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# Integrative research of Mediterranean climate regions: a global call to action

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## Perspectives

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## Summary

Mediterranean climate regions (hereafter 'Med-regions') cover small areas globally but harbour a wide diversity of ecosystems that are under serious threat due to current global climate change. Despite intensive research and conservation efforts in freshwater, marine and terrestrial ecosystems to prevent the consequences of habitat fragmentation, overfishing and changes in fire regimes and heatwaves, there is still no global consensus on how to conserve and manage Med-region ecosystems. We define integrative research as an interdisciplinary approach with common concepts and metrics enabling a better understanding of the general mechanisms underlying ecosystems. Building upon existing literature that promotes integrative research in Med-region ecosystems, we advocate for a more integrative approach that takes into consideration cross-ecosystem generalities and common resilience mechanisms. We propose examples of potential studies for implementing such integrative research, including: (1) integrative research across ecosystems; (2) integrative research across Med-regions; and (3) integrative research across political boundaries. We then offer recommendations for promoting integrative studies, including leveraging biodiversity data, establishing working groups in research syntheses and testing theoretical frameworks. Promoting integrative research in Med-regions would enable and facilitate the roadmap towards a better understanding of Med-region ecosystems' responses to natural and anthropogenic disturbances and the identification of ecological baselines. We seek to foster future research synergies to identify tipping points across ecosystems and aid in determining desired future conditions in Med-regions globally.

## Introduction

Mediterranean climate regions (hereafter 'Med-regions'), with unusual climatic conditions of mild wet winters and warm to hot dry summers (Lionello et al. 2006), are biodiversity hotspots that have historically been exposed to anthropogenic impacts (Fig. 1; Myers et al. 2000, Cramer et al. 2018) and thus are ideal open laboratories for global change research (Underwood et al. 2009, Lejeusne et al. 2010). Research on Med-regions has been conducted at various biological scales, ranging from the genetic (Aurelle et al. 2022, Fady et al. 2022) and species level (Heywood 2014, Bianchi et al. 2018, Zenetos & Galanidi 2020) to ecological communities (Angulo et al. 2016, Panitsa et al. 2021), and across freshwater (Gasith & Resh 1999, Bonada & Resh 2013), marine (Coll et al. 2010, Gianni et al. 2013, Darmaraki et al. 2019) and terrestrial (Lavorel et al. 1998, Underwood et al. 2009, Doblas-Miranda et al. 2017) ecosystems. Conservation efforts have been largely dedicated to reducing threats, including overfishing and habitat fragmentation, or predicting the effects of changing fire and heatwave regimes. Conversely, few integrative studies from different areas of knowledge exist, including comparisons amongst global Med-regions (e.g., Mediterranean and California plant communities; Quezel & Berbéro 1989, Medail & Quezel 1997, Marr et al. 2010) or across ecosystems (e.g., marine and terrestrial biodiversity in the Mediterranean Basin; Aurelle et al. 2022).

Terrestrial, freshwater and marine ecosystems in Med-regions are subject to natural and extreme climate disturbances, including wildfires, floods, droughts and heatwaves (Castri & Mooney 1973). To cope with these disturbances, species have evolved with similar life-history strategies regardless of Med-region, including, for instance, sclerophyllous leaves or animal aestivation to avoid the effects of the droughts (Fig. 2; David et al. 2007, Quero et al. 2011, Bussotti et al. 2014). Given these adaptations to natural disturbances, Med-region ecosystems could also be more tolerant of human disturbances, have wider safe operating spaces (i.e., situations where ecosystems can support essential resources and functions for human needs and well-being, as defined by Rockström et al. 2009) and show greater resilience than non-Mediterranean ecosystems (Fox & Fox 1986, Bonada et al. 2007, Helman et al. 2017). These

