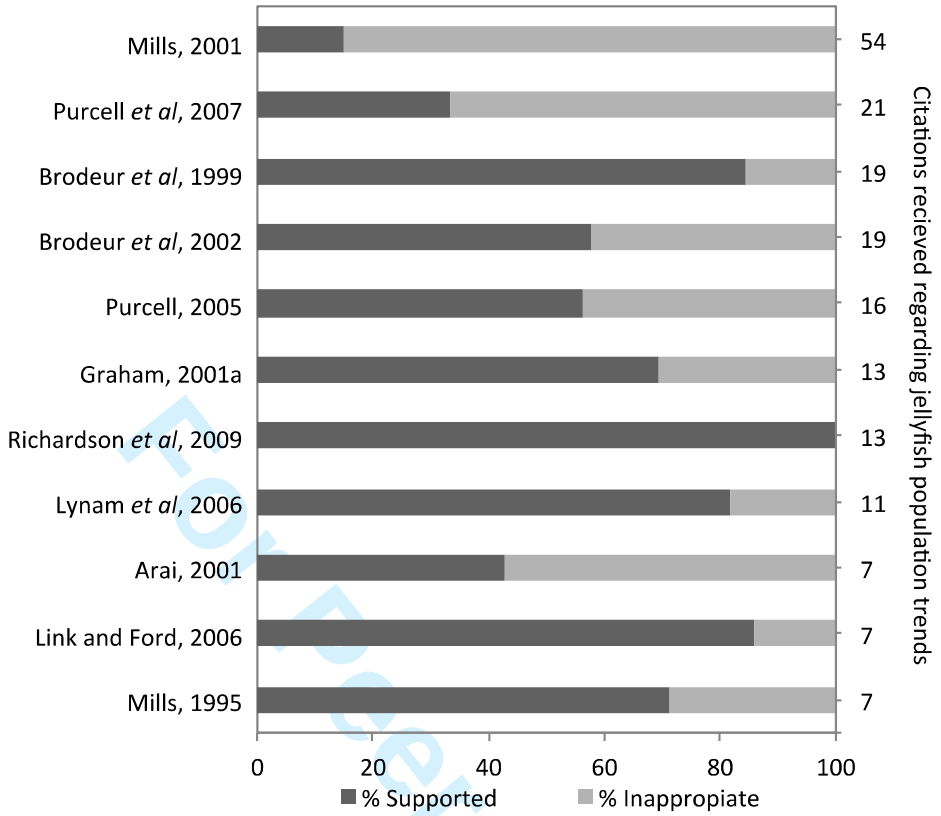


Figure 3

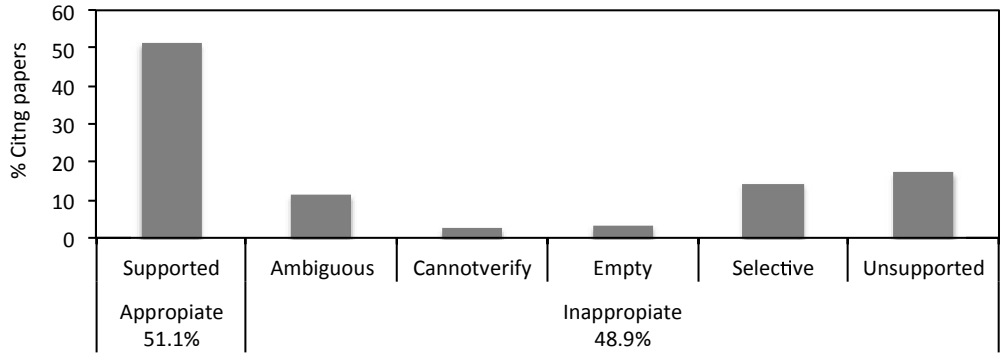


Figure 4

SUPPORTING INFORMATION

Appendix 1: Colour-blind friendly network Appendix 1.pdf

Dear Editor,

Please, find the revised version of our manuscript GEB-2015-0375, now entitled "*Flawed citation practices facilitates the unsubstantiated perception of a global trend toward increased jellyfish blooms*."

