Review of „Marine heatwaves deeply alter marine food web structure and function“

Summary

In this research article, the authors performed global hindcast simulations with the EcoTroph-Dyn numerical model to estimate the distinct impacts of marine heat waves (MHWs) on the trophodynamics of marine ecosystems. They found that MHWs generally lead to a decrease in biomass, with the decrease being stronger and longer lasting for higher trophic levels. They conclude that in the future, ecosystems may not be able to recover between successive MHW events, which may disrupt trends associated with long-term climate change.

General comments

Overall, the manuscript is coherently written and provides novel insights into an important and timely topic. However, the introduction is quite short and should be expanded to provide a better overview and deeper understanding of the topic (see specific comments). Several minor points should also be added or clarified in the Material and Methods, Results, and Discussion sections, which are nevertheless well written and understandable. The conclusions are quite short but precise; however, I think it should at least be specified which repercussions of MHWs where identified in the current study.

Linguistically, the manuscript contains some minor grammatical, typographical, and formatting issues, especially in the references, that need to be addressed. I have listed the issues I found in "Technical corrections" and also made some suggestions to improve clarity and readability.

Specific comments

- L. 33-48: A clear, quantitative definition of heatwaves would help this paragraph, especially since you give quantitative changes in heatwave duration, frequency etc.
- L. 49-60: This paragraph should introduce more MHW-related ecosystem modeling studies to put the current study into a broader context. Specifically, it should be made clear to the reader what has been done already and what is new about the current study. I would also recommend to place this paragraph before the last paragraph of the introduction (i.e., between l. 66 and l. 67) to create a nice transition to the description of the current study.
- L. 51-52: It is not clear which method(s) Carneiro et al. used.
- L. 62-63: Could you elaborate on this further and explain the processes behind?
- L. 78: I would leave out “proceeding their occurrences”, it makes the sentence difficult to understand.
- L. 89: Is there a specific reason for using TL width = 0.1?
- L. 92-93: Why is the biomass transfer in lower TLs faster?
- L. 97: biomass flows between(?) the trophic biomass spectra
- L. 118: I don’t understand what you mean by “the trophic level of each TL classes j.”. Do you mean the trophic level of the j^{th} TL class?
- L. 119-120: Is this assumption based on observations/experiments? Give appropriate references.
- L. 125-126: “Biomass spectra in EcoTroph-Dyn are split into trophic classes with variable widths of trophic levels.” – I don’t really understand this sentence. Do you mean: “Biomass spectra in EcoTroph-Dyn are split into trophic classes of variable width.”?

- L. 164-165: “lasting 15 days of the fortnight” − something must be wrong here.
- L. 168: I don’t understand this sentence. Do you mean: “We used an alpha of 0.2 in our simulations.”?
- Figure 1: How do you derive transfer efficiency, MHW mortality, and flow kinetic from satellite data?
- L. 193-194: Why did you use a single threshold and not one for each month, for example? Which impact may the use of only one threshold have on your results?
- L.215: How can a day with Yt < Tt + St be an MHW day? Can you explain this in more detail?
- L. 224-229: Could you further explain the EPPLEY-VGM method? Not all readers may be familiar with this method nor the VGM method, so I think especially basic information would be helpful. For example, what is the general concept of these methods and what is Pb_opt?
- L. 230-235: This should at least be mentioned in the Discussion (somewhere in the paragraph l. 656-675).
- L. 236-237: Which biases may be introduced by this duplication? This should also be included into Sect. 5.3.
- L. 285-287: “Furthermore, more days with MHWs with lower intensity were identified for low latitude regions (23°N - 6°S) (Figure 3c) compared to MHWs identified in higher latitude regions (> 23°N and 25°S).” This sentence is not really clear. Do you mean that the intensity of MHWs was generally lower in high latitude regions?
- Figure 3: The figure caption seems to be mixed up. The description for c) seems to match panel d), while the description for d) does not match any panel. Thus, panel c) has no fitting description.
- L. 304: “effects of the short-term impacts of MHWs on the long-term changes” This part seems a bit confusing and contradictory, I would leave out the “short-term impacts”.
- L. 320: Even if explained in the caption of Fig. 4, I would also define the three biomes in the text since the figure may be placed somewhere else in the typeset paper.
- L. 337: Using numbers for biomass increase for both scenarios would make it easier to compare the results, i.e., “a biomass ~~decrease~~increase was projected to occur in ~~76%~~24% of the global ocean”
- L. 358: Maybe it would be useful to give the number for global biomass loss without MHWs again for direct comparison.
- L. 365: What do you mean with “expected”? You already analyzed the differential impact of MHWs on trophic levels in Sect. 4.2.2, didn’t you?
- L. 377: Can you explain what an ANOVA is?
- L. 383: greatest instead of greater?
- L. 403: Why do you use different reference periods to define temperature anomalies? In this way, the anomalies are not consistent. I would suggest to choose one of both periods. Did you use the same reference periods to calculate the temperature anomalies shown in Fig. 8? If yes, these should be corrected as well.
- L. 408: The biomass decreased but the biomass loss increased
- L. 430-431: This part is difficult to understand. Do you mean: “Considering the influence of MHWs from 2013 to 2016 using the ‘with MHWs’ scenario and alpha=0.2 resistance capacity”?
- l. 456-459: This sentence is difficult to understand. Maybe replace with something like: “In this study, we accounted for MHWs in the last four decades using hindcast simulations and showed the potential of synergic impacts of MHWs (pulses) and long-term climate change (presses) on biomass and trophodynamics of ecosystems.”.