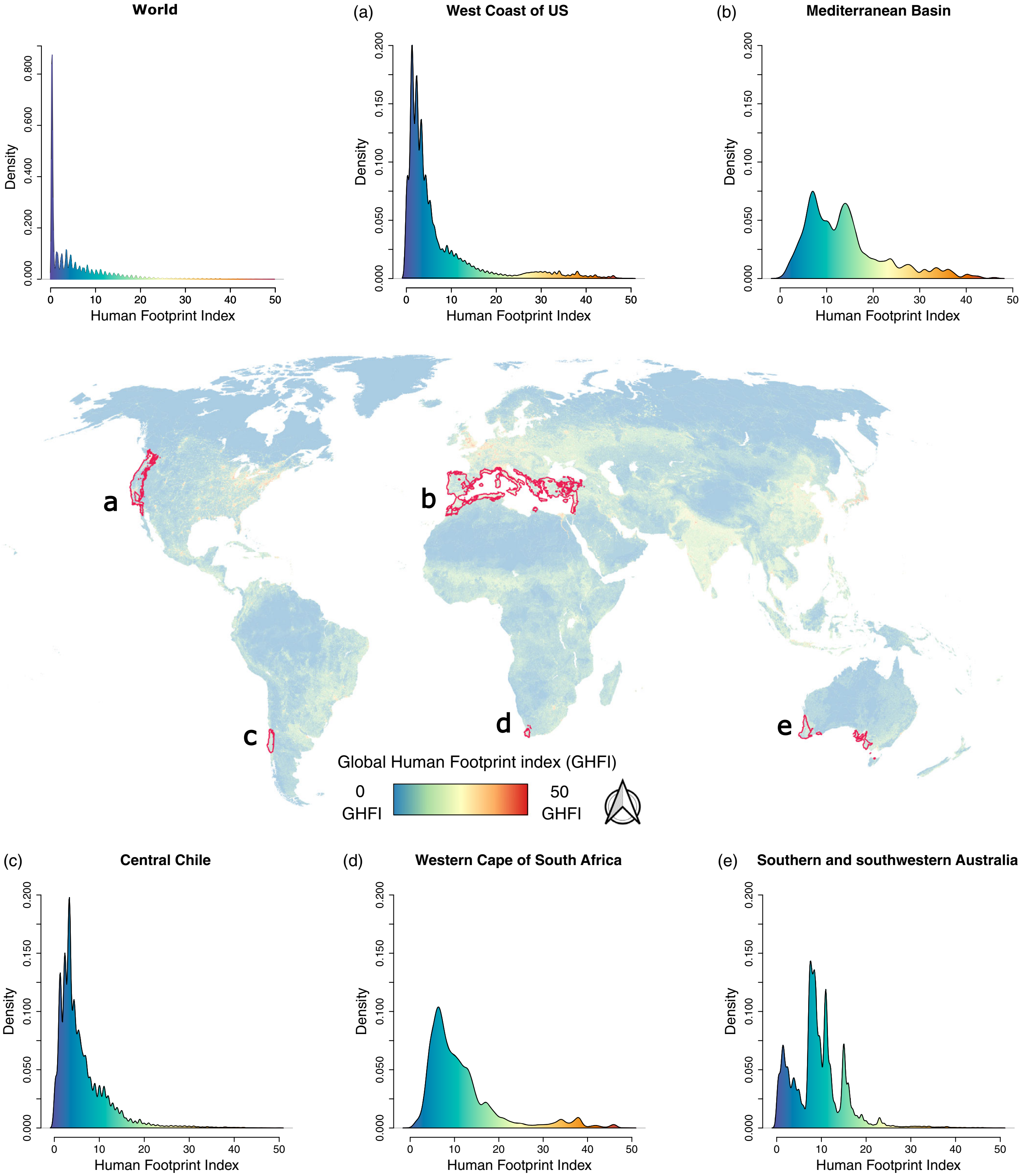

**Figure 1.** Global distribution of the Mediterranean climate regions (Med-regions) from the Western Cape of South Africa (small Med-region) to the Mediterranean Basin (large Med-region): (a) west coast of the USA; (b) Mediterranean Basin; (c) central Chile; (d) Western Cape of South Africa; and (e) southern and south-western Australia. Med-regions were represented by temperate areas with hot and warm summers following the Köppen–Geiger climate classification system (Köppen 1936, Geiger 1954). Density plots indicate the proportions of spatial areas with a Global Human Footprint Index (GHFI) value in each Med-region. The GHFI is the relative human influence that encompasses individual human pressures, including population density and access, infrastructure and land cover. It is a dataset of 1-km$^2$ grid cells from 1993 to 2009: the higher the value (deeper red colour), the higher the human influence (range of 0–50). The GHFI values used to generate this map were obtained and calculated following Venter et al. (2018). The values on the *y*-axes indicate the probability density of the data from a Kernel density function. The use of this approach is for illustrative the purposes of visualizing the shape of the distributions instead of plotting histograms with discrete values.

