Appendix 3

50 IMPORTANT QUESTIONS FOR THE CONSERVATION OF MEDITERRANEAN WETLANDS 2020–2050

Accompanying paper: Taylor NG, Grillas P, Al Hreisha H, Balkız Ö, Borie M, Boutron O, et al. The future for Mediterranean wetlands: 50 key issues and 50 important conservation research questions. *Reg Environ Change*

Comments define terminology, explain the importance of a question, suggest sub-questions and/or suggest possible methodologies to answer a question. The reader is often referred to related Issues (Appendix 2) for more detailed information. A **further reading** section provides up to five relevant references are provided to help readers start to explore each question. These include reviews, general conceptual papers, specific examples from the Mediterranean, or examples of studies carried out elsewhere in the world/on non-wetland systems that could be replicated for Mediterranean wetlands. Neither the comments nor the references are meant to be comprehensive or prescriptive, and that alternative interpretations of the questions are possible.

Agriculture and aquaculture

1. How can we minimise the impacts of agricultural chemicals on nearby wetlands?

Comments: "Agricultural chemicals" include fertilisers, herbicides and insecticides; principally synthetic but also organic. Answers to this question might include (a) a review of measures for reducing impacts of agricultural chemicals, e.g. using less, adjusting timing of application, planting cover crops, and/or (b) a consideration of how we can encourage Mediterranean farmers to actually adopt these measures, e.g. through financial incentives, education, legislation, or providing technology. Appropriate interventions may vary across the Mediterranean. See also Issue 2 and Issue 26.

Further reading

1. Dessart FJ, Barreiro-Hurlé J, van Bavel R (2019) Behavioural factors affecting the adoption of sustainable farming practices: a policy-oriented review. Eur Rev Agric Econ 46:417–471
2. Ripa MN, Leone A, Garnier M, Porto AL (2006) Agricultural land use and best management practices to control nonpoint water pollution. Environ Manag 38:253–266
3. Rodriguez JM, Molnar JJ, Fazio RA, Sydnor E, Lowe MJ (2009) Barriers to adoption of sustainable agriculture practices: change agent perspectives. Renew Agric Food Syst 24:60–71
4. Shackelford GE, Kelsey R, Robertson RJ, Williams DR, Dicks LV (2017) Sustainable agriculture in California and Mediterranean climates. Synopses of Conservation Evidence Series, University of Cambridge, Cambridge

2. What is the impact of livestock grazing on Mediterranean wetlands, and how can undesirable impacts be mitigated?

Comments: This question includes grazing within wetlands or their watersheds. Although there are some individual studies on the impacts of grazing on Mediterranean wetlands, it would be useful to synthesise these. Local densities of grazing animals in the Mediterranean are likely to increase in the future, to meet growing demand for food in general and meat in particular, and because climate change may reduce the area of good farming land. Equally, abandonment of currently grazed areas could have undesirable effects.

Further reading

1. Malek Ž, Verburg PH, R Geijzendorffer I, Bondeau A, Cramer W (2018) Global change effects on land management in the Mediterranean region. Glob Env Change 50:238–254
2. Mesléard F, Lepart J, Grillas P, Mauchamp A (1999) Effects of seasonal flooding and grazing on the vegetation of former ricefields in the Rhône delta (southern France). Plant Ecol 101–114
3. Shackelford GE, Kelsey R, Robertson RJ, Williams DR, Dicks LV (2017) Sustainable agriculture in California and Mediterranean climates. Synopses of Conservation Evidence Series, University of Cambridge, Cambridge
4. Sharps E, Smart J, Skov MW, Garbutt A, Hiddink JG (2015) Light grazing of saltmarshes is a direct and indirect cause of nest failure in common redshank *Tringa totanus*. Ibis 157:239–249
5. Van den Broeck M, Waterkeyn A, Rhazi L, Grillas P, Brendonck L (2015) Assessing the ecological integrity of endorheic wetlands, with focus on Mediterranean temporary ponds. Ecol Indic 54:1–11

Water and pollution

3. How do economic incentives for water-efficient agriculture affect water use on Mediterranean farms?

Comments: Examples of economic incentives are taxes, subsidies and variable pricing. Which incentives are effective, and in which countries/regions? Might there be any negative or unintended consequences of these incentives on water use? Answers to this question could help to reduce competition for water between agriculture and wetlands.

Further reading

1. Berman S, Jana U, Hoa E, Lavelle P, Geoffroy C, Hess T, et al. (2012) Water saving potential in agriculture in Europe: findings from the existing studies and application to case studies. Final report prepared for European Commission DG ENV
2. Daccache A, Ciurana JS, Rodriguez Diaz JA, Knox JW (2014) Water and energy footprint of irrigated agriculture in the Mediterranean region. Environ Res Lett 9:124014
3. Koundouri P, Akinsete E, Englezos N, Kartala XI, Souliotis I, Adler J (2017) Economic instruments, behaviour and incentives in groundwater management. In: Villholth KG, López-Gunn E, Conti KI, Garrido A, van der Gun J (eds) Advances in groundwater governance. CRC Press, Leiden, pp 157–175
4. Plan Bleu (2012) Sustainable solutions for water in the Mediterranean: managing scarcity and improving quality. Priority 1: "Improving water demand management". Report relating to target n°2 (MED 1-2)

4. What is the extent of microplastic pollution in Mediterranean wetlands, and what impact does it have on wildlife and human health?

Comments: Microplastics are synthetic polymers ≤5 mm long. The extent and impact of microplastic pollution in the Mediterranean, especially in inland wetlands, remain poorly understood. Robust surveys in a variety of locations and wetland types will be necessary to quantify extent. Impacts could be evaluated through a combination of laboratory, field, experimental and observational studies. Answers could help prioritise areas for remediation, or direct policy to prevent pollution. See also Issue 9.

Further reading

1. D'Souza JM, Windsor FM, Santillo D, Ormerod SJ (2020) Food web transfer of plastics to an apex riverine predator. Glob Change Biol 26:3846–3857
2. Li J, Liu H, Chen JP (2018) Microplastics in freshwater systems: a review on occurrence, environmental effects, and methods for microplastics detection. Water Res 137:362–374
3. Prata JC, da Costa JP, Duarte AC, Rocha-Santos T (2019) Methods for sampling and detection of microplastics in water and sediment: a critical review. Trends Anal Chem 110:150–159
4. Simon-Sánchez L, Grelaud M, Garcia-Orellana J, Ziveri P (2019) River deltas as hotspots of microplastic accumulation: the case study of the Ebro River (NW Mediterranean). Sci Total Environ 687:1186–1196
5. Wright SL, Kelly FJ (2017) Plastic and human health: a micro issue? Environ Sci Technol 51:6634–6647

5. What are the effects of emerging domestic and medical pollutants on wildlife in Mediterranean wetlands?

Comments: Emerging pollutants include (a) common domestic chemicals such as caffeine and triclosan, (b) chemicals with medicinal uses, such as testosterone, oestrogen, statins, anti-inflammatories (e.g. ibuprofen), antidepressants (e.g. fluoxetine), anticonvulsants (e.g. carbamazepine) and chemotherapy agents, and (c) illicit drugs. The impacts of these chemicals, the doses needed to cause them, and the interactive effects of an ever expanding cocktail of chemicals remain poorly understood. Answers could help prioritise areas for remediation, inform design of remediation actions, or direct policy to prevent pollution. See also Issue 28.

Further reading

1. Di Poi C, Costil K, Bouchart V, Halm-Lemeille M-P (2018) Toxicity assessment of five emerging pollutants, alone and in binary or ternary mixtures, towards three aquatic organisms. Environ Sci Pollut Res 25:6122–6134
2. Major KM, DeCourten BM, Li J, Britton M, Settles ML, Mehinto AC, et al. (2020) Early life exposure to environmentally relevant levels of endocrine disruptors drive multigenerational and transgenerational epigenetic changes in a fish model. Front Mar Sci 7:471
3. Sutherland WJ, Broad S, Caine J, Clout M, Dicks LV, Doran H, et al. (2016) A horizon scan of global conservation issues for 2016. Trends Ecol Evol 31:44–53
4. Thomaidi VS, Stasinakis AS, Borova VL, Thomaidis NS (2015) Is there a risk for the aquatic environment due to the existence of emerging organic contaminants in treated domestic wastewater? Greece as a case-study. J Hazard Mater 283:740–747

Physical environment and climate change

6. Which Mediterranean wetlands are most vulnerable to climate change, particularly associated changes in hydrological regimes?

Comments: Analyses might identify regions, countries, watersheds, wetland types and individual wetlands that will be most severely impacted by climate change. This includes changes in temperature, precipitation and sea levels [Issues 10–13], and associated changes in the amount and timing of water availability. Studies may consider impacts on the overall wetland ecosystem and the services it provides, or specific aspects or species. Answers to this question could inform a triage system to appropriately direct conservation resources, and help to identify appropriate interventions for management of specific wetlands.