- l. 494-495: This explanation of TE would be helpful in the methods section.
- L. 521: metabolic efficiency or transfer efficiency? Shouldn't the ratio between ingested and stored energy be high, i.e., only a small part of the ingested energy is stored and the rest is lost?
- L.529-530: Why is the mortality higher in low TLs?
- L. 534: If the increase is 1% I wouldn't use the word "sharp".
- L. 561-562: I don't understand part (ii), could you explain this further?
- L. 585-587: The structure of this sentence seems odd and makes it difficult to understand. Please check and revise.
- L. 599-600: What defines the models in this family? What do they have in common?
- L. 607-608: What are biomass density values?
- L. 615: The word "projection" usually refers to simulations/estimates for the future. Since you performed hindcast simulations, I would use a different word here to avoid confusion. Please also check the rest of the manuscript.
- L. 629-632: Can you quantitatively compare your results to those of Arimitsu et al. (2021)?
- L. 640: The reference Cheung et al. (2020) does not exist in your reference list. Do you mean Cheung & Frölicher (2020)?
- L. 647-448: This part is difficult to understand. Maybe replace with "It would therefore have been valuable to test EcoTroph-Dyn against other MHWs in the world ocean".
- L. 681: What do you mean by "dismiss any possibility"?
- L. 684-688: This sentence is quite complex and difficult to understand. Maybe replace with something like: "Even though the global impact of MHWs is negative, species-explicit modelling could improve our understanding of how various impacts of climate change and species-level responses will affect trophodynamics and ecosystem structure and function.".
- Sect. 5.4: You could highlight here how future work can build on your study in particular. For example, what analyses should your model be used for in the future? Should your model be modified/extended, and if so, how?

Technical corrections

- Throughout the manuscript, there are some issues with reference formatting (i.e., the use of parentheses, commas, and semicolons). I have already included a few examples below.
- L. 11: ~~are becoming~~ have become
- L. 20: (NPP) data
- L. 21: observations
- L. 22: by trophic level~~s~~
- L. 25: ~~specific~~ MHW-induced decline in biomass of 8.7% ± 1.0 (standard error) ~~in the region~~ from 2013 to 2016.
- L. 27: than in lower
- L. 36: resulting in more than a doubling of the number of MHW~~s~~ days
- L. 37: a space is missing before the reference
- L. 43: have caused a decrease
- L. 50: ~~simulation~~numerical modelling
- L. 51: Don't use a comma for in-text citations: Carneiro et al.~~,~~ (2020)
- L. 66: function ~~globally~~ have not yet been clearly understood on a global scale
- L. 68: climate change~~s~~
- L. 69 and l. 70: Since this is an article with multiple authors, I would use "we" consistently.