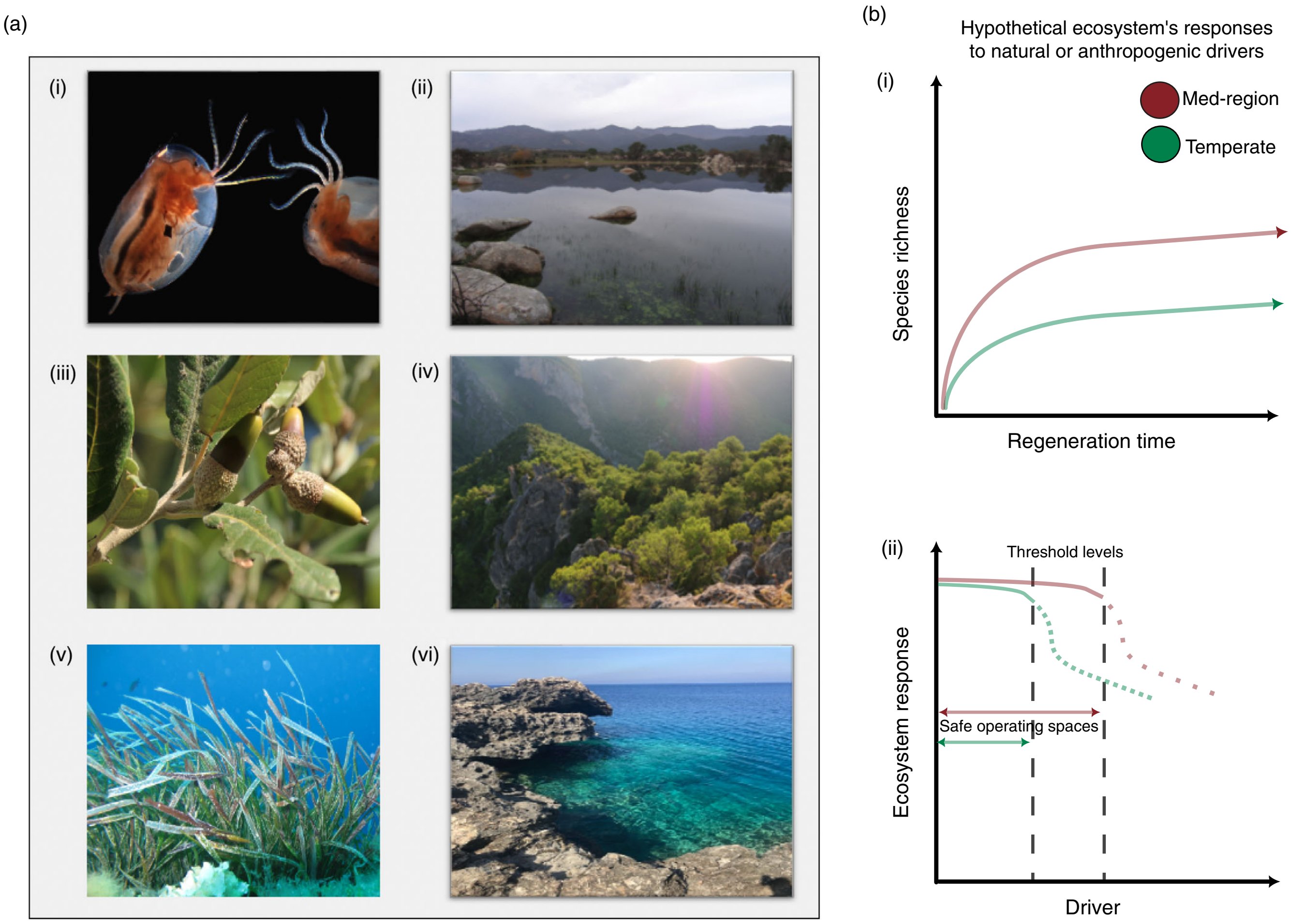

**Figure 2.** Mediterranean climate regions (Med-regions) sharing similarities in adaptive strategies amongst species and ecosystem resilience capacity. In (a), examples are given of organisms (i, iii, v) and their corresponding ecosystems (ii, iv, vi) in which Med-regions have been studied. In (b), a hypothetical ecosystem's responses to natural or anthropogenic drivers between Med-regions (brown colour) and temperate regions (green colour) are given. (b, i) Med-regions show a faster increase over time in richness than temperate regions. (b, ii) Med-regions show a wider safe operating space than temperate regions, as marked by the continuous lines. The threshold levels allow us to avoid reaching uncertainty in the ecosystem responses, as marked by the dashed lines. (a, i) *Spinicaudata* (photo credit: Ignasi Arranz), (a, ii) temporary pond (photo credit: Ignasi Arranz), (a, iii) *Quercus ilex* (oak; photo credit: José María Escolano), (a, iv) sclerophyllous community of shrublands and woodlands (photo credit: Enric Batllori), (a, v) *Posidonia oceanica* (Neptune grass or Mediterranean tapeweed; photo credit: Cristina Linares) and (a, vi) Mediterranean Sea (photo credit: Antigoni Karakoulli). The image in (b, ii) is adapted from Barbier & Burgess (2019).

characteristics should allow Med-region ecosystems to react rapidly to overcome ecosystem degradation (Fig. 2b; Lavorel et al. 1998, Underwood et al. 2009).

Forecasting the dynamics of ecosystems' responses to changing environmental conditions is challenging due to the difficulty in predicting tipping points (i.e., points at which ecosystems transition from one stable state to another), especially given the uncertainty of ecological baseline conditions (Moore 2018). For instance, in the Mediterranean Basin, megafires might shift terrestrial ecosystems towards vegetation formations characteristic of more arid regions (Piñol et al. 2007, San-Miguel-Ayanz et al. 2013). Similarly, high grazing pressure in other terrestrial Med-region ecosystems pushes biotic integrity towards the edge of extinction with decreased canopy cover and high erosion (Kéfi et al. 2007). Increased aridity can then lead to irreversible desertification, in which the possibility of recovery is likely to be low. In freshwater ecosystems, reduced amounts of precipitation and falling groundwater levels (e.g., 30% rainfall reduction in spring/summer by 2080; MedECC 2020) can reduce the longevity of the hydroperiods of temporary ponds and intermittent streams (Zacharias & Zamparas 2010). In marine ecosystems, the depletion of sea urchin predators caused by chronic overfishing has been one of the main drivers of macroalgal collapse in the Mediterranean Sea (Ling et al. 2015). To predict future conditions, it is essential to establish clear ecological baselines and recognize significant changes in ecosystem states.

In this work, we define integrative research as the interdisciplinary approach from multiple fields of study with common concepts and metrics (Winder 2003, Tress et al. 2005) that enables a better understanding of the general mechanisms underlying ecosystems. In Med-regions, integrative research could provide more effective conservation strategies with a suite of resilience-based management approaches, including developing incentives that encourage sustainability, identifying ecological baselines and protecting key species and ecosystems (Abiven et al. 2017). Previous integrative studies in Med-regions have elucidated common ecological patterns, contributing to the enhancement of conservation practices. A synthesis by Bonada & Resh (2013) based on 22 papers addressed diversity patterns and conservation practices but only regarding Mediterranean rivers and streams.

Lavorel et al. (1998) provided the first roadmap for conducting global change research in Mediterranean forests and pointed out the need for 'appropriate coordination and synthesis of that research'. More recently, a group of scientists with different scientific backgrounds has coordinated an exhaustive report emphasizing the potential hazards of climate and environmental changes in the Mediterranean Basin (Cramer et al. 2018, Hassoun et al. 2021). In the current work, building on previous efforts highlighting the need to promote integrative research in Med-regions, we advocate for the exploration of cross-ecosystem generalities and common resilience mechanisms (e.g., tipping points) in Med-regions.

Here, we aim to promote integrative research across ecosystems in Med-regions, which are heavily threatened by the most significant factors raised in the World Scientists' Warning to Humanity manifesto (e.g., increased temperature, human population density; Ripple et al. 2017, 2023). Although integrative research covering Med-regions globally was scarce at the time of the first World Scientists' Warning, more comprehensive ecological knowledge and datasets are now available, allowing for the identification of ecological commonalities across Med-regions (e.g., Aurelle et al. 2022, Albassatneh et al. 2023, Herrera et al. 2023). Thus, we first propose a call to action to the research community for integrative studies in Med-regions. We then offer recommendations for improving such integrative studies, including leveraging biodiversity data, promoting working groups in research syntheses and testing theoretical frameworks.

## Integrative studies in Med-regions

We suggest that there are three main types of integrative studies at different spatial scales, from local to global, which would enable and facilitate an integrative research framework in Med-regions. We propose such studies to represent (1) integrative research across ecosystems, (2) integrative research across Med-regions and (3) integrative research across political boundaries.

### *Integrative research across ecosystems*

The connectivity amongst different ecosystem types plays a vital role in shaping nutrient exchanges, community dynamics and food web structure (Polis et al. 1997). This is because ecosystems are never isolated in space but interact through the movement of matter, nutrients and organisms across habitat boundaries (Gravel et al. 2010). Few studies on Med-regions have focused on the connectivity amongst ecosystem types (Bastow et al. 2002, Rundio & Lindley 2012, Orihuela-Torres et al. 2022). For instance, Orihuela-Torres et al. (2022) found in Mediterranean ponds (Spain) that the consumption of carp carcasses by terrestrial vertebrate scavengers serves as a link between the aquatic and terrestrial ecosystems. Bastow et al. (2002) showed in a Mediterranean river in California that large populations of terrestrial grasshoppers can be sustained due to their high rates of consumption of algae, providing an alternative pathway for energy exchange between rivers and riparian habitats. We argue that a priority in integrative research within Med-regions would be to identify cross-ecosystem boundaries that encompass aquatic–terrestrial linkages (e.g., coastal dune–sea, pond–surrounding landscape, stream–riparian forest) and to integrate knowledge from diverse disciplines, placing a specific focus on establishing ecological baselines (Graham et al. 2023). The prioritization of zones with the highest level of inter-ecosystem connectivity (i.e., aquatic–terrestrial or freshwater–marine linkages) would complement earlier perspectives, in which priority-setting relied more heavily on iconic or single species within an ecosystem (Panou et al. 1993, Alessandro & Antonello 2010, Palomares et al. 2011).