Further reading

1. Kraiem H (2002) Biophysical and socio-economic impacts of climate change on wetlands in the Mediterranean. Mediterranean Regional Roundtable, Athens
2. Lefebvre G, Redmond L, Germain C, Palazzi E, Terzago S, Willm L, et al. (2019) Predicting the vulnerability of seasonally-flooded wetlands to climate change across the Mediterranean Basin. Sci Total Environ 692:546–555
3. Pumo D, Caracciolo D, Viola F, Noto LV (2016) Climate change effects on the hydrological regime of small non-perennial river basins. Sci Total Environ 542:76–92

7. How will relative sea level rise impact coastal Mediterranean wetlands?

Comments: The level of the Mediterranean Sea is predicted to rise by approximately 25 cm, under a range of climate change scenarios, by 2050. Analyses of the impact of sea level rise will probably focus on individual wetlands, with predicted impacts being used to inform mitigation strategies or planned retreat. Modelling will be a key methodological tool to investigate this question. See also Issue 13.

Further reading

1. Ibáñez C, Day JW, Reyes E (2014) The response of deltas to sea-level rise: natural mechanisms and management options to adapt to high-end scenarios. Ecol Eng 65:122–130
2. Marcos M, Jorda G, Cozannet GL (2016) Sea level rise and its impacts on the Mediterranean. In: Moatti J-P, Thiébault S (eds) The Mediterranean region under climate change. IRD Éditions, Marseille, pp 265–275
3. Reimann L, Vafeidis AT, Brown S, Hinkel J, Tol RSJ (2018) Mediterranean UNESCO World Heritage at risk from coastal flooding and erosion due to sea-level rise. Nat Commun 9:4161

4. Schuerch M, Spencer T, Temmerman S, Kirwan ML, Wolff C, Lincke D, et al. (2018) Future response of global coastal wetlands to sea-level rise. Nature 561:231–234
5. Spencer T, Schuerch M, Nicholls RJ, Hinkel J, Lincke D, Vafeidis AT, et al. (2016) Global coastal wetland change under sea-level rise and related stresses: the DIVA Wetland Change Model. Glob Planet Change 139:15–30

8. How will Mediterranean wetland biodiversity respond to future climate change?

Comments: Answers to this question could involve analyses for individual species or analyses of overall patterns (structure and function of ecosystems and communities). What will be the relative importance of adaptation vs migration vs extinction? Which wetland-dependent species are most vulnerable to climate change impacts? What novel combinations of species might be formed as a result of species movements, and how might they function? Answers to this question can inform proactive conservation management, such as where to establish protected areas, which species to translocate and where, or where to focus efforts to control invasive species.

Further reading

1. Essl F, Dullinger S, Genovesi P, Hulme PE, Jeschke JM, Katsanevakis S, et al. (2019) A conceptual framework for range-expanding species that track human-induced environmental change. BioScience 69:908–919
2. Gaget E, Galewski T, Jiguet F, Le Viol I (2018) Waterbird communities adjust to climate warming according to conservation policy and species protection status. Biol Conserv 227:205–212
3. Guisan A, Tingley R, Baumgartner JB, Naujokaitis-Lewis I, Sutcliffe PR, Tulloch AIT, et al. (2013) Predicting species distributions for conservation decisions. Ecol Lett 16:1424–1435
4. MWO (2018) Mediterranean Wetlands Outlook 2: solutions for sustainable Mediterranean wetlands. Mediterranean Wetlands Observatory, Arles
5. Ramírez F, Rodríguez C, Seoane J, Figuerola J, Bustamante J (2018) How will climate change affect endangered Mediterranean waterbirds? PLOS ONE 13:e0192702

9. To what extent will Mediterranean wetlands provide climate change refugia for biodiversity?

Comments: A refuge is an area where a population of organisms can survive a period of unfavourable conditions, including those associated with climate change. Wetlands may be a vital source of water for aquatic and terrestrial animals during predicted hot, dry spells [cf. Issue 10 & Issue 11] – but perhaps not if they will dry out themselves. Answers to this question might identify wetland types or individual wetlands that are the most critical refugia, and thus may be important targets for conservation.

Further reading

1. Bogan MT, Boersma KS, Lytle DA (2015) Resistance and resilience of invertebrate communities to seasonal and supraseasonal drought in arid-land headwater streams. Freshw Biol 60:2547–2558
2. Chester ET, Robson BJ (2013) Anthropogenic refuges for freshwater biodiversity: their ecological characteristics and management. Biol Conserv 166:64–75
3. Davies PM (2010) Climate change implications for river restoration in global biodiversity hotspots. Restor Ecol 18:261–268
4. Médail F (2017) The specific vulnerability of plant biodiversity and vegetation on Mediterranean islands in the face of global change. Reg Environ Change 17:1775–1790
5. Selwood KE, Zimmer HC (2020) Refuges for biodiversity conservation: a review of the evidence. Biol Conserv 245:108502

10. How will acidification affect Mediterranean wetlands, both coastal and inland?

Comments: Drivers of wetland acidification include: dissolution of atmospheric carbon dioxide; inputs of sulphates from the atmosphere, groundwater and surface water; drought-induced oxidation of sulphur compounds in wetland sediments; and salinity-induced oxidation of iron compounds in wetland sediments. To what extent are these processes occurring in Mediterranean wetlands, and what effects do they have on biodiversity and ecosystem services? Current research is heavily biased towards ocean acidification, rather than inland wetlands.

Further reading

1. Hall-Spencer JM, Rodolfo-Metalpa R (2012) Effects of ocean acidification on Mediterranean coastal habitats: lessons from carbon dioxide vents off Ischia. In: Stambler N (ed) Life in the Mediterranean Sea: a look at habitat changes. Nova Science Publishers, Hauppage, NY, pp 671–684
2. Klein AR, Baldwin DS, Singh B, Silvester EJ (2010) Salinity-induced acidification in a wetland sediment through the displacement of clay-bound iron(II). Environ Chem 7:413–421
3. Lacoue-Labarthe T, Nunes PALD, Ziveri P, Cinar M, Gazeau F, Hall-Spencer JM, et al. (2016) Impacts of ocean acidification in a warming Mediterranean Sea: an overview. Reg Stud Mar Sci 5:1–11
4. Lamers LP, Van Roozendaal SM, Roelofs JG (1998) Acidification of freshwater wetlands: combined effects of non-airborne sulfur pollution and desiccation. Water Air Soil Pollut 105:95–106
5. Weiss LC, Pötter L, Steiger A, Kruppert S, Frost U, Tollrian R (2018) Rising pCO2 in freshwater ecosystems has the potential to negatively affect predator-induced defenses in *Daphnia*. Curr Biol 28:327–332.e1–e3

Biotic environment, ecology, biodiversity

11. Which invasive species have the greatest potential to negatively impact Mediterranean wetlands over the next 30 years?

Comments: Answers to this question will be based on a consideration of factors such as (a) likelihood of arrival, (b) likelihood of establishment, and (c) magnitude of impact on Mediterranean wetland biodiversity, habitats, functions and services. This question could be answered at the overall Mediterranean scale and/or with focused location- or taxon-specific assessments. Ecological and socioeconomic impacts should be assessed separately, as each can occur independently of the other. There are various frameworks in place for such assessments. This question is primarily concerned with invasive *alien* species, but could also include consideration of problematic *native* species.

Further reading

1. Bacher S, Blackburn TM, Essl F, Genovesi P, Heikkilä J, Jeschke JM, et al. (2018) Socio-economic impact classification of alien taxa (SEICAT). Methods Ecol Evol 9:159–168
2. Blackburn TM, Essl F, Evans T, Hulme PE, Jeschke JM, Kühn I, et al. (2014) A unified classification of alien species based on the magnitude of their environmental impacts. PLOS Biol 12:e1001850
3. Glamuzina B, Tutman P, Nikolić V, Vidović Z, Pavličević J, Vilizzi L, et al. (2017) Comparison of taxon-specific and taxon-generic risk screening tools to identify potentially invasive non-native fishes in the River Neretva catchment (Bosnia and Herzegovina and Croatia). River Res Applic 33:670–679
4. Peyton J, Martinou AF, Pescott OL, Demetriou M, Adriaens T, Arianoutsou M, et al. (2019) Horizon scanning for invasive alien species with the potential to threaten biodiversity and human health on a Mediterranean island. Biol Invasions 21:2107–2125
5. Peyton JM, Martinou AF, Adriaens T, Chartosia N, Karachle PK, Rabitsch W, et al. (2020) Horizon scanning to predict and prioritize invasive alien species with the potential to threaten human health and economies on Cyprus. Front Ecol Evol 8:566281

12. How can we prevent the spread of invasive species within and between Mediterranean wetlands?

Comments: Answers may relate to: practical control methods (e.g. how best to kill specific species); detection methods (including reports from the public); identifying dispersal vectors and pathways and methods to minimise the likelihood of transport (e.g. ballast water exchange, biosecurity at recreational boating or angling sites); communication techniques (e.g. encouraging the public to engage with biosecurity). May be a synthesis across species, or species-specific analyses. Proactive analyses, for high-impact species on the horizon but not yet in Mediterranean wetlands [Question 11] would be useful. This question is primarily concerned with invasive *alien* species, but could also include consideration of problematic *native* species.

