

Web links to the author's journal account have been redacted from the decision letters as indicated to maintain confidentiality.

26th Mar 21

Dear Mr Arafeh-Dalmau,

Please accept my sincerest apologies for the delay in obtaining reports on your manuscript titled "Uneven protection of persistent giant kelp forest in the Northeast Pacific Ocean". Your manuscript has now been seen by our reviewers, whose comments appear below. In light of their advice I am delighted to say that we are happy, in principle, to publish a suitably revised version in Communications Earth & Environment under the open access CC BY license (Creative Commons Attribution v4.0 International License).

We therefore invite you to revise your paper one last time to address the remaining concerns of our reviewers. At the same time we ask that you edit your manuscript to comply with our format requirements and to maximise the accessibility and therefore the impact of your work.

EDITORIAL REQUESTS:

Please review our specific editorial comments and requests regarding your manuscript in the attached "Editorial Requests Table". Please outline your response to each request in the right hand column. Please upload the completed table with your manuscript files.

If you have any questions or concerns about any of our requests, please do not hesitate to contact me.

SUBMISSION INFORMATION:

In order to accept your paper, we require the files listed at the end of the Editorial Requests Table; the list of required files is also available at <https://www.nature.com/documents/commsj-file-checklist.pdf>.

OPEN ACCESS:

Communications Earth & Environment is a fully open access journal. Articles are made freely accessible on publication under a [CC BY license](http://creativecommons.org/licenses/by/4.0) (Creative Commons Attribution 4.0 International License). This license allows maximum dissemination and re-use of open access materials and is preferred by many research funding bodies.

For further information about article processing charges, open access funding, and advice and support from Nature Research, please visit <https://www.nature.com/commsenv/about/open-access>

At acceptance, the corresponding author will be required to complete an Open Access Licence to Publish on behalf of all authors, declare that all required third party permissions have been obtained and provide billing information in order to pay the article-processing charge (APC) via credit card or invoice.

Please note that your paper cannot be sent for typesetting to our production team until we have received these pieces of information; therefore, please ensure that you have this information ready when submitting the final version of your manuscript.

Please use the following link to submit the above items:

[link redacted]

** This url links to your confidential home page and associated information about manuscripts you may have submitted or be reviewing for us. If you wish to forward this email to co-authors, please delete the link to your homepage first **

We hope to hear from you within two weeks; please let us know if you need more time.

Best regards,

Dr Clare Davis

Associate Editor
Communications Earth & Environment
www.nature.com/commsenv/
@CommsEarth

REVIEWERS' COMMENTS:

Reviewer #1 (Remarks to the Author):

The authors use 35 years of Landsat imagery to define the persistence of kelp on a pixel basis and enrich the analysis by calculating the percentage of different kelp persistence levels within the region and protected areas. The work is novel, and it will be of considerable interest to others in the community and beyond, including marine planners. This reviewer wants to congratulate the authors on this important piece of work.

Some of the main issues I encountered are as follows. (1) The data analysis relies on satellite-derived kelp maps as part of Bell et al., 2020 and Cavanaugh et al., 2019. Therefore, I recommend the authors briefly address the methods from the above references, and most importantly, the uncertainties associated with the quaternary maps produced for the time series: for example, possible area overestimation (movement of kelp beds, and potentially counted twice for the same year, and potential area underestimation due to environmental conditions, wind, currents, tides, submersed and satellite constraints such as pixel resolution. Adding this information does not invalidate the results but instead put into perspective that there are likely uncertainties in the original data used for the analysis and their implication in calculating, for example, the extension of kelp in marine reserves in Baja California, which is only 1%. How does this estimate of 1% relate to possible uncertainties on the input data? Satellite-derived kelp maps are the only way to define

these trends based on historical data, but, as a community, we should highlight the issues with the data.

(2) A better explanation of estimated probability of persistence (is this basically a pixel-based average of the persistence of a pixel for all years? meaning you have an output map with pixel-based averages? Like a climatology?); add a reference and rationale for the chosen representation target; it is not clear how the multiplicative factor is defined and how it adjusts the representation target. In summary, the methods need better explanation (I understand that there is a supplement, but the paper itself should be sufficient for the reader to understand the methods).

Reviewer #2 (Remarks to the Author):

The authors present a compelling case of a mismatch between protection and vulnerability of kelp forest ecosystems. The authors identify metrics of kelp bed persistence and compare these to the coverage of protection offered by marine protected areas. The results show that as vulnerability of kelp beds increases at their southern limits, the relative protection of persistent beds drops away dramatically.