### *Integrative research across Med-regions*

Although extensive research has been conducted to understand the impacts of global change factors on biodiversity in the Mediterranean Basin (e.g., Bonada & Resh 2013, Doblas-Miranda et al. 2017), limited knowledge applies to less developed Med-regions such as central Chile (Figueroa et al. 2013). This leads to a piecemeal understanding of Med-regions and a less effective integration of research from different Med-regions worldwide. An operational framework for addressing this can be accomplished through the identification of other effective area-based conservation measures (i.e., those extending beyond traditional protected areas; Dudley 2018) and the implementation of successful conservation strategies aimed at establishing ecological baselines (Dudley et al. 2018, Petza et al. 2019). Moreover, the implementation of research programmes or new tools from one region may improve the knowledge of the ecological status of ecosystems in other regions. For instance, the European Water Framework Directive, drawing on the river knowledge in the northern Mediterranean Basin, has already been employed to facilitate the implementation of conservation plans for Chilean river ecosystems (Fuster et al. 2015). The Nature Futures Framework developed by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IBPES; available at www.ipbes.net) may improve the effectiveness of conservation plans and actions.

### *Integrative research across political boundaries*

Because biological diversity exists in a combination of public and private lands, the designation of protected areas (e.g., national parks, nature reserves; Dudley 2008) is influenced by diverse and complex socio-economic and political factors. For instance, in Chile, only 10% of the Mediterranean region is formally protected (i.e., as a national asset by the government), and the rest belongs to private lands (Simonetti 1999, Pauchard & Villarroeal 2002). Moreover, there are some Med-regions with a high percentage of protected land (e.g., over 39% in southern and south-western Australia; Fig. 3) that can still fail to coordinate cross-boundary conservation because this often requires extra logistical support and resources compared to local initiatives (Kark et al. 2009). Quantitative conservation geography is a subfield in biogeography that integrates elements of human geography, such as cultures and people, and the environmental context (Minin et al. 2022). Quantitative conservation geography aims to implement conservation actions in order to mitigate threats and support sustainable people–nature interactions (Minin et al. 2022), and it can ensure the designation of more integrative research by identifying priority areas with high levels of endemism (Kier et al. 2009), establish biological corridors (Gonçalves et al. 2018) and foster collaboration between public services and private landowners (Cortés-Capano et al. 2020). We suggest that moving towards quantitative conservation geography, with a strong emphasis on data acquisition from multiple sources such as remote sensing or field surveys rather than being constrained by political boundaries (Médail & Diadema 2009, Cheikh Albassatneh et al. 2021), will enhance the process of identifying ecological baselines and the formulation of effective conservation strategies. Similarly, international organizations, including