Further reading

1. Aldridge DC, Aldridge SL, Mead A, Rocha R, Scales H, Smith RK, et al. (2017) Control of freshwater invasive species. Synopses of Conservation Evidence Series, University of Cambridge, Cambridge

2. Anderson LG, Rocliffe S, Stebbing PD, Dunn AM (2014) Aquatic biosecurity best practice: lessons learned from New Zealand. Cefas, University of Leeds, University of York
3. Green AJ (2016) The importance of waterbirds as an overlooked pathway of invasion for alien species. Divers Distrib 22:239–247
4. Vander Zanden MJ, Olden JD (2008) A management framework for preventing the secondary spread of aquatic invasive species. Can J Fish Aquat Sci 65:1512–1522

13. What are the critical factors affecting the population dynamics of the most endangered animal and plant species in Mediterranean wetlands?

Comments: "Population dynamics" refers to spatial and temporal variation in population size and density. Population dynamics may be driven by demographic factors (e.g. population density, sex ratio), environmental factors (e.g. temperature, prey availability, parasites) or interactions between the two. Critical factors may be identified in species-specific assessments, or synthesised across multiple species. Assessments could be made by experts or through analyses of long-term data. "Endangered species" may need to be selected by expert judgement, as many species (especially invertebrates) have not been assessed using IUCN Red List criteria. Metapopulation dynamics depend on mechanisms of dispersal between wetlands, which are poorly understood for many organisms.

Further reading

1. Begon M, Townsend CR (2021) Ecology: from individuals to ecosystems. John Wiley & Sons, Hoboken, NJ
2. Eisenhauer N, Bonn A, Guerra CA (2019) Recognizing the quiet extinction of invertebrates. Nat Commun 10:50
3. Millennium Ecosystem Assessment (2005) Ecosystems and human well-being: biodiversity synthesis. World Resources Institute, Washington, DC
4. Murray NJ, Marra PP, Fuller RA, Clemens RS, Dhanjal-Adams K, Gosbell KB, et al. (2018) The large-scale drivers of population declines in a long-distance migratory shorebird. Ecography 41:867–876
5. Tesson SVM, Okamura B, Dudaniec RY, Vyverman W, Löndahl J, Rushing C, et al. (2015) Integrating microorganism and macroorganism dispersal: modes, techniques and challenges with particular focus on co-dispersal. Écoscience 22:109–124

14. What is the role/value of temporary wetlands for biodiversity in the Mediterranean?

Comments: Ephemeral terrestrial and aquatic phases in wetlands can favour the establishment of unique and diverse biological communities. What is the importance of temporary wetlands for specific threatened species, or for maintaining landscape-level biodiversity and metapopulations? Understanding their role will help us know if, where and how they need conserving. See also Issue 16.

Further reading

1. Bagella S, Caria MC (2012) Diversity and ecological characteristics of vascular flora in Mediterranean temporary pools. C R Biol 335:69–76
2. Grillas P, Gauthier P, Yavercovski N, Perennou C (2004) Mediterranean temporary pools. Volume 1 – issues relating to conservation, functioning and management. Tour du Valat, Arles
3. Skoulikidis NT, Sabater S, Datry T, Morais MM, Buffagni A, Dörflinger G, et al. (2017) Non-perennial Mediterranean rivers in Europe: status, pressures, and challenges for research and management. Sci Total Environ 577:1–18
4. Tesson SVM, Okamura B, Dudaniec RY, Vyverman W, Löndahl J, Rushing C, et al. (2015) Integrating microorganism and macroorganism dispersal: modes, techniques and challenges with particular focus on co-dispersal. Écoscience 22:109–124
5. Zacharias I, Zamparas M (2010) Mediterranean temporary ponds. A disappearing ecosystem. Biodivers Conserv 19:3827–3834

15. How resistant and resilient are Mediterranean wetlands to disturbance? What factors, including human activities, affect resistance and resilience?

Comments: Disturbances affecting (or likely to affect) Mediterranean wetlands include fire, drought, flooding, trampling and harvesting. Resistance refers to the ability of an ecosystem to remain unchanged despite disturbance. Resilience refers to the ability of an ecosystem to recover from a disturbance, returning

to its pre-disturbance state. How do Mediterranean wetland ecosystems respond to disturbance? Do they change temporarily or permanently? If there is some resilience, how fast is the recovery? Answers to this question will help us to understand the normal behaviour of Mediterranean wetlands, and to design interventions to improve resistance or resilience (if necessary).

Further reading

1. Capdevila P, Stott I, Beger M, Salguero-Gómez R (2020) Towards a comparative framework of demographic resilience. Trends Ecol Evol 35:776–786
2. Gunderson LH, Carpenter SR, Folke C, Olsson P, Peterson G (2006) Water RATs (resilience, adaptability, and transformability) in lake and wetland social-ecological systems. Ecol Soc 11:art16
3. Hershkovitz Y, Gasith A (2013) Resistance, resilience, and community dynamics in Mediterranean-climate streams. Hydrobiologia 719:59–75
4. Tooth S (2018) The geomorphology of wetlands in drylands: resilience, nonresilience, or …? Geomorphology 305:33–48
5. Zhang Y, Li W, Sun G, King JS (2019) Coastal wetland resilience to climate variability: a hydrologic perspective. J Hydrol 568:275–284

16. How do/will dams and altered flow regimes affect organisms in Mediterranean wetlands?

Comments: The general effects of large dams on wetland biodiversity are understood, but not necessarily in a Mediterranean context and not for all species. The cumulative effects of multiple small dams, currently proliferating along Mediterranean rivers and stream, are less well understood. This question may be (partially) answered with a synthesis of existing evidence, complemented by further primary research in novel locations and in novel species.

Further reading

1. Clavero M, Blanco-Garrido F, Prenda J (2004) Fish fauna in Iberian Mediterranean river basins: biodiversity, introduced species and damming impacts. Aquatic Conserv: Mar Freshw Ecosyst 14:575–585
2. Fencl JS, Mather ME, Costigan KH, Daniels MD (2015) How big of an effect do small dams have? Using geomorphological footprints to quantify spatial impact of low-head dams and identify patterns of across-dam variation. PLOS ONE 10:e0141210
3. McAllister DE, Craig JF, Davidson N, Delany S, Seddon M (2001) Biodiversity impacts of large dams. Background Paper Nr. 1, Prepared for IUCN/UNEP/WCD
4. Zema DA, Bombino G, Denisi P, Lucas-Borja ME, Zimbone SM (2018) Evaluating the effects of check dams on channel geometry, bed sediment size and riparian vegetation in Mediterranean mountain torrents. Sci Total Environ 642:327–340

17. How does/will light pollution affect organisms in Mediterranean wetlands?

Comments: Light pollution is particularly intense in coastal wetlands near human development and tourist sites. Rivers and lakes in urban areas may also be affected. Sources of light pollution include street lighting, architectural lighting, domestic lighting, vehicles and advertising boards. Potential effects on physiology, behaviour, community composition, trophic structure and ecosystem functions. Answers to this question could help to guide city planning and development projects, and inform the design of mitigation measures (if necessary).

Further reading

1. Davies TW, Duffy JP, Bennie J, Gaston KJ (2014) The nature, extent, and ecological implications of marine light pollution. Front Ecol Environ 12:347–355
2. Grubisic M (2018) Waters under artificial lights: does light pollution matter for aquatic primary producers? Limnol Oceanogr Bull 27:76–81
3. Jechow A, Hölker F (2019) How dark is a river? Artificial light at night in aquatic systems and the need for comprehensive night-time light measurements. WIREs Water 6:e1388
4. Zapata MJ, Sullivan SMP, Gray SM (2019) Artificial lighting at night in estuaries—implications from individuals to ecosystems. Estuaries Coasts 42:309–330

18. How do Mediterranean wetlands interact with neighbouring ecosystems?

Comments: It is important to understand how neighbouring ecosystems – such as forest, marine, riparian and agricultural systems – affect the condition of Mediterranean wetlands (so we know how to manage the neighbouring systems to conserve wetlands) and how Mediterranean wetlands affect the condition of neighbouring systems (to inform arguments for wetland conservation in policy/funding arenas).