We thank the Editor-In-Chief and the Editor for their constructive suggestions, which have contributed to significantly improving the paper, specially the Conclusions section. We attach with a detailed, point-by-point, account of the actions taken to accommodate their suggestions.

We are confident that the changes and modifications made have greatly improved the manuscript and we hope that you will find the manuscript acceptable for publication in *Global Ecology and Biogeography* in its present form.

Yours sincerely,

Marina Sanz-Martín and Co-authors.

Responses to Comments

EDITOR-IN-CHIEF'S COMMENTS TO AUTHORS

Please look for reasonably pain-free ways of shortening the manuscript slightly. Importantly, please do not allow it to grow in size.

Comment and action: We agree, some paragraphs have been summarized and others have been omitted to do not repeat the same issues. Now it contains 5510 words. We hope that you will find this length acceptable.

EDITOR'S COMMENTS TO AUTHORS

Editor: Tittensor, Derek

Comments to the Author:

The authors have carefully addressed the points of the reviewer, and I am happy that they have done so effectively. I do have, however, a few issues that I'd like to see addressed:

1) Firstly, it would be great if the authors could provide some suggestions as to how people might NOT be mis-cited. There is much in the discussion about how the factors that lead to mis-citation, and the suggestion that 'we must ensure our statements about scientific findings in general are accurately substantiated and carefully communicated such that incorrect perceptions'. It would be good to see an example of how to do this, perhaps from a paper with 'ambiguous' findings. Are there any commonalities to the papers that are NOT mis-cited in terms of

phrasing or style?

Comment: Thank you for your suggestion, this reflexion has helped to close properly the manuscript and provide a take-home-message.

Action: The next paragraph has been included.

Line 547: "Guidelines to robust citation practices highlight the importance of including the citation immediately after the phrase that calls on it and avoid clustering references at the end of a sentence (Dupps, 2003). This helps clarify which statement each reference supports. It is also important to provide a balanced account of the research question discussed and acknowledge the caveats the authors introduced, and actively search for counter-evidence (Harzing, 2002). However, the onus of avoiding miss-citations also rest on the authors, who should not only ensure they adhere to robust citation practices but that that they too avoid ambiguous statements that may lead to misinterpretations. Catchy, declaratory titles are conducive to misinterpretations as they typically captured only some of the findings reported, which might direct citing readers to focus on the conclusion highlighted in the title. Furthermore we highlight the importance of adhering to best practices in hypothesis testing enabling strong inferences in science (Platt, 1964). As a community, we must ensure our statements about scientific findings in general are accurately substantiated and carefully communicated, thereby minimizing the possibility of being mis-cited, such that incorrect perceptions, as in the case of jellyfish blooms, do not develop in the absence of rigorous testing and robust evidence."

One perhaps amusing thought: the authors highlight a paper (Mills 2001) where the title poses a question in terms of 'jellyfish blooms... increasing globally'. I note that the author's one title includes very similar wording: 'global trend towards increased jellyfish blooms.' How would they ensure that their own paper is not mis-cited by someone skimming the literature? Would it pass the test? Would it be better phrased as 'mis-perception of a global trend in jellyfish blooms'? Something to think about.

Comment: The word "perception" has been used to highlight that the suspected rising trend cannot be fully supported with the data available and the global trend of jellyfish blooms remains inconclusive. Thereby, the word "mis-perception" won't be appropriate.

Action: The title has been changed to "*Flawed citation practices facilitates the unsubstantiated perception of a global trend toward increased jellyfish blooms*."

Action: changed also in line 262: *"Flawed citation practices facilitates the unsubstantiated perception of a global trend toward increased jellyfish blooms."*

Action: We have run the same method with our manuscript. We have searched for the highest and broadest statement regarding jellyfish population trends. We have identified the statements (line 122) *"Two recent analyses reported evidence for increasing jellyfish blooms in 28 of the 45 (i.e. 62%) Large Marine Ecosystems investigated (Brotz et al., 2012)"*; it can be classified as "global/generic" and "are

increasing" and this citation is "supported".