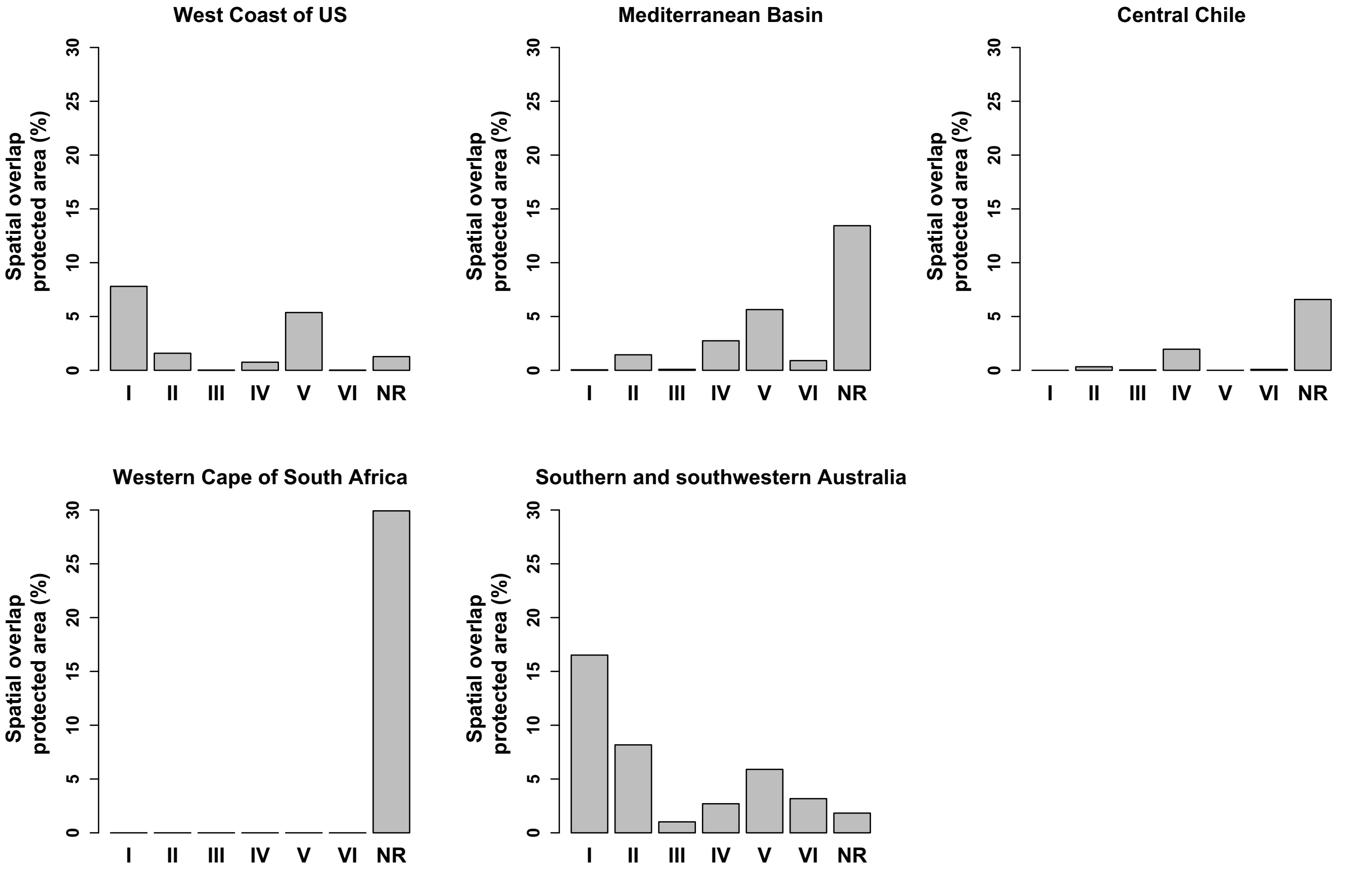

**Figure 3.** Proportion (%) of protected area occupied according to the six management categories proposed by the International Union for Conservation of Nature (IUCN; Dudley 2008). The spatial overlap is calculated as the percentage of the overlapping area between each management category and the total geographical area of each Mediterranean climate region. I = Strict Nature Reserve or Wilderness Area; II = National Park; III = Natural Monument or Feature; IV = Habitat/Species Management Area; V = Protected Landscape/Seascape; VI = Protected Area with Sustainable Use of Natural Resources. NR (Non-Reported) is a specific national designation category for habitat conservation, but it is not included within the IUCN management categories.

non-governmental or multilateral development entities, can play a crucial role in incorporating global policies in Med-regions by facilitating effective transboundary coordination and flexible decision-making within global protected area planning frameworks. For instance, the International Organization for Standardization (2018) emphasizes the importance of developing standardized research designs and methodologies to establish baseline references for ecosystem states.

## Identifying ecological baselines

Developing integrative studies would improve our comprehension of ecological baselines in Med-regions holistically. Ecological baselines are essential for reliably measuring biodiversity change and assisting management goals (Mihoub et al. 2017). Although Med-regions are already heavily altered by global change impacts, long-term biodiversity monitoring can track the trends and magnitudes of future biodiversity changes and disentangle anthropogenic effects from the impacts of natural factors. Additionally, prior to the original work on biodiversity monitoring, information regarding anthropogenic pressures might not have been accessible, affecting views of the ecological baselines (Pauly 1995). Promoting integrative research across Med-regions will help increase the chances of locating the most pristine areas and using them as ecological baselines for those that have experienced long-term anthropogenic disturbances.

## Implications and future directions

Our purpose is to engage the research community in the implementation of integrative research by promoting potential studies that focus on aquatic–terrestrial linkages across different Med-regions and across political boundaries. Despite the strong ecological similarities across Med-regions, to date there has been little integrative research amongst them (but see Lavorel et al. 1998, Bonada & Resh 2003). We point to several major impediments that can explain why inconsistencies still exist in management strategies across Med-regions worldwide, including lags in data exchange, barriers to an effective working synthesis and a lack of initiatives from international organizations. Moreover, such impediments can also result in unresolved fundamental questions regarding how Mediterranean biodiversity will respond to impacts of global change. Future studies could address these research gaps by investigating where and why biological diversity responds most significantly to global change impacts and identifying the most successful management regulations across Med-regions. Therefore, we emphasize the importance of developing research tools to implement integrative studies. Given the strong ecological similarities amongst Med-regions, a joint research strategy could be beneficial for ensuring the effective conservation and management of Med-regions worldwide experiencing the impacts of global change.

Apart from advocating for an interdisciplinary approach in integrative research, it is also worth considering the cooperation between stakeholders (e.g., managers or policymakers) and researchers, focusing on a transdisciplinary approach. This could allow for the implementation of better decisions, the quicker formulation of problem resolutions and the identification of knowledge gaps in the process of planning integrative studies (Voinov & Bousquet 2010, Cimpoiasu et al. 2021). Stakeholders harbour local ecological knowledge that researchers could use to frame their theoretical hypotheses by considering the context dependency of the local environment (Jongman & Padovani 2006). Similarly, stakeholders offer a historical perspective on the local environmental changes that researchers can exploit when conducting long-term analyses. Collectively, coordinated research projects involving stakeholders may yield mutual benefits for forecasting the dynamics of ecosystems' responses to changing environmental conditions and for developing scientific-based practices and policies.

Future studies in Med-regions could be framed within the three types of integrative studies outlined above, which could serve to establish ecological baseline conditions and aid in predicting tipping points through an increased understanding of causal factors (Houlahan et al. 2017). We believe that these recommendations could serve as a starting point for improving our understanding of the responses of Med-region ecosystems to natural and anthropogenic disturbances and for identifying ecological baselines. One promising avenue involves applying and testing the resilience of Med-region ecosystems in conjunction with existing mechanistic theoretical frameworks (e.g., the theory of island biogeography; McArthur & Wilson 1967). This interdisciplinary approach could help to elucidate complex phenomena, including the non-equilibrium aspect of Med-region ecosystems due to natural disturbances, as well as help to identify key drivers that might influence the stability and adaptive capacity of Med-regions. Another important task for future research is leveraging the availability of large spatial and temporal biodiversity datasets in Med-regions. The increasing number of biodiversity datasets offers exciting prospects and challenges for documenting and forecasting changes in the biological diversity and resilience of Med-region ecosystems (Dornelas et al. 2018, Comte et al. 2021). Synthesis centres offer the opportunity to bring together experts from diverse backgrounds, disciplines and perspectives to collectively address big questions in ecology using these existing biodiversity datasets (Rodrigo et al. 2013, Baron et al. 2017). Overall, such approaches would increase the knowledge available for addressing many fundamental and applied questions in Med-regions, facilitating cross-validations and providing a clearer picture of remaining gaps, thereby guiding future sampling and research efforts.

## Conclusion

Integrative research is key to detecting similarities that bridge gaps in our understanding of the nature of different ecosystem types in Med-regions. Here, we highlight this in the context of the claim presented in the 1992 World Scientists' Warning to Humanity manifesto (Ripple et al. 2017, 2023) that there is an urgent need for integrative research to avert the consequences of irreversible ecosystem changes. Considering that most Med-regions feature highly heterogeneous landscapes and seascapes and their species show considerable genetic adaptation to stressors (Rundel et al. 2018, Aurelle et al. 2022), Med-regions contain unique sets of ecosystems that might exhibit higher resilience capacities to natural disturbance and wider safe operation spaces than more temperate (Bonada et al. 2007) or humid (Helman et al. 2017) ecosystems. However, crossing certain biophysical thresholds could have disastrous consequences for ecosystem integrity, to the point of pushing Med-regions outside their stable zone (e.g., a desertification process). Promoting integrative research could therefore help us to elucidate ecological generalities, promote knowledge–action outcomes and foster multiple disciplinary approaches to anticipate tipping points before the appearance of irreversible ecosystem changes in Med-regions.