Further reading

1. Bongiorni L, Nasi F, Fiorentino F, Auriemma R, Rampazzo F, Nordström MC, et al. (2018) Contribution of deltaic wetland food sources to coastal macrobenthic consumers (Po River Delta, north Adriatic Sea). Sci Total Environ 643:1373–1386
2. Verdiell-Cubedo D, Oliva-Paterna FJ, Ruiz-Navarro A, Torralva M (2013) Assessing the nursery role for marine fish species in a hypersaline coastal lagoon (Mar Menor, Mediterranean Sea). Mar Biol Res 9:739–748
3. Vila-Escalé M, Vegas-Vilarrúbia T, Prat N (2007) Release of polycyclic aromatic compounds into a Mediterranean creek (Catalonia, NE Spain) after a forest fire. Water Res 41:2171–2179
4. Wood A, van Halsema GE (2008) Scoping agriculture-wetland interactions: towards a sustainable multiple-response strategy. Food and Agriculture Organization of the United Nations, Rome

19. What is the role of Mediterranean wetlands in spreading antimicrobial resistance, or as hotspots for evolution of antimicrobial resistance?

Comments: Antimicrobial resistance (AMR) occurs when microbes (such as bacteria, viruses and fungi) no longer respond to chemicals designed to kill them. Wetlands may be crucibles for the evolution of AMR and the transmission of resistant organisms to humans. Answering this question would help to inform rational decisions about whether and how to manage AMR in Mediterranean wetlands. See also Issue 33.

Further reading

1. Dolejska M (2020) Antibiotic-resistant bacteria in wildlife. In: Manaia C, Donner E, Vaz-Moreira I, Hong P (eds) The handbook of environmental chemistry. Springer Berlin Heidelberg, Berlin
2. Taylor NGH, Verner-Jeffreys DW, Baker-Austin C (2011) Aquatic systems: maintaining, mixing and mobilising antimicrobial resistance? Trends Ecol Evol 26:278–284
3. Vittecoq M, Godreuil S, Prugnolle F, Durand P, Brazier L, Renaud N, et al. (2016) Antimicrobial resistance in wildlife. J Appl Ecol 53:519–529

Ecosystem services and use of wetlands

20. What level of sustainable use can be tolerated by Mediterranean wetlands? Where are the thresholds above which damage occurs?

Comments: The Ramsar convention encourages wise use of wetlands, ensuring they maintain social and economic value to compete with other land uses. What level of use is sustainable (e.g. for water abstraction, recreation, tourism, harvesting, hunting)? Answers will probably be at the scale of individual wetlands, or for particular types of wetlands at a national or regional scale. Answers may be based on experiments, long-term observational data and/or modelling, potentially including future climate change scenarios.

Further reading

1. Bieger K, Arnold JG, Rathjens H, White MJ, Bosch DD, Allen PM, et al. (2017) Introduction to SWAT+, a completely restructured version of the soil and water assessment tool. J Am Water Resour Assoc 53:115–130
2. Brotherton S, Joyce CB, Scharlemann JPW (2020) Global offtake of wild animals from wetlands: critical issues for fish and birds. Hydrobiologia 847:1631–1649
3. Cataudella S, Crosetti D, Massa F (2015) Mediterranean coastal lagoons: sustainable management and interactions among aquaculture, capture fisheries and the environment. General Fisheries Commission for the Mediterranean Studies and Reviews, No 95. FAO, Rome
4. Ramsar Convention on Wetlands (2012) Wetland tourism: a great experience. https://www.ramsar.org/sites/default/files/documents/library/ramsar-wwd2012-leaflet-en.pdf. Accessed 11 May 2020
5. Ramsar Convention Secretariat (2010) Wise use of wetlands: concepts and approaches for the wise use of wetlands. Ramsar Handbooks for the Wise Use of Wetlands, 4th Edition, Vol. 1. Ramsar Convention Secretariat, Gland

21. What is the relationship between ecosystem condition and service provision in Mediterranean wetlands?

Comments: In general, it is likely that ecosystem service provision is positively related to the physical, chemical and/or biological condition of wetlands. Does this rule hold for Mediterranean wetlands? Is there a threshold condition above which service provision plummets? What services, if any, are provided by Mediterranean wetlands in poor condition?

Further reading

1. Balvanera P, Quijas S, Martín-López B, Barrios E, Dee L, Isbell F, et al. (2016) The links between biodiversity and ecosystem services. In: Potschin M, Haines-Young R, Fish R, Turner RK (eds) Routledge Handbook of Ecosystem Services, 1st Edition. Routledge, New York, NY, pp 45–61
2. Grizzetti B, Liquete C, Pistocchi A, Vigiak O, Zulian G, Bouraoui F, et al. (2019) Relationship between ecological condition and ecosystem services in European rivers, lakes and coastal waters. Sci Total Environ 671:452–465
3. Maes J, Teller A, Erhad M, Grizzetti B, Barredo JI, Paracchini ML, et al. (2018) Mapping and assessment of ecosystems and their services: an analytical framework for ecosystem condition. Publications Office of the European Union, Luxembourg
4. Ziv G, Mullin K, Boeuf B, Fincham W, Taylor N, Villalobos-Jiménez G, et al. (2016) Water quality is a poor predictor of recreational hotspots in England. PLOS ONE 11:e0166950

22. How do the services and habitat provided by artificial Mediterranean wetlands differ from natural Mediterranean wetlands? Can they compensate for lost natural wetlands?

Comments: Across the Mediterranean, the surface area of natural wetlands is declining whilst the surface are of natural wetlands is increasing. How concerned should we be about this conversion? Is there scope to enhance the services and habitat provided by artificial wetlands, to mimic desirable features of natural wetlands? See also Issue 25.

Further reading

1. De Groot D, Stuip M, Finlayson M, Davidson N (2006) Valuing wetlands: guidance for valuing the benefits derived from wetland ecosystem services. Ramsar Convention Secretariat, Gland and Secretariat of the Convention on Biological Diversity, Montreal, Quebec
2. Fasola M, Ruiz X (1996) The value of rice fields as substitutes for natural wetlands for waterbirds in the Mediterranean region. Colon Waterbird 19:122–128
3. Sebastián-González E, Green AJ (2016) Reduction of avian diversity in created versus natural and restored wetlands. Ecography 39:1176–1184
4. Yang W, Chang J, Xu B, Peng C, Ge Y (2008) Ecosystem service value assessment for constructed wetlands: a case study in Hangzhou, China. Ecol Econ 68:116–125

23. How can Mediterranean wetlands contribute to societal adaptation to climate change?

Comments: Climate change adaptation is the process of adjustment to actual or expected climate change and its effects, including extreme weather events. This includes moderating or avoiding harm to human systems, and exploiting beneficial opportunities for human systems. Understanding the potential for Mediterranean wetlands to contribute to climate change adaptation could strengthen arguments for their protection, restoration or creation. It would also inform practical action to utilise this potential.

Further reading

1. Dubreuil C, Dutreix N (2017) Mediterranean wetlands: an economic valuation of their services to climate change adaptation and regulation. Plan Bleu Notes #33. Plan Bleu, Sophia Antipolis
2. IPCC (2013) Annex II: glossary. In: Stocker TF, Qin D, Plattner G-K, Tignor M, Allen SK, Boschung J., et al. (eds) Climate change 2013: the physical science basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge and New York
3. IUCN French Committee (2019) Nature-based solutions for climate change adaptation & disaster risk reduction. International Union for Conservation of Nature, Paris

24. What is the role of Mediterranean wetlands in the carbon cycle? How might they be used in climate change mitigation?

Comments: Climate change mitigation refers to human interventions that reduce the sources or enhance the sinks of greenhouse gases. Mediterranean wetlands may be both a source and a sink of greenhouse gases. The balance between these options is strongly related to wetland type, but may be affected by management decisions. Understanding the potential for Mediterranean wetlands to contribute to climate change mitigation could strengthen arguments for their protection, restoration or creation. It would also inform practical action to utilise this potential.

Further reading

1. IPCC (2013) Annex II: glossary. In: Stocker TF, Qin D, Plattner G-K, Tignor M, Allen SK, Boschung J., et al. (eds) Climate change 2013: the physical science basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge and New York
2. Meijide A, Gruening C, Goded I, Seufert G, Cescatti A (2017) Water management reduces greenhouse gas emissions in a Mediterranean rice paddy field. Agr Ecosyst Environ 238:168–178
3. Moomaw WR, Chmura GL, Davies GT, Finlayson CM, Middleton BA, Natali SM, et al. (2018) Wetlands in a changing climate: science, policy and management. Wetlands 38:183–205
4. Morris EP, Flecha S, Figuerola J, Costas E, Navarro G, Ruiz J, et al. (2013) Contribution of Doñana wetlands to carbon sequestration. PLOS ONE 8:e71456
5. Plan Bleu (2016) Economic assessment of ecosystem services provided by Mediterranean wetlands in terms of climate regulation. Plan Bleu, Valbonne

25. What is the relationship between Mediterranean wetlands and human health? How do human health effects of Mediterranean wetlands align with, or trade off with, other ecosystem services?