- L. 70: MHWs (see ~~(~~Guibourd de Luzinais et al., 2024)
- L. 77: occurred in ~~on~~ the
- L. 79: Material and methods
- L. 83: ~~from~~ by primary producers
- L. 85: food web~~s~~
- L. 87: TLs, i.e.,
- L. 88: trophic ~~spectra~~ spectrum
- L. 90: the whole consumer~~s~~ biomass
- L. 92: generally being faster
- L. 94-95: the references should be put into parentheses
- L. 96: ecosystem~~s~~ biomass
- L. 102: MHW~~s~~ occurrence. EcoTroph-Dyn's algorithm~~s'~~ details
- L 112: TL~~.~~ year-1
- L. 114: trophic level~~,~~ using
- L. 131: within the TL class [τ,τ+Δτ~~[. It~~], is expressed as
- L. 144: ~~depenant~~ dependent
- L. 147: flow kinetic (K)) and where
- L. 149: 3.2 MHW loss rate algorithm ~~computation~~
- L. 152: loss rate algorithm ~~computation~~
- L. 153: into EcoTroph-Dyn
- L. 154: ~~period~~ (period 1982-2011)
- L. 156: Matching historical MHW~~s' historical~~ distribution~~s~~ and characteristics with species distribution
- L. 158: ~~Estimation b~~Based on this percentage estimation of an additional loss rate
- L. 159-160: Finally, ~~through loss rate (ηi) mathematical expression,~~ we assumed in the mathematical expression of loss rate ηi that species are~~were~~ continuously challenged by ~~MHW~~ increased MHW intensity, which is expressed as:
- L. 164-165: with β ~~ranges~~ranging from β=0~~;~~ (no MHW)~~,~~ to β=1~~;~~ (MHW lasting 15 days of the fortnight)
- L. 165: MHWcat,i corresponds to an MHW intensity index
- L. 169: to community resistance capacity ~~to MHW~~ by testing
- L. 184: without MHWs
- L. 189: every MHW~~s~~ day
- L. 207: seasonal component (St)~~,~~ is then
- L. 208: estimation of ~~(St)~~ on the trend-adjusted series
- L. 212-213: without MHWs
- L. 215: component, i.e.,
- L. 215: For MHW days with Yt below ~~(Tt + St)~~ or ~~not an MHW day~~non-MHW-days, we keep
- L. 217: referred to here as
- L. 218: ~~match~~ adapt
- L. 222: when an MHW lasts for an entire fortnight.
- L. 225: is a hybrid model
- L. 239-240: ~~under~~ for the scenarios
- L. 246: of ~~simulating~~ 12 years

- L. 254: past MHW~~s~~ events
- L. 267: ~~by~~ in the period 2015-2021
- L. 268: NPP changes ~~were~~ was observed
- L. 268: ~~Notably~~ In particular
- L. 270, 272: in the period 2015-2021
- L. 273: ~~warmed up~~ warming by 1°C ~~during~~ over
- L. 277: ~~relative to the average between~~ and the average of
- L. 292: Evolution of the spatial extent
- L. 292-293: Evolution of MHW~~s~~ average~~d~~ duration categorised by ~~their~~ intensity
- L. 299: on average~~,~~ by 0.07 ± 0.02%
- L. 317: S2 for biome~~s~~ spatial definition
- L. 321: with MHWs', the declines
- L. 332, L. 339, L. 358, L. 375: ~~by~~ in the period 2015-2021
- L. 335 and Fig. 5 caption: For the trophic level classes, the second opening parenthesis needs to be a closing parenthesis
- L. 336-337: ~~notably~~ with the tropical and upwelling biomes being notably more impacted.
- Fig. 5: Change in trophic group~~s~~ biomass (y-axis)
- L. 345-346: Projected changes in consumer biomass by trophic level~~s~~ and biome~~s~~ under the 'without MHW' and 'with MHWs' scenarios relative to the 1998-2009 average ~~between 1998-2009~~.
- L. 362: off the coast of Papua New Guinea ~~Coast~~
- L. 389: by trophic level~~s~~
- L. 392: 75th quantiles
- L. 395: the response of low TLs ~~response~~
- L. 402: in the biomass spectrum
- L. 403: relative to the 2016 average
- L. 416: exhibited a significant total consumer biomass decrease
- L. 417: the scenarios with and without MHWs
- L. 420: the most
- L. 420-421: ~~However, u~~Under
- L. 425: provinces were ~~the~~ most affected by the MHW
- L. 426: biomass decreases of 5% and 3.8% ~~'with MHWs'~~ relative to the 'without MHW' scenario
- L. 429: lower TLs
- L. 433: ~~as of~~ by 2021
- L. 443: change in the 'without MHW' and 'with MHWs' scenarios
- L. 444: indicates the duration of 'the Blob' ~~duration~~.
- L. 451: 0.2, while
- L. 452: ~~by~~ in the period 2013-2016
- L. 457-458: ~~longterm~~ long-term
- L. 466, 468: Be careful with the use of past tense. The suggestions of your study have not expired, so use "suggest" instead of "suggested" in L. 466. Similar cases appear throughout the manuscript.