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## References

Abiven S, Altermatt F, Backhaus N, Deplazes-Zemp A. Furrer R, Korf B, et al. (2017) Integrative research efforts at the boundary of biodiversity and global change research. *Current Opinion in Environmental Sustainability* 29: 215–222.

Albassatneh MC, Dubuisson J-Y, Escudero M, Fady B, Ponger L, Muller S (2023) Effect of environmental and spatial factors on the phylogenetic and functional diversity of the Mediterranean tree communities of Europe. *Plant Biology* 25: 631–645.

Alessandro L, Antonello S (2010) An overview of loggerhead sea turtle (*Caretta caretta*) bycatch and technical mitigation measures in the Mediterranean Sea. *Reviews in Fish Biology and Fisheries* 20: 141–161.

Angulo E, Boulay R, Ruano F, Tinaut A, Cerdá X (2016) Anthropogenic impacts in protected areas: assessing the efficiency of conservation efforts using Mediterranean ant communities. *PeerJ* 4: e2773.

Aurelle D, Thomas S, Albert C, Bally M, Bondeau A, Boudouresque C-F, et al. (2022) Biodiversity, climate change, and adaptation in the Mediterranean. *Ecosphere* 13: e3915.

Barbier EB, Burgess JC (2019) Scarcity and safe operating spaces: the example of natural forests. *Environmental and Resource Economics* 74: 1077–1099.

Baron JS, Specht A, Garnier E, Bishop P, Campbell CA, Davis FW, et al. (2017) Synthesis centers as critical research infrastructure. *BioScience* 67: 750–759.

Bastow JL, Sabo JL, Finlay JC, Power ME (2002) A basal aquatic–terrestrial trophic link in rivers: algal subsidies via shore-dwelling grasshoppers. *Oecologia* 131: 261–268.

Bianchi CN, Caroli F, Guidetti P, Morri C (2018) Seawater warming at the northern reach for southern species: Gulf of Genoa, NW Mediterranean. *Journal of the Marine Biological Association of the United Kingdom* 98: 1–12.

Bonada N, Dolédec S, Statzner B (2007) Taxonomic and biological trait differences of stream macroinvertebrate communities between mediterranean and temperate regions: implications for future climatic scenarios. *Global Change Biology* 13: 1658–1671.

Bonada N, Resh VH (2013) Mediterranean-climate streams and rivers: geographically separated but ecologically comparable freshwater systems. *Hydrobiologia* 719: 1–29.

Bussotti F, Ferrini F, Pollastrini M, Fini A (2014) The challenge of Mediterranean sclerophyllous vegetation under climate change: from acclimation to adaptation. *Environmental and Experimental Botany* 103: 80–98.

Castri F, Mooney HA (eds) (1973) *Mediterranean Type Ecosystems: Origin and Structure*. Berlin, Germany: Springer-Verlag.

Cheikh Albassatneh M, Escudero M, Monnet A-C, Arroyo J, Bacchetta G, Bagnoli F, et al. (2021) Spatial patterns of genus-level phylogenetic endemism in the tree flora of Mediterranean Europe. *Diversity and Distributions* 27: 913–928.

Cimpoiasu MO, Dowdeswell-Downey E, Evans DL, McCloskey CS, Rose LS, Sayer EJ (2021) Contributions and future priorities for soil science: comparing perspectives from scientists and stakeholders. *European Journal of Soil Science* 72: 2538–2557.

Coll M, Piroddi C, Steenbeek J, Kaschner K, Lasram FBR, Aguzzi J, et al. (2010) The biodiversity of the Mediterranean Sea: estimates, patterns, and threats. *PLoS ONE* 5: e11842.

Comte L, Carvajal-Quintero J, Tedesco PA, Giam X, Brose U, Erös T, et al. (2021) RivFishTIME: a global database of fish time-series to study global change ecology in riverine systems. *Global Ecology and Biogeography* 30: 38–50.

Cortés-Capano G, Toivonen T, Soutullo A, Fernández A, Dimitriadis C, Garibotto-Carton G, Di Minin E (2020) Exploring landowners' perceptions, motivations and needs for voluntary conservation in a cultural landscape. *People and Nature* 2: 840–855.

Cramer W, Guiot J, Fader M, Garrabou J, Gattuso J-P, Iglesias A, et al. (2018) Climate change and interconnected risks to sustainable development in the Mediterranean. *Nature Climate Change* 8: 972–980.

MedECC (2020) *Climate and Environmental Change in the Mediterranean Basin – Current Situation and Risks for the Future. First Mediterranean Assessment Report* (W Cramer, J Guiot, K Marini, eds). Marseille, France: Union for the Mediterranean, Plan Bleu, UNEP/MAP.

Darmaraki S, Somot S, Sevault F, Nabat P, Narvaez WDC, Cavicchia L, et al. (2019) Future evolution of marine heatwaves in the Mediterranean Sea. *Climate Dynamics* 53: 1371–1392.

David TS, Henriques MO, Kurz-Besson C, Nunes J, Valente F, Vaz M, et al. (2007) Water-use strategies in two co-occurring Mediterranean evergreen oaks: surviving the summer drought. *Tree Physiology* 27: 793–803.

Doblas-Miranda E, Alonso R, Arnan X, Bermejo V, Brotons L, de las Heras J, et al. (2017) A review of the combination among global change factors in forests, shrublands and pastures of the Mediterranean region: beyond drought effects. *Global Planetary Change* 148: 42–54.

Dornelas M, Antao LH, Moyes F, Bates AE, Gould WA, Henshaw DL (2018) BioTIME: a database of biodiversity time series for the Anthropocene. *Global Ecology and Biogeography* 27: 760–786.