Comments: An evaluation of human health benefits (e.g. provision of clean water, open natural spaces for recreation) and problems (e.g. mosquito-borne diseases, antimicrobial resistance) would inform management that maintains a desirable balance between the two. See also Issue 33 and Issue 34.

Further reading

1. Dale PER, Connelly R (2012) Wetlands and human health: an overview. Wetlands Ecol Manag 20:165–171
2. Horwitz P, Finlayson CM (2011) Wetlands as settings for human health: incorporating ecosystem services and health impact assessment into water resource management. BioScience 61:678–688
3. Horwitz P, Finlayson CM, Weinstein P (2012) Healthy wetlands, healthy people: a review of wetlands and human health interactions. Ramsar Technical Report No. 6. Ramsar Convention Secretariat, Gland and The World Health Organization, Geneva
4. Vittecoq M, Godreuil S, Prugnolle F, Durand P, Brazier L, Renaud N, et al. (2016) Antimicrobial resistance in wildlife. J Appl Ecol 53:519–529

Socioeconomics

26. What land use and land management conflicts will emerge in the Mediterranean over the next 30 years? How can they be addressed?

Comments: For example, conflicts might emerge between wetlands and urban areas, especially as sea level rise forces coastal wetlands inland. There might also be conflicts between different stakeholder groups or conservation goals within wetlands. Answers will involve a more detailed analysis of specific conflicts and for specific areas than we have provided in our list of issues. Answers will help us to anticipate conflicts and manage them proactively.

Further reading

1. Malek Ž, Verburg PH, Geijzendorffer IR, Bondeau A, Cramer W (2018) Global change effects on land management in the Mediterranean region. Glob Env Change 50:238–254

2. Martín-Cantarino C (2010) Environmental conflicts and conflict management: some lessons from the WADI Experience at El Hondo Nature Park (South-Eastern Spain). In: Scapini F, Ciampi G (eds) Coastal water bodies. Springer Netherlands, Dordrecht, pp 61–77
3. MWO (2018) Mediterranean Wetlands Outlook 2: solutions for sustainable Mediterranean wetlands. Mediterranean Wetlands Observatory, Arles

27. How can we balance human development and conservation of Mediterranean wetlands?

Comments: Answers may consider how to balance these needs within policy (e.g. ensuring wetlands are better considered in land use planning) and/or in practice (e.g. practical measures for incorporating wetlands within urban development, or mitigating the impacts of urbanisation on wetlands). Could be answered with a collection of case studies from the Mediterranean or analogous regions/countries/wetlands.

Further reading

1. Bennett NJ, Cisneros-Montemayor AM, Blythe J, Silver JJ, Singh G, Andrews N, et al. (2019) Towards a sustainable and equitable blue economy. Nat Sustain 2:991–993
2. Grimm NB, Grove JM, Pickett STA, Redman CL (2000) Integrated approaches to long-term studies of urban ecological systems. BioScience 50:571–584
3. Ramsar Convention on Wetlands (2018) Wetlands and the SDGs: scaling up wetland conservation, wise use and restoration to achieve the Sustainable Development Goals. Ramsar Convention Secretariat, Gland
4. Sebastiá-Frasquet M-T, Altur V, Sanchis J-A (2014) Wetland planning: current problems and environmental management proposals at supra-municipal scale (Spanish Mediterranean coast). Water 6:620–641
5. WWT Consulting (2018) Good practices handbook for integrating urban development and wetland conservation. Wildfowl and Wetlands Trust, Slimbridge

28. How can the private sector be engaged in the conservation of Mediterranean wetlands?

Comments: There is a need to identify opportunities for engagement of business and industry in wetland conservation to mutual benefit, and to understand how achieve this (i.e. what framings, incentives or policies effectively engage the private sector).

Further reading

1. Bishop J (2012) The economics of ecosystems and biodiversity in business and enterprise. Earthscan, Oxford
2. Braye N (2017) Les partenariats publics privés pour la gestion des aires protégées: etat des lieux du cadre juridique des PPP pour la gestion des aires protégées dans le Sud et l'Est de la Méditerranée. Plan Bleu, Valbonne
3. Perrot-Maître D (2006) The Vittel payments for ecosystem services: a "perfect" PES case? International Institute for Environment and Development, London
4. Ramsar Convention Secretariat (2010) Partnerships: key partnerships for implementation of the Ramsar Convention. Ramsar Handbooks for the Wise Use of Wetlands, 4th edition, Vol. 5. Ramsar Convention Secretariat, Gland
5. WWF France (2020) Fondation Coca-Cola – restaurer des zones humides et lutter contre les rejets plastiques. https://www.wwf.fr/qui-sommes-nous/entreprises-partenaires/fondation-coca-cola. Accessed 29 May 2020

29. What is the net economic value of Mediterranean wetlands and the services they provide? How is this accounted for in public accounts?

Comments: Answers may consider the value of Mediterranean wetlands to local people, entire countries, the region or the world. The scale of analysis could range from individual wetlands to all Mediterranean wetlands. Answering this question could help to conserve Mediterranean wetlands, by ensuring their values are included in balance sheets.

Further reading

1. De Groot D, Stuip M, Finlayson M, Davidson N (2006) Valuing wetlands: guidance for valuing the benefits derived from wetland ecosystem services. Ramsar Convention Secretariat, Gland and Secretariat of the Convention on Biological Diversity, Montreal, Quebec

2. Maes J, Teller A, Erhad M, Grizzetti B, Barredo JI, Paracchini ML, et al. (2018) Mapping and assessment of ecosystems and their services: an analytical framework for ecosystem condition. Publications Office of the European Union, Luxembourg
3. Plan Bleu (2016) Economic assessment of ecosystem services provided by Mediterranean wetlands in terms of climate regulation. Plan Bleu, Valbonne
4. Ramsar Convention on Wetlands (2018) Wetlands and the SDGs: scaling up wetland conservation, wise use and restoration to achieve the Sustainable Development Goals. Ramsar Convention Secretariat, Gland
5. Salles J-M (2011) Valuing biodiversity and ecosystem services: why put economic values on Nature? C R Biol 334:469–482

30. What is the net cost/benefit of conserving Mediterranean wetlands?

Comments: Perhaps assessed economically, or through another method that captures the non-monetisable values of wetlands. May involve a comparison of different conservation options, e.g. protection vs restoration vs creation. Analyses at the Mediterranean scale or for specific wetlands would likely strengthen arguments for wetland conservation.

Further reading

1. De Groot RS, Blignaut J, Van Der Ploeg S, Aronson J, Elmqvist T, Farley J (2013) Benefits of investing in ecosystem restoration. Conservation Biology 27:1286–1293
2. Feuillette S, Levrel H, Boeuf B, Blanquart S, Gorin O, Monaco G, et al. (2016) The use of cost–benefit analysis in environmental policies: some issues raised by the Water Framework Directive implementation in France. Environ Sci Policy 57:79–85
3. Logar I, Brouwer R, Paillex A (2019) Do the societal benefits of river restoration outweigh their costs? A cost-benefit analysis. J Environ Manag 232:1075–1085
4. Naidoo R, Ricketts TH (2006) Mapping the economic costs and benefits of conservation. PLOS Biol 4:e360
5. Prato T, Hey D (2006) Economic analysis of wetland restoration along the Illinois River. J Am Water Resour Assoc 7:125–131

31. How are Mediterranean wetlands perceived by society? How have these perceptions changed/how are they changing?

Comments: Perceptions of wetlands are likely to differ across the Mediterranean as a result of varying political, economic and cultural doctrines. Understanding regional and local perceptions would aid the design and implementation of conservation policies, and tailored framing of conservation messages. Potential to consider the role of social media and 'fake news' in changing perceptions. Possible sources of data include news articles, social media, and popular media such as films and books. Direct surveys/questionnaires could also be useful.

Further reading

1. Bennett NJ (2016) Using perceptions as evidence to improve conservation and environmental management: perceptions and conservation. Conserv Biol 30:582–592
2. Bouahim S, Rhazi L, Ernoul L, Mathevet R, Amami B, Er-Riyahi S, et al. (2015) Combining vulnerability analysis and perceptions of ecosystem services in sensitive landscapes: a case from western Moroccan temporary wetlands. J Nat Conserv 27:1–9
3. Jarić I, Roll U, Arlinghaus R, Belmaker J, Chen Y, China V, et al. (2020) Expanding conservation culturomics and iEcology from terrestrial to aquatic realms. PLOS Biol 18:e3000935
4. Ladle R, Correia RA, Do Y, Joo G-J, Malhado ACM, Proulx R, et al. (2016) Conservation culturomics. Front Ecol Environ 14:269–275

32. What strategies are effective for (a) increasing public understanding of the importance of Mediterranean wetlands, and (b) changing public behaviour to have less impact on Mediterranean wetlands?