I found this manuscript interesting and relevant to the wider fields of marine ecology and conservation. Timeseries of bed persistence has been used before by the authors, but this research is novel in the context of broad-scale protective measures. This research sets the scene for informing future MPA placement and provides a mechanism for robustly determining valuable areas for protection.

The methods are well described in other published work by the authors, and the application of the methods in this context are mostly well explained in this manuscript.

While I found this manuscript to be novel and relevant, I do note that the figures, particularly the use of percentage across multiple independent metrics and the general organisation of figures are a little confusing. Further explanation on some finer points of the data presented in the figures is required.

For example:

- Is the total area of kelp defined as each pixel in which kelp was detected over the 35 year period?
- I take it the gaps in the timeseries (Fig 1 panel d) represent a lack of appropriate satellite data (cloud cover etc)? Perhaps this is explained elsewhere, but what is the cause of the large gaps in data for the southern regions? It would be great to be able to more easily spot true zero values on these panels.
- The authors bin the persistence into three broad categories, low, mid, and high. I would like to see some more comprehensive products for the extremes, particularly single kelp detections (kelp detected within a pixel only once in 35 years) and very persistent beds (detected in almost every quarter). Comparing the "singletons" and "consistent" coverage for each region could provide a useful metric for understanding the turnover.

Fig 1. panel a- y-axis is Percentage of kelp protected compared to total kelp detected (i.e., generated from a composite of every pixel in which kelp was detected over 35 years and the percentage of these pixels inside and outside of MPAs). Is this correct?

panel b- y-axis is percentage of pixels which had the three ranges of persistence, removing all pixels for which kelp was never detected.

panel c- y-axis is the percentage of protection for each pixel in which kelp was detected (at least once) with kelp persistence split by region.

While the "percentage" unit for the y-axis is shared between each panel, it is clearly representing quite different values. These differences should be better outlined in the figure, the legend and the methods.

Kind regards.

Leigh Tait

Reviewer #3 (Remarks to the Author):

The ms entitled 'Uneven protection of persistent giant kelp forest in the Northeast Pacific Ocean' written by the following authors Nur Arafeh-Dalmau, Kyle C. Cavanaugh, Hugh P. Possingham, Adrian Munguia-Vega, Gabriela Montaña-Moctezuma, Tom W. Bell, Kate Cavanaugh, Fiorenza Micheli, developed a subject which is in the scope of the journal.

The paper provides a large-scale assessment of mapping the persistence of kelp forests across ten degrees of latitude in the Northeast Pacific Ocean and quantified the representation of persistent kelp in marine protected areas across time. The use of a 35-year satellite time series is a very interesting analysis. They highlighted potential climate-refugia for the kelp *Macrocystis pyrifera* and put forward the need to protect highly persistent kelp forest that exhibiting high resilience to climate variability and extreme phenomena. The paper is outstanding and well explained.

The only thing I find is that the authors could indicate the authority of the species in the introduction (line 66): *Macrocystis pyrifera* (Linnaeus) C. Agardh.

I strongly recommend this ms for publication.

RESPONSE TO REVIEWERS

REVIEWER 1 COMMENTS

Comment:

The authors use 35 years of Landsat imagery to define the persistence of kelp on a pixel basis and enrich the analysis by calculating the percentage of different kelp persistence levels within the region and protected areas. The work is novel, and it will be of considerable interest to others in the community and beyond, including marine planners. This reviewer wants to congratulate the authors on this important piece of work.

Response:

We thank the reviewer for their positive and encouraging review. We are very thankful that the reviewer congratulates our work and implies its importance.

Comment:

Some of the main issues I encountered are as follows. (1) The data analysis relies on satellite-derived kelp maps as part of Bell et al., 2020 and Cavanaugh et al., 2019. Therefore, I recommend the authors briefly address the methods from the above references, and most importantly, the uncertainties associated with the quaternary maps produced for the time series: for example, possible area overestimation (movement of kelp beds, and potentially counted twice for the same year, and potential area underestimation due to environmental conditions, wind, currents, tides, submersed and satellite constraints such as pixel resolution. Adding this information does not invalidate the results but instead put into perspective that there are likely uncertainties in the original data used for the analysis and their implication in calculating, for example, the extension of kelp in marine reserves in Baja California, which is only 1%. How does this estimate of 1% relate to possible uncertainties on the input data? Satellite-derived kelp maps are the only way to define these trends based on historical data, but, as a community, we should highlight the issues with the data.