Dudley N (2008) *Guidelines for Applying Protected Area Management Categories*. Gland, Switzerland: IUCN.

Dudley N, Jonas H, Nelson F, Parrish J, Pyhälä A, Stolton S, Watson JEM (2018) The essential role of other effective area-based conservation measures in achieving big bold conservation targets. *Global Ecology and Conservation* 15: e00424.

Fady B, Esposito E, Abulaila K, Aleksic JM, Alia R, Alizoti P, et al. (2022) Forest genetics research in the Mediterranean Basin: bibliometric analysis, knowledge gaps, and perspectives. *Current Forestry Repository* 8: 277–298.

Figueroa R, Bonada N, Guevara M, Pedreros P, Correa-Araneda F, Díaz ME, Ruiz VH (2013) Freshwater biodiversity and conservation in Mediterranean climate streams of Chile. *Hydrobiologia* 719: 269–289.

Fox BJ, Fox MD (1986) Resilience of animal and plant communities to human disturbance. In: B Dell, AJM Hopkins, BB Lamont (eds), *Resilience in Mediterranean-Type Ecosystems* (pp. 39–64). Berlin, Germany: Springer.

Fuster R, Escobar C, Lillo G, de la Fuente A (2015) Construction of a typology system for rivers in Chile based on the European Water Framework Directive (WFD). *Environmental Earth Science* 73: 5255–5268.

Gasith A, Resh VH (1999) Streams in Mediterranean climate regions: abiotic influences and biotic responses to predictable seasonal events. *Annual Review of Ecology and Systematics* 30: 51–81.

Geiger R (1954) *Klassifikation der Klimate nach W. Köppen [Classification of climates after W. Köppen]. Landolt-Börnstein – Zahlenwerte und Funktionen aus Physik, Chemie, Astronomie, Geophysik und Technik, alte Serie* (vol. 3, pp. 603–607). Berlin, Germany: Springer.

Gianni F, Bartolini F, Airoldi L, Ballesteros E, Francour P, Meinesz A, et al. (2013) Conservation and restoration of marine forests in the Mediterranean Sea and the potential role of Marine Protected Areas. *Advances in Oceanography and Limnology* 4: 83–101.

Gonçalves DV, Martínez-Freiría F, Crochet P-A, Geniez P, Carranza S, Brito JC (2018) The role of climatic cycles and trans-Saharan migration corridors in species diversification: biogeography of *Psammophis schokari* group in North Africa. *Molecular Phylogenetics and Evolution* 118: 64–74.

Graham S, Wary M, Calcagni F, Cisneros M, de Luca C, Gorostiza S, et al. (2023) An interdisciplinary framework for navigating social–climatic tipping points. *People and Nature* 5: 1445–1456.

Gravel D, Guichard F, Loreau M, Mouquet N (2010) Source and sink dynamics in meta-ecosystems. *Ecology* 91: 2172–2184.

Hassoun AER, Guiot J, Marini K, Cramer W (2021) The changing Mediterranean Basin through the lens of Mediterranean experts. *International Journal of Euro-Mediterranean Studies* 13: 117–137.

Helman D, Lensky IM, Yakir D, Osem Y (2017) Forests growing under dry conditions have higher hydrological resilience to drought than do more humid forests. *Global Change Biology* 23: 2801–2817.

Herrera CM, Núñez A, Valverde J, Alonso C (2023) Body mass decline in a Mediterranean community of solitary bees supports the size shrinking effect of climatic warming. *Ecology* 104: e4128.

Heywood VH (2014). An overview of in situ conservation of plant species in the Mediterranean. *Flora Mediterranea* 24: 5–24.

Houlahan JE, McKinney ST, Anderson TM, McGill BJ (2017) The priority of prediction in ecological understanding. *Oikos* 126: 1–7.

International Organization for Standardization (2018) *Occupational health and safety management systems – requirements with guidance for use* (ISO Standard No. 45001:2018) [www document]. URL https://www.iso.org/standard/63787.html

Jongman RHG, Padovani CR (2006) Interaction between stakeholders and research for integrated river basin management. *International Journal of Water Resources Development* 22: 49–60.

Kark S, Levin N, Grantham HS, Possingham HP (2009) Between-country collaboration and consideration of costs increase conservation planning efficiency in the Mediterranean Basin. *Proceedings of the National Academy of Sciences of the United States of America* 106: 15368–15373.

Kéfi S, Rietkerk M, Alados CL, Pueyo Y, Papanastasis VP, ElAich A, de Ruiter PC (2007) Spatial vegetation patterns and imminent desertification in Mediterranean arid ecosystems. *Nature* 449: 213–217.

Kier G, Kreft H, Lee TM, Jetz W, Ibisch PL, Nowicki C, et al. (2009) A global assessment of endemism and species richness across island and mainland regions. *Proceedings of the National Academy of Sciences of the United States of America* 106: 9322–9327.

Köppen W (1936) *Das geographische System der Klimate*. Berlin, Germany: Gebrüder Borntraeger.

Lavorel S, Canadell J, Rambal S, Terradas J (1998) Mediterranean terrestrial ecosystems: research priorities on global change effects. *Global Ecology and Biogeography* 7: 157–166.

Lejeusne C, Chevaldonné P, Pergent-Martini C, Boudouresque CF, Pérez T (2010) Climate change effects on a miniature ocean: the highly diverse, highly impacted Mediterranean Sea. *Trends in Ecology and Evolution* 25: 250–260.

Ling SD, Scheibling RE, Rassweiler A, Johnson CR, Shears N, Connell SD, et al. (2015) Global regime shift dynamics of catastrophic sea urchin overgrazing. *Philosophical Transactions of the Royal Society B* 370: 20130269.

Lionello P, Malanotte-Rizzoli P, Boscolo R (2006) *Mediterranean Climate Variability*. Amsterdam, The Netherlands: Elsevier.

MacArthur RH, Wilson EO (1967) *The Theory of Island Biogeography*. Princeton, NJ, USA: Princeton University Press.

Marr SM, Marchetti MP, Olden JD, García-Berthou E, Morgan DL, Arismendi I, et al. (2010) Freshwater fish introductions in mediterranean-climate regions: are there commonalities in the conservation problem? *Diversity and Distributions* 16: 606–619.