Comments: Answers might compare different ways of framing messages, or different communication media, for example. Should messages focus on biodiversity and intrinsic values of wetlands, or ecosystem services and economic benefits? Regarding behavioural changes, this question focuses on those that might directly

benefit Mediterranean wetlands (e.g. reduced water use and proper waste disposal) rather than more general environmentally friendly actions (e.g. to reduce an individual's carbon footprint). Be aware that increasing understanding or awareness of wetlands might not always lead to desirable behaviour change – and could even lead to undesirable change.

Further reading

1. Koop SHA, Van Dorssen AJ, Brouwer S (2019) Enhancing domestic water conservation behaviour: a review of empirical studies on influencing tactics. Journal of Environmental Management 247:867–876
2. Michie S, van Stralen MM, West R (2011) The behaviour change wheel: a new method for characterising and designing behaviour change interventions. Implement Sci 6:42
3. Osman M, McLachlan S, Fenton N, Neil M, Löfstedt R, Meder B (2020) Learning from behavioural changes that fail. Trends Cogn Sci 24:969–980
4. Varner J (2014) Scientific outreach: toward effective public engagement with biological science. BioScience 64:333–340
5. Watkins E, Schweitzer J-P, Leinala E, Börkey P (2019) Policy approaches to incentivise sustainable plastic design. Environment working paper N°149. Organisation for Economic Co-operation and Development, Paris

Governance

33. How do governance settings affect wetland management and conservation in the Mediterranean?

Comments: Governance is about "who decides and how" within a country or region. Continued research into evolving governance structures and their relationship with wetland conservation would be useful, given that effective governance is likely fundamental to successful wetland conservation. In particular, what are the key components of governance (e.g. corruption, bureaucracy, departmental organisation) that hinder or benefit wetland conservation within the Mediterranean? See also Issue 22.

Further reading

1. Amano T, Székely T, Sandel B, Nagy S, Mundkur T, Langendoen T, et al. (2018) Successful conservation of global waterbird populations depends on effective governance. Nature 553:199–202
2. CEPF (2017) Ecosystem Profile: Mediterranean Basin Biodiversity Hotspot. Critical Ecosystem Partnership Fund, Arlington, VA
3. Mansourian S (2012) Natural resource governance in North Africa: challenges and opportunities. IUCN Social Policy and IUCN Mediterranean Programme
4. Swiderska K, Roe D, Siegele L, Grieg-Gran M (2008) The governance of nature and the nature of governance: policy that works for biodiversity and livelihoods. International Institute for Environment and Development, London

34. How can we improve the efficacy of the science-policy interface related to Mediterranean wetlands?

Comments: There is a widely-recognised gap between science and policy, whereby policy is not based on scientific research because it is inaccessible, irrelevant, or poorly communicated, and researchers are not tackling questions of interest to policymakers. Answers to this question might identify key problems and possible solutions in the context of Mediterranean wetlands, from experience with other ecosystems in the Mediterranean or wetlands elsewhere in the world.

Further reading

1. Arlettaz R, Schaub M, Fournier J, Reichlin TS, Sierro A, Watson JEM, et al. (2010) From publications to public actions: when conservation biologists bridge the gap between research and implementation. BioScience 60:835–842
2. Futhazar G, Lafitte A, Sauzade D, Le Tellier J (2018) Science-policy interfaces for environmental governance in the Mediterranean. Plan Bleu Notes #35. Plan Bleu, Sophia Antipolis
3. Rose DC, Sutherland WJ, Amano T, González-Varo JP, Robertson RJ, Simmons BI, et al. (2018) The major barriers to evidence-informed conservation policy and possible solutions. Conserv Lett 11:e12564
4. Toomey AH, Knight AT, Barlow J (2017) Navigating the space between research and implementation in conservation: research-implementation spaces. Conserv Lett 10:619–625

35. What are effective framings for ensuring Mediterranean wetlands are incorporated into policy decisions?

Comments: The way in which scientific information is communicated to policy-makers can greatly affect their receptiveness to it. Subtle changes in language, tone or information can be important. What works when discussing wetland conservation with policy-makers? Perhaps there are lessons to be shared within the Mediterranean, or to be learned from other countries outside the region.

Further reading

1. Burgman MA (2016) Testing judgements: how to get the best out of experts. Cambridge University Press, Cambridge
2. Scienseed (2016) Communicating climate change and biodiversity to policy makers. Scienseed, Madrid
3. Wilhelm-Rechmann A, Cowling RM (2011) Framing biodiversity conservation for decision makers: insights from four South African municipalities. Conserv Lett 4:73–80

Management and monitoring

36. How can we help Mediterranean wetlands cope with climate change?

Comments: This question could be studied from a policy perspective and/or with a focus on individual management interventions (e.g. manipulating hydrology or translocating species). What stressors could be managed to maintain a 'safe operating space' for Mediterranean wetlands? Which interventions are the most effective and efficient? Which interventions are feasible?

Further reading

1. Fenu G, Bacchetta G, Charalambos SC, Fournaraki C, Giusso del Galdo GP, Gotsiou P, et al. (2019) An early evaluation of translocation actions for endangered plant species on Mediterranean islands. Plant Divers 41:94–104
2. Green AJ, Alcorlo P, Peeters ET, Morris EP, Espinar JL, Bravo-Utrera MA, et al. (2017) Creating a safe operating space for wetlands in a changing climate. Front Ecol Environ 15:99–107
3. MedWet (2020) Briefing note: environmental water requirements of wetlands and their importance for river basin management in the Mediterranean, including the effects of climate change on natural water flow. Medwet, Arles
4. Moomaw WR, Chmura GL, Davies GT, Finlayson CM, Middleton BA, Natali SM, et al. (2018) Wetlands In a changing climate: science, policy and management. Wetlands 38:183–205
5. Ramírez F, Coll M, Navarro J, Bustamante J, Green AJ (2018) Spatial congruence between multiple stressors in the Mediterranean Sea may reduce its resilience to climate impacts. Sci Rep 8:14871

37. How can we manage sources of pollution to Mediterranean wetlands?

Comments: Including agricultural chemicals [Issue 2], plastics [Issue 9] and emerging domestic and medical pollutants [Issue 28]. This question focuses on preventing pollutants from reaching Mediterranean wetlands, for example through legislation and policy [cf. Question 47], education and communication [cf. Question 45], or modifications to water treatment infrastructure.

Further reading

1. Fletcher J, Willby N, Oliver DM, Quilliam RS (2020) Phytoremediation using aquatic plants. In: Shmaefsky B (ed) Phytoremediation. Concepts and strategies in plant sciences. Springer, Cham, pp 205–260
2. Guittonny-Philippe A, Masotti V, Höhener P, Boudenne J-L, Viglione J, Laffont-Schwob I (2014) Constructed wetlands to reduce metal pollution from industrial catchments in aquatic Mediterranean ecosystems: a review to overcome obstacles and suggest potential solutions. Environ Int 64:1–16
3. Koundouri P, Papadaki L, Guittard A, Demian E, Akinsete E (2020) Tackling single-use-plastic products in the Eastern Mediterranean Sea: the BL.EU Climate and MedFreeSup projects. DEOS Working Papers 20-24, Athens University of Economics and Business
4. Ripa MN, Leone A, Garnier M, Porto AL (2006) Agricultural land use and best management practices to control nonpoint water pollution. Environ Manag 38:253–266

38. How can we effectively and efficiently clean up polluted Mediterranean wetlands?

Comments: This question considers techniques for the restoration and rehabilitation of wetlands that have already been polluted. Answers might review existing techniques, or outline new or improved techniques. They might consider remediation of pollutants already present in wetlands from historical activities, or pollutants likely to accumulate in wetlands in the near future: nutrients (see Issue 2 and Issue 9), plastics (see Issue 8) and other solid waste (see Issue 29), and household/medical chemicals (see Issue 28).