- L. 470: ecosystems, which is congruent with studies by Arimitsu et al.~~,~~ (2021)~~;~~ Gomes et al.~~,~~ (2024)~~;~~, and Smith et al.~~,~~ (2023) ~~studies~~.
- L. 373: ecosystem~~s~~ perturbations
- L. 475: of the perturbation in ecosystem functioning ~~perturbation~~
- L. 476-477: intensity and duration of MHWs ~~characteristics~~ have continuously increased
- L. 478: hindcast period ~~hindcast~~
- L. 482: recover to pre-perturbed
- L. 484: upwelling biomes, where the hindcast biomass of high TLs consistently
- L. 488: may~~, therefore,~~ be
- L. 490: ~~continuing~~ continued
- L. 514: , which is used
- L. 551: ~~These~~ MHWs
- L. 564: ~~through our modelling approach~~ in our simulations
- L. 566: in the California Ocean
- L. 568: with an~~the~~ increase
- L. 570: ~~differently~~ differentially
- L. 575: Differences in ~~exposure to~~ the intensity
- L. 577: subject~~ed~~
- L. 592-595: For example, communities in the Gulf of Alaska~~n Gulf~~ are more efficient than those in the California~~n~~ Current (du Pontavice et al., 2020), and the energy entering the food web was less disrupted than in the California~~n~~ Current, which may explain the greater impact of the MHW on the California~~n~~ Current.
- L. 598: MHW~~s~~ hindcast
- L. 602: by their trophic level~~s~~
- L. 632-634: It is worth noting that projections obtained ~~from~~using a smaller (larger) α led to an underestimation (overestimation) of biomass losses and changes in biomass flow parameters relative to the estimates of Cheung & Frölicher~~,~~ (2020) and Gomes et al.~~,~~ (2024) ~~estimates~~.
- L. 640-641: Grey violin plots correspond to results from Cheung et al.~~,~~ (2020), while the red ones correspond~~s~~ to our hindcast~~ed~~ EcoTroph-Dyn simulation with α=0.2 ~~scenario~~.
- L. 656: Furthermore, uncertainties ~~about~~in our results arise from ~~EcoTroph-Dyn~~ the environmental drivers of EcoTroph-Dyn.
- L. 657: EcoTroph-Dyn ~~has been~~ was driven
- L. 660: In this study, we did not consider the 'with' and 'without' MHWs scenarios for NPP.
- L. 663: ~~could~~may have overestimated MHW~~s~~ impacts
- L. 666: Why do you capitalize marine ecosystem models?
- L. 681-682: Running the aforementioned~~these~~ five MHW-induced loss rate ~~induced~~ scenarios
- L. 683-684: with ~~a worsening~~ an increasing biomass loss over marine ecosystems with decreasing resistance capacities ~~decreasing~~ (increasing α ~~increasing~~).
- L. 690: ~~From~~ In our study
- L. 693: anomalously low wind, an anomalously weak Ekman transport~~s~~
- L. 694: north, and~~,~~ coupled with anomalously low air-sea heat exchange~~s~~
- L. 696: have already contributed
- L. 700: better understand ~~better~~