Medail F, Quezel P (1997) Hot-spots analysis for conservation of plant biodiversity in the Mediterranean Basin. *Annals of the Missouri Botanical Garden* 84: 112–127.

Médail F, Diadema K (2009) Glacial refugia influence plant diversity patterns in the Mediterranean Basin. *Journal of Biogeography 36*: 1333–1345.

Mihoub J-B, Henle K, Titeux N, Brotons L, Brummitt NA, Schmeller DS (2017) Setting temporal baselines for biodiversity: the limits of available monitoring data for capturing the full impact of anthropogenic pressures. *Scientific Reports* 7: 41591.

Minin ED, Correia RA, Toivonen T (2022) Quantitative conservation geography. *Trends in Ecology & Evolution* 37: 42–52.

Moore JC (2018) Predicting tipping points in complex environmental systems. *Proceedings of the National Academy of Sciences of the United States of America* 115: 635–636.

Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GAB, Kent J (2000) Biodiversity hotspots for conservation priorities. *Nature* 403: 853–858.

Orihuela-Torres A, Pérez-García JM, Sánchez-Zapata JA, Botella F, Sebastián-González E (2022) Scavenger guild and consumption patterns of an invasive alien fish species in a Mediterranean wetland. *Ecology and Evolution* 12: e9133.

Palomares F, Rodríguez A, Revilla E, López-Bao JV, Calzada J (2011) Assessment of the conservation efforts to prevent extinction of the Iberian lynx. *Conservation Biology* 25: 4–8.

Panitsa M, Iliopoulou N, Petrakis E (2021) Citizen science, plant species, and communities' diversity and conservation on a Mediterranean biosphere reserve. *Sustainability* 13: 9925.

Panou A, Jacobs J, Panos D (1993) The endangered mediterranean monk seal *Monachus monachus* in the Ionian Sea, Greece. *Biological Conservation* 64: 129–140.

Pauchard A, Villaroel P (2002) Protected areas in Chile: history, current status, and challenges. *Natural Areas Journal* 22: 318–330.

Pauly D (1995) Anecdotes and the shifting baseline syndrome of fisheries. *Trends in Ecology and Evolution* 10: 430.

Petza D, Chalkias C, Koukourouvli N, Coll M, Vassilopoulou V, Karachle PK, et al. (2019) An operational framework to assess the value of fisheries restricted areas for marine conservation. *Marine Policy* 102: 28–39.

Piñol J, Castellnou M, Beven KJ (2007) Conditioning uncertainty in ecological models: assessing the impact of fire management strategies. *Ecological Modelling* 207: 34–44.

Polis GA, Anderson WB, Holt RD (1997) Toward an integration of landscape and food web ecology: the dynamics of spatially subsidized food webs. *Annual Review of Ecology, Evolution, and Systematics* 28: 289–316.

Quero JL, Sterck FJ, Martínez-Vilalta J, Villar R (2011) Water-use strategies of six co-existing Mediterranean woody species during a summer drought. *Oecologia* 166: 45–57.

Quezel P, Barbéro M (1989) Zonation altitudinale des structures forestières de végétation en Californie méditerranéenne Leur interprétation en fonction des méthodes utilisées sur le pourtour méditerranéen. *Annals of Forest Science* 46: 233–250.

Ripple WJ, Wolf C, Gregg JW, Rockström J, Newsome TM, Law BE, et al. (2023) The 2023 state of the climate report: entering uncharted territory. *BioScience* 73: 841–850.

Ripple WJ, Wolf C, Newsome TM, Galetti M, Alamgir M, Crist E, et al. (2017) World Scientists' Warning to Humanity: a second notice. *BioScience* 67: 1026–1028.

Rockström J, Steffen W, Noone K, Persson Å, Chapin III FSC, Lambin EF, et al. (2009) A safe operating space for humanity. *Nature* 461: 472–475.

Rodrigo A, Alberts S, Cranston K, Kingsolver J, Lapp H, McClain C, et al. (2013) Science incubators: synthesis centers and their role in the research ecosystem. *PLoS Biology* 11: e1001468.

Rundel PW, Arroyo MTK., Cowling RM, Keeley JE, Lamont BB, Pausas JG, Vargas P (2018) Fire and plant diversification in Mediterranean-climate regions. *Frontiers in Plant Science* 9: 851.

Rundio DE, Lindley ST (2012) Reciprocal fluxes of stream and riparian invertebrates in a coastal California basin with Mediterranean climate. *Ecological Research* 27: 539–550.

San-Miguel-Ayanz J, Moreno JM, Camia A (2013) Analysis of large fires in European Mediterranean landscapes: lessons learned and perspectives. *Forest Ecology and Management* 294: 11–22.

Simonetti J (1999) Diversity and conservation of terrestrial vertebrates in Mediterranean Chile. *Revista Chilena de Historia Natural* 72: 493–500.

Tress G, Tress B, Fry G (2005) Clarifying integrative research concepts in landscape ecology. *Landscape Ecology* 20: 479–493.

Underwood EC, Viers JH, Klausmeyer KR, Cox RL, Shaw MR (2009) Threats and biodiversity in the Mediterranean biome. *Diversity and Distributions* 15: 188–197.

Venter O, Sanderson A, Magrach A, Allan JR, Beher J, Jones KR, et al. (2018) *Last of the Wild Project, Version 3 (LWP-3): 2009 Human Footprint, 2018 Release.* Palisades, NY, USA: NASA Socioeconomic Data and Applications Center (SEDAC).

Voinov A, Bousquet F (2010) Modelling with stakeholders. *Environmental Modelling & Software* 25: 1268–1281.

Winder N (2003) Successes and problems when conducting interdisciplinary or transdisciplinary (= integrative) research. In: B Tress, G Tress, A Van der Valk, G Fry (eds), *Interdisciplinarity and Transdisciplinarity in Landscape Studies: Potential and Limitations.* Delta Series 2 (pp. 74–90). Wageningen, The Netherlands: Alterra Green World Research.

Zacharias I, Zamparas M (2010) Mediterranean temporary ponds. A disappearing ecosystem. *Biodiversity and Conservation* 19: 3827–3834.

Zenetos A, Galanidi M (2020) Mediterranean non indigenous species at the start of the 2020s: recent changes. *Marine Biodiversity Records* 13: 10.