Further reading

1. Fletcher J, Willby N, Oliver DM, Quilliam RS (2020) Phytoremediation using aquatic plants. In: Shmaefsky B (ed) Phytoremediation. Concepts and strategies in plant sciences. Springer, Cham, pp 205–260
2. Kordella S, Geraga M, Papatheodorou G, Fakiris E, Mitropoulou IM (2013) Litter composition and source contribution for 80 beaches in Greece, eastern Mediterranean: a nationwide voluntary clean-up campaign. Aquat Ecosyst Health Manag 16:111–118
3. Michel J, Rutherford N (2013) Oil spills in marshes: planning & response considerations. National Oceanic and Atmospheric Administration & American Petroleum Institute
4. Rodrigo MA, Martín M, Rojo C, Gargallo S, Segura M, Oliver N (2013) The role of eutrophication reduction of two small man-made Mediterranean lagoons in the context of a broader remediation system: effects on water quality and plankton contribution. Ecol Eng 61:371–382

39. What are the minimum inputs of water needed to maintain major Mediterranean wetlands? How will their water balance be affected by climate change?

Comments: Mediterranean wetlands receive water inputs from surface water (e.g. rivers), groundwater, precipitation and – for coastal wetlands – the sea. Insufficient water inputs will cause degradation or loss of Mediterranean wetlands. Understanding how inputs might be affected by climate change could inform management to avoid these impacts. Note that water quantity and quality are often tightly linked; for example, reduced water inputs are often associated with increased salinity and concentrations of pollutants.

Further reading

1. Coppens J, Trolle D, Jeppesen E, Beklioğlu M (2020) The impact of climate change on a Mediterranean shallow lake: insights based on catchment and lake modelling. Reg Environ Change 20:62
2. Green AJ, Alcorlo P, Peeters ET, Morris EP, Espinar JL, Bravo-Utrera MA, et al. (2017) Creating a safe operating space for wetlands in a changing climate. Front Ecol Environ 15:99–107
3. Lefebvre G, Redmond L, Germain C, Palazzi E, Terzago S, Willm L, et al. (2019) Predicting the vulnerability of seasonally-flooded wetlands to climate change across the Mediterranean Basin. Sci Total Environ 692:546–555
4. Vassilis S (2008) Characterisation of Mediterranean wetlands' water requirements. AgroParisTech, Montpellier

40. How effective are Ramsar sites in the Mediterranean? Are there any lessons to be learned from the most and least successful sites?

Comments: Effectiveness may be judged against the overall aim of the Ramsar Convention (to halt the loss of wetlands), or specific aims of individual sites. Assessments could be focused on wetland condition, individual taxa, or socioeconomic indicators. Robust studies are desirable, ideally with a before-after-control-impact design and quantification of effects.

Further reading

1. Castro G, Chomitz K, Thomas TS (2002) The Ramsar Convention: measuring its effectiveness for conserving wetlands of international importance. Independent report prepared for 8th Meeting of the Conference of the Contracting Parties to the Convention on Wetlands, Valencia, 18–26 November 2002
2. Gaget E, Le Viol I, Pavón-Jordán D, Cazalis V, Kerbiriou C, Jiguet F, et al. (2020) Assessing the effectiveness of the Ramsar Convention in preserving wintering waterbirds in the Mediterranean. Biol Conserv 243:108485
3. Hettiarachchi M, Morrison TH, McAlpine C (2015) Forty-three years of Ramsar and urban wetlands. Glob Env Change 32:57–66
4. Hockings M, Stolton S, Leverington F, Dudley N, Courrau J (2006) Evaluating effectiveness: a framework for assessing management effectiveness of protected areas. 2nd edition. IUCN, Gland and Cambridge
5. Kleijn D, Cherkaoui I, Goedhart PW, van der Hout J, Lammertsma D (2014) Waterbirds increase more rapidly in Ramsar-designated wetlands than in unprotected wetlands. J Appl Ecol 51:289–298

41. How should we manage protected areas involving Mediterranean wetlands, including the Ramsar network, in the face of climate change?

Comments: Answers to this question might involve modelling future scenarios, then adjusting protected area boundaries or altering management to allow adaptation or migration of Mediterranean wetlands, biodiversity and people. Bear in mind that activities *outside* protected areas (e.g. water abstraction, prescribed burning, forestry) might also require management if they affect protected habitats.

Further reading

1. D'Aloia CC, Naujokaitis-Lewis I, Blackford C, Chu C, Curtis JMR, Darling E, et al. (2019) Coupled networks of permanent protected areas and dynamic conservation areas for biodiversity conservation under climate change. Front Ecol Evol 7:27
2. Hijmans RJ, Graham CH (2006) The ability of climate envelope models to predict the effect of climate change on species distributions. Glob Change Biol 12:2272–2281
3. Pavón-Jordán D, Abdou W, Azafzaf H, Balaž M, Bino T, Borg JJ, et al. (2020) Positive impacts of important bird and biodiversity areas on wintering waterbirds under changing temperatures throughout Europe and North Africa. Biol Conserv 246:108549
4. Rannow S, Macgregor NA, Albrecht J, Crick HQP, Förster M, Heiland S, et al. (2014) Managing protected areas under climate change: challenges and priorities. Environ Manag 54:732–743

42. How effective are different conservation scenarios in protecting Mediterranean wetlands and their biodiversity? How, and why, might future approaches to conservation differ across the Mediterranean?

Comments: Answers could involve comparisons of existing and potential future scenarios. They may also consider local variations in optimal scenarios, ideally within a Mediterranean-wide conservation strategy. Effectiveness may be judged against the overall aim of the Ramsar Convention (to halt the loss of wetlands), or specific aims of individual sites.

Further reading

1. Levin N, Watson JEM, Joseph LN, Grantham HS, Hadar L, Apel N, et al. (2013) A framework for systematic conservation planning and management of Mediterranean landscapes. Biol Conserv 158:371–383
2. Margules CR, Pressey RL (2000) Systematic conservation planning. Nature 405:243–253
3. Peterson GD, Cumming GS, Carpenter SR (2003) Scenario planning: a tool for conservation in an uncertain world. Conserv Biol 17:358–366
4. Regos A, D'Amen M, Titeux N, Herrando S, Guisan A, Brotons L (2016) Predicting the future effectiveness of protected areas for bird conservation in Mediterranean ecosystems under climate change and novel fire regime scenarios. Diversity Distrib 22:83–96

43. What are the services provided by Mediterranean wetlands under different management scenarios? What are the trade-offs when managing Mediterranean wetlands for different services?

Comments: Ecosystem services are the benefits that people derive from ecosystems: from provisioning of food and building materials, to flood control, carbon storage and cultural heritage. Trade-offs between ecosystem services are common, although conscious planning for win-win scenarios is possible.

Further reading

1. Cohen-Shacham E, Dayan T, Feitelson E, de Groot RS (2011) Ecosystem service trade-offs in wetland management: drainage and rehabilitation of the Hula, Israel. Hydrol Sci J 56:1582–1601
2. Horwitz P, Finlayson CM (2011) Wetlands as settings for human health: incorporating ecosystem services and health impact assessment into water resource management. BioScience 61:678–688
3. Howe C, Suich H, Vira B, Mace GM (2014) Creating win-wins from trade-offs? Ecosystem services for human well-being: a meta-analysis of ecosystem service trade-offs and synergies in the real world. Glob Env Change 28:263–275
4. Martinez-Harms MJ, Bryan BA, Balvanera P, Law EA, Rhodes JR, Possingham HP, et al. (2015) Making decisions for managing ecosystem services. Biol Conserv 184:229–238
5. UNESCO (2019) Management and protection of Mediterranean groundwater-related coastal wetlands and their services. United Nations Educational, Scientific and Cultural Organization, Paris

44. How can we mitigate disservices of Mediterranean wetlands but with minimal environmental damage?

Comments: Ecosystem disservices are features of ecosystems that are perceived as harmful, unpleasant or unwanted. In Mediterranean wetlands, this includes features such as algal blooms [Issue 15], antimicrobial resistant organisms [Issue 32] and mosquitoes [Issue 33 & Issue 34]. What measures can we take to minimise these disservices and thus reduce the incentive to destroy wetlands, without damaging wetlands in the process? In some cases, there may be synergies in which management of disservices improves overall wetland health and service provision. Answers to this question might involve reviews of current technologies, perhaps focusing on the Mediterranean context, or development of completely novel approaches.

Further reading

1. Knight J, Dale P, Dwyer P, Marx S (2017) A conceptual approach to integrate management of ecosystem service and disservice in coastal wetlands. AIMS Environ Sci 4:431–442
2. Poulin B, Lefebvre G, Muranyi-Kovacs C, Hilaire S (2017) Mosquito traps: an innovative, environmentally friendly technique to control mosquitoes. Int J Env Res Public Health 14:313
3. Shackleton CM, Ruwanza S, Sinasson Sanni GK, Bennett S, De Lacy P, Modipa R, et al. (2016) Unpacking Pandora's Box: understanding and categorising ecosystem disservices for environmental management and human wellbeing. Ecosystems 19:587–600

45. How can we effectively engage citizens (farmers, fishermen, hunters, the public, etc.) in management and monitoring of Mediterranean wetlands?