Response:

We agree with the reviewer that the dataset contains some uncertainties and thank the valuable recommendations of the reviewer. To address their recommendations and concerns, we added two paragraphs in the methods section and one in the discussion. Here we give a more detailed description of the methods used to detect giant kelp canopy, and point out the recent improvements that minimize the uncertainties with the detection method (e.g. area overestimation). See Lines 180-202 for added methods. We also added a paragraph in the discussion where we acknowledge and point out the potential uncertainties that remain and the implications to our study. See Lines 146-160 for added paragraph in the discussion.

Comment:

(2) A better explanation of estimated probability of persistence (is this basically a pixel-based average of the persistence of a pixel for all years? meaning you have an output map with pixel-based averages? Like a climatology?); add a reference and rationale for the chosen representation target; it is not clear how the multiplicative factor is defined and how it adjusts the representation target. In

summary, the methods need better explanation (I understand that there is a supplement, but the paper itself should be sufficient for the reader to understand the methods).

Response:

We thank the reviewer comment which allowed us to better explain the method used to estimate the representation of present kelp and the adjusted representation targets. We re-wrote the methods section for the adjusted representation targets, and moved the worked example from supplementary methods to the main text. See Lines 230-309. We also present a new Table (Table 1) which contains the estimates of the probability of present kelp and the representation of present kelp inside marine reserves for the Northeast Pacific Ocean and the four regions.

To answer the reviewer's questions. The probability of present kelp (we changed the name for clarity) is indeed the average value of occupancy (years kelp was detected in the time series) for all pixels in the Northeast Pacific Ocean, or in each region separately. We added a boxplot with the values of kelp occupancy as a supplementary figure (Supplementary Figure 2) to support our estimates. We do have an output map with pixel-based occupancy values ($n=408,906$), which we added as a supplementary Figure (Supplementary Figure 2). We added a citation to justify the representation target value of 10% chosen in the worked example, based on The Convention on Biological Diversity Aichi Target 11. See Line: 287.

Specific Comments:

Methods need to be clear. See comments above.

Discussion: should add some consideration about data uncertainties as part of the final estimates. It does not need to be quantified but considered in the final discussion. See comments above.

Figure 1d. Does it represent the total area (sum) of the quarterly data yearly? If yes, is it a UNION of areas considering 4 products per year? If so, how do you account for the movement of floating kelp beds with, for example, the tide for the different products in a year?

Figure 2: Are the colors in the plots with the same meaning as the map colors? This is not clear??? persistence vs. protection??? please add the boundaries of the region in the figure.

Line 207: Can you clarify what is 0.24 years??? Does it mean 24% of the years? Is this O_i in your following equation (calculate P)? If yes, make the proper link.

Line 237: If a pixel is classified as kelp at least once in the 35 years time series, it means the pixel is "a potential kelp habitat"?

L238: this is not clear..., is it only a potential habitat when the pixel has kelp every year?

L247: where does the value of T come from? make sure you say the 10% and rational???

L278: multiplicative factor not clear L249: T_a not clear.

Specific Response

We are very grateful with the reviewer's final detailed comments. As we mentioned previously, we address the main reviewer's comments by providing a more detailed explanation of the methods, and the discussion includes a new paragraph addressing uncertainties.

Response to other details:

In the caption of the Figure 1d we specified the time series is presented as the area of detected kelp in each quarter of a year in each region. It is not a UNION of areas, but the number of pixels (which multiplied by their resolution of 900m² (30 x 30m) we can estimate the area) in each quarter of a year that the satellite detected kelp. Movement of kelp and other uncertainties are addressed in the methods and discussion.

The colours in Figure 2 are the same for the plots and mapping. We slightly modified the map in the figure to separate regions and specified the boundaries in the caption by adding the following text: The buffer in the coastline represents the territorial seas and the horizontal lines the limits of each region.

Again, we thank the reviewer's comments, which improved the clarity of our methods. To address his questions in Line 207 we changed "average" to "fraction" (see Line 204), made the link with (O_i) by adding this variable at the end of sentence, and added a line "A pixel with zero value means the satellite never found kelp forest; while a value of one means, it detected kelp forest for all years" to clarify what the values (e.g. 0.24) represent". See Lines 205-208.

To avoid confusion in Line 237, we changed the terminology from "potential" kelp to "detected" kelp, which is more accurate. We did so throughout the manuscript. This also applies to Line 233, its detected kelp. We also addressed the reviewer's concerns in Lines 247 and 278 as mentioned before in the methods.

REVIEWER 2 COMMENTS

Comment:

The authors present a compelling case of a mismatch between protection and vulnerability of kelp forest ecosystems. The authors identify metrics of kelp bed persistence and compare these to the coverage of protection offered by marine protected areas. The results show that as vulnerability of kelp beds increases at their southern limits, the relative protection of persistent beds drops away dramatically.