2) I would like to see the authors mention, perhaps in the abstract and introduction, the current understanding of global trends in jellyfish blooms, which seems to be ambiguous from the two meta-analyses.

Comment: We agree.

Action: the Introduction now highlights that this perception remains inconclusive with a final sentence on the following paragraph.

Line 109: "prior to the two meta-analyses that finally tested the hypotheses (Brotz et al. 2012; Condon et al. 2013). These meta-analyses provided evidence of increasing jellyfish blooms in 28 of 45 (i.e. 62%) Large Marine Ecosystems investigated (Brotz *et al.*, 2012) and 30% of long-term records of jellyfish abundance (Condon *et al.*, 2013), with the latter also indicating that global jellyfish populations undergo multi-decadal cycles. Hence, whereas the hypothesis that jellyfish may be rising globally cannot be rejected, it cannot be fully supported with the data available and the global trend of jellyfish blooms remains inconclusive. Here we examine how the perception that jellyfish blooms are rising, developed in absence of quantitative meta-analysis and solid evidence."

3) One question about the methods. The following quote ' "Over the last decade, a significant increase in jellyfish blooms has been observed worldwide in marine ecosystems and are becoming seen as an indicator of a state shift in pelagic ecosystems (Arai, 2001; Graham, 2001; Mills, 2001; Purcell, 2005; Purcell et al., 2007; Uye, 2008; Zhang et al., 2009; Richardson et al., 2009)". This statement was classified as "are increasing" and "global/generic" and all of the accompanying citations as "unsupported" (score = 3 per citation) as none of these papers carried out a global analysis to achieve this conclusion except Zhang et al. (2009)'

Is it possible that by the 'worldwide' in the cited statement the original authors meant that there are cases of jellyfish blooms in numerous parts of the world, and hence it is a worldwide phenomenon? If so, it seems a bit harsh to label the accompanying citations as unsupported, since in conjunction they might suggest a worldwide pattern (and of course, they may not).

We agree partially, as the author should not leave the statement open to interpretation, and in this case the use of the term "worldwide" would have been inadequate if the authors would indeed have liked to indicate "in numerous parts of the world" as worldwide is not a synonymous for "numerous parts of the world". This maybe a case for imprecision, but the consequence is that the statement is unsupported.

However, we indeed acknowledge that our interpretation of the statements can be challenged and, hence, this is the main reason of making available our database as an Excel file in Digital-CSIC under the reference Sanz-Martín et al., 2016, which is

already available to let you consult the data set and show the comments that justify the inappropriate classifications. During the submission it was not possible to attach the database as Excel because it was automatically converted into PDF, thereby loosing the comments inserted in the cells that justified them. The dataset will be available in DIGITAL.CSIC with the reference:

Line 275: "The data set has been archived on the Spanish Research Council database repository (CSIC Digital) with the reference Sanz-Martín et al, 2016.

The reference is: Sanz-Martín, M.; Pitt, K. A.; Condon, R. H.; Lucas, C. H.; Novaes de Santana, C. & Duarte, C. M. (2016). Flawed citation practices facilitates the unsubstantiated perception of a global trend toward increased jellyfish blooms [Dataset]. CSIC - UIB - Instituto Mediterráneo de Estudios Avanzados (IMEDEA) (http://digital.csic.es/handle/10261/130769)"

The citation to this data set was mentioned in the previous submission. The reference to Appendix S1 and S2 has been replaced by Sanz-Martín et al., 2016 in lines: 155, 169, 186, 195, 246, 259, 273, 299 and 310. Appendix S3 has been replaced by Appendix 1 in line 273, colour-blind friendly network.

To clarify why it has been classified as "global/generic" we have included the following sentence:

Line 269: "This statement was classified as "*are increasing*" and "*global/generic*" because the authors claim it is a "worldwide" phenomenon and the accompanying citations were "*unsupported*" (score = 3 per citation) as none of them carried out a global analysis to achieve this conclusion except..."