Comments: There are two aspects to this question: how to get citizens involved in wetland monitoring or management, and how to maximise the value of this involvement (e.g. ensuring data are collected in a robust manner, ensuring interventions are effective, taking advantage of opportunities to educate citizens). It is thought that community engagement in conservation benefits ecosystems and biodiversity, encourages sustainable use and reduces poverty.

Further reading

1. Cohen-Shacham E, Dayan T, de Groot R, Beltrame C, Guillet F, Feitelson E (2015) Using the ecosystem services concept to analyse stakeholder involvement in wetland management. Wetlands Ecol Manag 23:241–256
2. Ramsar Convention Secretariat (2010) Wetland CEPA: the Convention's programme on communication, education, participation and awareness (CEPA) 2009-2015. Ramsar Handbooks for the Wise Use of Wetlands, 4th edition, Vol. 6. Ramsar Convention Secretariat, Gland
3. Reed MS (2008) Stakeholder participation for environmental management: a literature review. Biol Conserv 141:2417–2431
4. TCV (2014) Engaging volunteers: guide to engaging volunteers in citizen science projects. The Conservation Volunteers, Stirling
5. Wiggins A, Newman G, Stevenson RD, Crowston K (2011) Mechanisms for data quality and validation in citizen science. In: Seventh International Conference on e-Science Workshops. IEEE, Stockholm, pp 14–19

46. Are existing large-scale conservation policies appropriate for the conservation of Mediterranean wetlands? If not, how might they be adapted for Mediterranean wetlands?

Comments: This question would analyse how global conservation policies (e.g. the Ramsar Convention on Wetlands; the Paris Agreement within the United Nations Framework Convention on Climate Change) and regional conservation policies (e.g. the Barcelona Convention, European Union or African Union policies) are related to conservation of Mediterranean wetlands. Does their generality mean wetlands or Mediterranean countries are forgotten, or poorly defined? How can shortcomings be mitigated: by adapting existing policies or creating new, local ones? Which articles within policies present opportunities to drive conservation of Mediterranean wetlands?

Further reading

1. Apostolaki S, Akinsete E, Tsani S, Koundouri P, Pittis N, Levantis E (2019) Assessing the effectiveness of the WFD as a tool to address different levels of water scarcity based on two case studies of the Mediterranean region. Water 11:840
2. Geijzendorffer IR, Beltrame C, Chazee L, Gaget E, Galewski T, Guelmami A, et al. (2019) A more effective Ramsar Convention for the conservation of Mediterranean wetlands. Front Ecol Evol 7:21
3. Lanovoy V (2017) Barcelona Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean and its Protocols. In: Faure M (ed) Elgar encyclopedia of environmental law. Edward Elgar Publishing Limited, Cheltenham, pp 204–214
4. MWO (2018) Mediterranean Wetlands Outlook 2: solutions for sustainable Mediterranean wetlands. Mediterranean Wetlands Observatory, Arles
5. Shine C, de Klemm C (1999) Wetlands, water and the law: using law to advance wetland conservation and wise use. IUCN Environmental Policy and Law Paper No. 38. IUCN, Gland, Cambridge and Bonn

47. How can principles from the EU's Water Framework Directive be used to benefit Mediterranean wetlands outside the EU?

Comments: The Water Framework Directive commits EU member states to good biological, chemical and hydromorphological status of water bodies, with a focus on catchment-scale management (considering the entirety of the watershed and connections between land and water, rather than treating them as separate entities). There may be lessons to be learned from existing application of WFD principles in non-EU countries, including Morocco and Israel.

Further reading

1. EU (2000) Council Directive 2000/60/EC of 23 October 2000 establishing a framework for community action in the field of water policy (Water Framework Directive). Official Journal of the European Communities L327/1
2. MWO (2018) Mediterranean Wetlands Outlook 2: solutions for sustainable Mediterranean wetlands. Mediterranean Wetlands Observatory, Arles
3. Sullivan CA, Finlayson CM, Heagney E, Pelletier M-C, Acreman MC, Hughes JMR (2018) Wetland landscapes and catchment management. In: Hughes JMR (ed) Freshwater ecology and conservation. Oxford University Press, Oxford, pp 404–422

48. What indicators can be used to monitor the condition and functioning of Mediterranean wetlands?

Comments: Includes (a) field-collected indicators such as hydrology, water chemistry, individual species, overall biodiversity, and human usage/perceptions of wetlands, plus (b) remotely-sensed indicators such as satellite monitoring of wetland extent, or GPS tracking of animal movements. The presence or condition of indicators should reveal something about the environment more generally. Answers could synthesise knowledge on existing indicators, validate and improve existing indicators, and/or develop new indicators – perhaps incorporating technological advances.

Further reading

1. Guareschi S, Abellán P, Laini A, Green AJ, Sánchez-Zapata JA, Velasco J, et al. (2015) Cross-taxon congruence in wetlands: assessing the value of waterbirds as surrogates of macroinvertebrate biodiversity in Mediterranean Ramsar sites. Ecol Indic 49:204–215
2. MWO (2018) Mediterranean Wetlands Outlook 2: solutions for sustainable Mediterranean wetlands. Mediterranean Wetlands Observatory, Arles
3. Paredes I, Ramírez F, Forero MG, Green AJ (2019) Stable isotopes in helophytes reflect anthropogenic nitrogen pollution in entry streams at the Doñana World Heritage Site. Ecol Indic 97:130–140
4. Sanchez A, Abdul Malak D, Guelmami A, Perennou C (2015) Development of an indicator to monitor Mediterranean wetlands. PLOS ONE 10:e0122694
5. Van den Broeck M, Waterkeyn A, Rhazi L, Grillas P, Brendonck L (2015) Assessing the ecological integrity of endorheic wetlands, with focus on Mediterranean temporary ponds. Ecol Indic 54:1–11

49. How will key stressors or drivers of change interact to affect Mediterranean wetlands and their biodiversity?

Comments: Stressors include climate change, water use, pollution, invasive species, human migration and land use change. Are their cumulative effects additive, antagonistic or synergistic? Do effects depend on the sequence of stressors, their relative timing and the delay between them? Answers to this question will help to guide mitigation strategies, informing decisions about which stressors to manage and when.

Further reading

1. Birk S, Chapman D, Carvalho L, Spears BM, Andersen HE, Argillier C, et al. (2020) Impacts of multiple stressors on freshwater biota across spatial scales and ecosystems. Nat Ecol Evol 4:1060–1068
2. Green AJ, Alcorlo P, Peeters ET, Morris EP, Espinar JL, Bravo-Utrera MA, et al. (2017) Creating a safe operating space for wetlands in a changing climate. Front Ecol Environ 15:99–107
3. Ramírez F, Coll M, Navarro J, Bustamante J, Green AJ (2018) Spatial congruence between multiple stressors in the Mediterranean Sea may reduce its resilience to climate impacts. Sci Rep 8:14871
4. Segurado P, Almeida C, Neves R, Ferreira MT, Branco P (2018) Understanding multiple stressors in a Mediterranean basin: combined effects of land use, water scarcity and nutrient enrichment. Sci Total Environ 624:1221–1233
5. Smeti E, von Schiller D, Karaouzas I, Laschou S, Vardakas L, Sabater S, et al. (2019) Multiple stressor effects on biodiversity and ecosystem functioning in a Mediterranean temporary river. Sci Total Environ 647:1179–1187

50. What are possible scenarios for positive futures relating to Mediterranean wetlands? How do we achieve them?

Comments: This question encourages thinking about various possible futures for Mediterranean wetlands and creating structured accounts of these, whilst acknowledging uncertainties. Policy and practice needed to achieve desirable scenarios, or achieve undesirable scenarios, can then be mapped onto timelines. Diverse stakeholders should be engaged to incorporate varying perspectives on the meaning of "positive".

Further reading

1. Geijzendorffer IR, Beltrame C, Chazee L, Gaget E, Galewski T, Guelmami A, et al. (2019) A more effective Ramsar Convention for the conservation of Mediterranean wetlands. Front Ecol Evol 7:21
2. MWO (2018) Mediterranean Wetlands Outlook 2: solutions for sustainable Mediterranean wetlands. Mediterranean Wetlands Observatory, Arles
3. Peterson GD, Cumming GS, Carpenter SR (2003) Scenario planning: a tool for conservation in an uncertain world. Conserv Biol 17:358–366
4. Tickner D, Opperman JJ, Abell R, Acreman M, Arthington AH, Bunn SE, et al. (2020) Bending the curve of global freshwater biodiversity loss: an emergency recovery plan. BioScience 70:330–342
5. van Rees CB, Waylen KA, Schmidt-Kloiber A, Thackeray SJ, Kalinkat G, Martens K, et al. (2020) Safeguarding freshwater life beyond 2020: recommendations for the new global biodiversity framework from the European experience. Conserv Lett. 2020:e12771