I found this manuscript interesting and relevant to the wider fields of marine ecology and conservation. Timeseries of bed persistence has been used before by the authors, but this research is novel in the context of broad-scale protective measures. This research sets the scene for informing future MPA placement and provides a mechanism for robustly determining valuable areas for protection.

The methods are well described in other published work by the authors, and the application of the methods in this context are mostly well explained in this manuscript.

Response:

We thank the reviewer for their positive and encouraging review. We are very thankful that the reviewer finds our work interesting and relevant.

Comment:

While I found this manuscript to be novel and relevant, I do note that the figures, particularly the

use of percentage across multiple independent metrics and the general organisation of figures are a little confusing. Further explanation on some finer points of the data presented in the figures is required.

For example:

- Is the total area of kelp defined as each pixel in which kelp was detected over the 35 year period?
- I take it the gaps in the timeseries (Fig 1 panel d) represent a lack of appropriate satellite data (cloud cover etc)? Perhaps this is explained elsewhere, but what is the cause of the large gaps in data for the southern regions? It would be great to be able to more easily spot true zero values on these panels.
- The authors bin the persistence into three broad categories, low, mid, and high. I would like to see some more comprehensive products for the extremes, particularly single kelp detections (kelp detected within a pixel only once in 35 years) and very persistent beds (detected in almost every quarter). Comparing the "singletons" and "consistent" coverage for each region could provide a useful metric for understanding the turnover.

Fig 1. panel a- y-axis is Percentage of kelp protected compared to total kelp detected (i.e., generated from a composite of every pixel in which kelp was detected over 35 years and the percentage of these pixels inside and outside of MPAs). Is this correct?

panel b- y-axis is percentage of pixels which had the three ranges of persistence, removing all pixels for which kelp was never detected.

panel c- y-axis is the percentage of protection for each pixel in which kelp was detected (at least once) with kelp persistence split by region.

While the "percentage" unit for the y-axis is shared between each panel, it is clearly representing quite different values. These differences should be better outlined in the figure, the legend and the methods.

Kind regards.

Leigh Tait

Response:

- We thank the reviewer for his detailed review of the figures which allowed us to improve their clarity. Yes, the total area of kelp is the number of pixels detected in each quarter of a year in the time series. In response to both reviewer 1 and 3, in the caption of the Figure 1d we specified the time series is presented as the area of detected kelp in each quarter of a year in each region.

- We thank the reviewer for raising this point. Yes, the gaps in the time series in Figure 1d represent a lack of appropriate satellite data. We addressed the cause of the gaps for the southern region by adding a paragraph in discussion. See Lines 146-160.

- We thank the reviewer's comment and acknowledge the importance of having a more comprehensive product for the extreme. We addressed the reviewer's comments by adding two figures in Supplementary material (Supplementary Figure 1 and 2) which provide more insights into the distribution of the occupancy dataset. Supplementary Figure 1 has the raw occupancy values for each pixel, without classification into categories. Supplementary Figure 2 is a boxplot with the occupancy values for each region.

- To address the overall issues with Fig 1 raised by the reviewer, we changed the caption legend to clarify the interpretation. We also added in Line 207 that pixels with no value for kelp (that means

that kelp was never detected in the time series) are not included in the dataset and thus the analysis and figures, which should prevent confusion.

REVIEWER 3 COMMENTS

Comment:

The ms entitled 'Uneven protection of persistent giant kelp forest in the Northeast Pacific Ocean' written by the following authors Nur Arafeh-Dalmau, Kyle C. Cavanaugh, Hugh P. Possingham, Adrian Munguia-Vega, Gabriela Montaña-Moctezuma, Tom W. Bell, Kate Cavanaugh, Fiorenza Micheli, developed a subject which is in the scope of the journal.

The paper provides a large-scale assessment of mapping the persistence of kelp forests across ten degrees of latitude in the Northeast Pacific Ocean and quantified the representation of persistent kelp in marine protected areas across time. The use of a 35-year satellite time series is a very interesting analysis. They highlighted potential climate-refugia for the kelp *Macrocystis pyrifera* and put forward the need to protect highly persistent kelp forest that exhibiting high resilience to climate variability and extreme phenomena. The paper is outstanding and well explained.

The only think I find is that the authors could indicate the authority of the species in the introduction (line 66): *Macrocystis pyrifera* (Linnaeus) C. Agardh.

I strongly recommend this ms for publication.

Response:

We thank the reviewer for their positive and encouraging review. We are thankful that the reviewer finds our work outstanding and well explained.

We addressed the reviewer comment by adding the authority of the species in the introduction: (Linnaeus) C. Agardh after *Macrocystis pyrifera* in line 65.