4) Finally, the authors could run through the paper and give it a quick edit for clarity. Eg p31: 'Finally 3.8% of papers claimed jellyfish trend statements without supporting these claims with citations but other papers did not cite their claims; and 1.9% were cited papers that could not be verified' could be better worded. I suggest that a careful edit might make the paper flow a little better for the reader.

Comment: We agree.

Actions:

Line 326: "3.8% of papers claimed jellyfish trend statements, but they were classified as 'neither citing nor cited' papers because they did not support their claims with citations and no other papers cite them. 1.9% of papers were cited papers that could not be verified."

Comment: In order to shorten the manuscript the following changes have been made.

Actions:

Line 116: Omit the paragraph "The role of mis-citation in developing this perception was provided by a seminal paper, which pointed to outbreaks of jellyfish being the result of the widespread degradation of the oceans (Jackson *et al*., 2001). Despite Jackson *et al.* (2001) did not make a statement on jellyfish population trends; they provided only anecdotal evidence from a single location and study, Newell (1988), to support this claim. However, it is the most cited paper among those referring to the global rise of jellyfish in the context of global impacts in the ocean ecosystem, having received 4,523 cites according to Google Scholar (accessed January 2016)."

And mention this case only in the Discussion as follows:

Line 464: "First, Jackson *et al*. (2001), a highly cited paper in the context of global impacts in the ocean ecosystem (4,523 cites according to Google Scholar, January 2016) proposed that oceanic degradation resulted, among other consequences, in outbreaks of jellyfish, providing only anecdotal evidence from a single location and study, Newell (1988), to support this claim."

Omit the sentence in line 182: "Citing entire volumes like these in support of trends in jellyfish population represent examples of poor citation practices."

Omit the paragraph in line 229 since it does not provide relevant information: "Statements in which the spatial scale was originally classified as "*global/generic*" were reclassified as "*multiple regions*" 12 times, "regional" statements were reclassified as "*global/generic*" 3 times and "*multiple regions*" were reclassified as "*global/generic*" twice, indicating that, in case of disagreement between assessors, we generally converged towards a more conservative classification of spatial scale. Changes in the degree of affirmation varied ("*equivocal*" statements were reclassified as "*are increasing*" and "*may be increasing*" once; "*may be increasing*" statements were reclassified as "*are increasing*" twice, and "*are increasing*" statements were reclassified as "*may be increasing*" twice and "*may be increasing*" was reclassified as "*equivocal*" once)."

Line 311: Omit the paragraph in line 317: "In the citation network, he in-degree and the out-degree of a node are associated with the citing frequency and the cited frequency of paper respectively, and represent how often paper *i* cites other papers and how often is cited by other papers in the network."

And include the information summarized in the previous paragraph, line 281: "1) in-degree and out-degree of nodes, which are the number of incoming arrows and outgoing arrow respectively and represent how often paper *i* cites other papers (citing frequency) and how often it is cited by other papers (cited frequency); and 2) betweenness centrality, b_i, that estimates the fraction of all shortest paths connecting any pair of nodes that pass through node *i* (Freeman, 1977)."

Add the sentence in line 420: "...these papers had zero betweenness centrality and they contributed the initiate the perception."

Line 470 as been rewritten as follows "The fourth phase involves the present study, which follows the thread of citations in support of jellyfish trend statements

flowing from the quantitative analyses of Brotz *et al.* (2012) and Condon *et al.* (2013) to previous speculative studies because available evidence is still subject to different interpretations. Poor citation practices lends credence to the perception of a global trend toward increased jellyfish blooms which may be less likely once more quantitative data are available and increasing data availability limits the margin for misinterpreting results. "

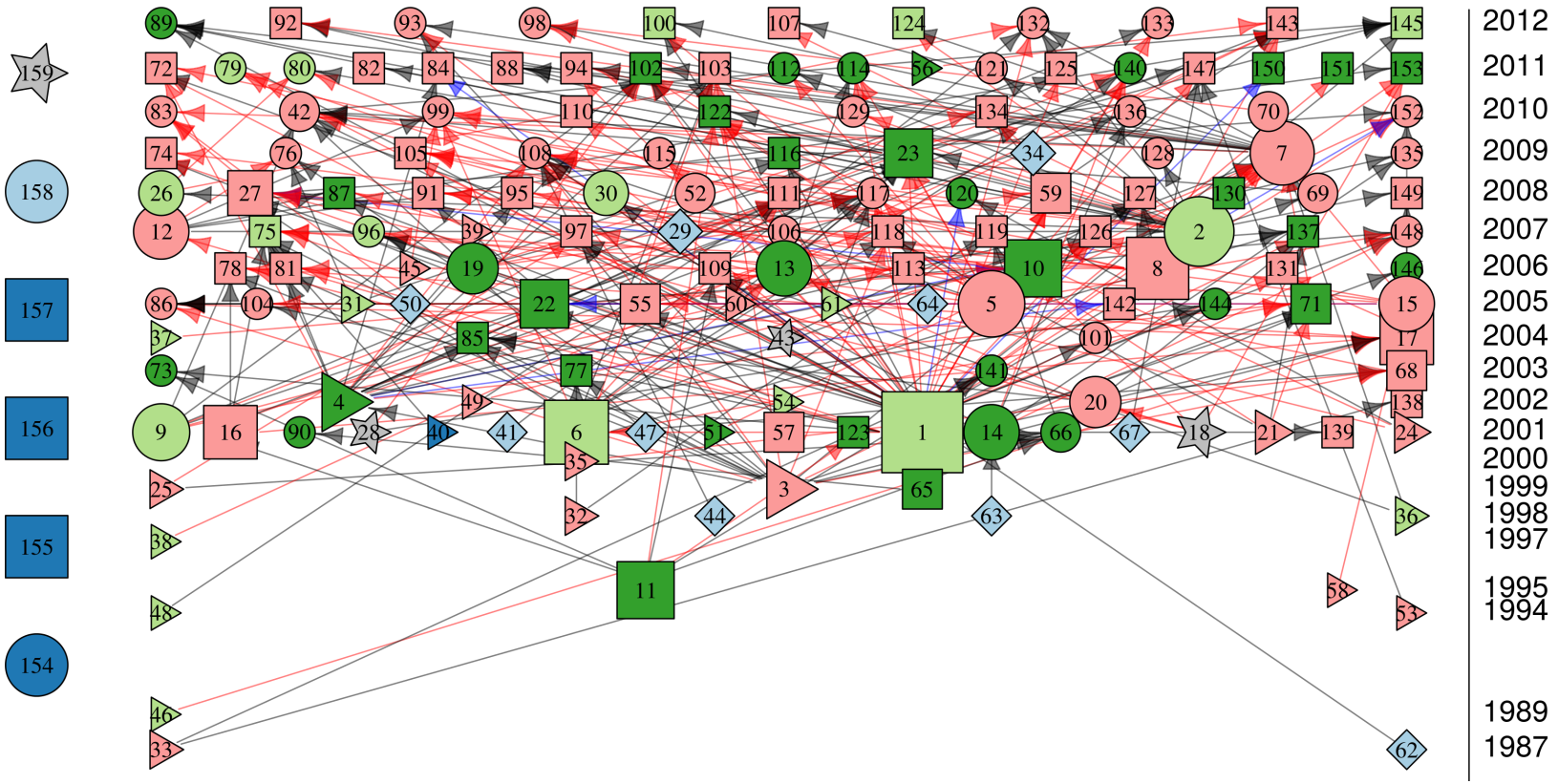
Line 504: The sentence "Our study confirms that that mis-citation facilitated the perception of rising jellyfish populations." Has been added.

Line 557: the addition of "or false negatives" to facilitate the reading.

Line 30: Change to "Words in main body: 5477," and "Words in the Abstract: 173"

Although I have listed 4 concerns, these are all quite minor, and suggestions for improvement rather than problems with the manuscript. This could be an important, controversial, and highly-cited manuscript. I suggest that if the authors can return a minor revision in short order, the manuscript would be suitable for publication.

Dr. Derek Tittensor, Editor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Number of received citations
Citing paper
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Inappropriate
Cannot verify
Cited paper