Appendix 2

50 KEY ISSUES FOR 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*

This list is split into:

- **25 critical issues**, most likely to have a large impact on Mediterranean wetlands (high Likelihood × Impact score in our assessment, i.e. Novelty not taken into account. Size of impact incorporates both intensity and spatial extent).
- **25 overlooked issues**, likely to have a large impact on Mediterranean wetlands, but not currently well known amongst Mediterranean wetland stakeholders (high Likelihood × Impact × Novelty score in our assessment, once the critical issues had been removed).

"Mediterranean wetlands" includes all aspects of these systems, including the physical habitat, the ecology and living organisms, functions, services and cultural values (see Main Paper for full definition).

Supporting information defines and describes each issue, including past trends and likely future projections (supported with references, where possible). We also offer suggestions of how each issue presents a **threat** and/or **opportunity** for Mediterranean wetlands in the future. For issues that present threats, we do not list "avoid or mitigate this threat" as an opportunity: opportunities must arise from the issue itself. We caution that this supporting information is neither exhaustive nor systematically collated. Unreferenced statements reflect the best judgement of the assessment panel or participants in the original survey.

25 CRITICAL ISSUES

Agriculture and aquaculture

1. Expansion of agriculture

Supporting information: The area of irrigated agricultural land in the Mediterranean doubled between 1965 and 2005[1] and is projected to increase further in the future, albeit at a slower rate and not in all countries[1,2]. As a more specific example, the area of agricultural land in the catchments of several North African lagoons has increased in recent decades, with scope for further expansion[3]. Countries with a projected increase in agricultural land area between 2015 and 2030 include France, Spain, Greece, Malta and Croatia[4]. Balkan countries will be particularly reliant on agricultural expansion, rather than intensification, to increase future crop production[5] and meet the needs of a growing human population[6].

How does this issue pose a threat to Mediterranean wetlands? Direct conversion of wetlands to agriculture; this accounted for around 46% of the area of natural Mediterranean wetlands converted to other land uses between 1975 and 2005[1]. Specific examples include the Aveiro Estuary, Portugal, the Karavasta Lagoon, Albania and the Macta Marshes, Algeria[7]. Increased abstraction of water, leaving less available for wetlands [Issue 4]. Pollution of wetlands due to runoff of agricultural chemicals and soil[8]. Physical, chemical and biological land degradation, especially as a result of irrigated, mechanised arable agriculture and overgrazing[9,10].

How does this issue present an opportunity for Mediterranean wetlands? Wetlands can be incorporated into multifunctional agroecosystems[11]. Careful management can enhance the ecological value of wetland sites used for agriculture, e.g. rice fields (especially during the fallow season), seasonal marshes, and floodplains[12].

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2. Increasing use of synthetic chemicals in agriculture

Supporting information: Over the next 30 years, North Africa and Western Europe will be particularly reliant on intensification of agriculture to meet a growing demand for food[1]. Intensification usually involves greater inputs of chemicals such as fertilisers, herbicides, insecticides and antimicrobials[2]. Accordingly, pesticide use in France increased by 25% between 2008 and 2018[3]. Over the past 50 years, the global production and diversity of synthetic chemicals have increased at a rate far higher than other recognised agents of global change, such as population growth, atmospheric CO_2 concentrations and biodiversity loss[4]. However, it is possible that strengthening regulation on the use of synthetic chemicals may temper the future impact of this issue locally and/or in the long term [cf. Issue 26].

How does this issue pose a threat to Mediterranean wetlands? Pollution into adjacent wetlands[5–7], with negative impacts on biodiversity, water quality, and ecosystem functions and services[8–10]. Impacts may arise from the chemicals themselves or breakdown products, and may persist for many decades[4]. The collective impact of a cocktail of chemicals may differ from the impacts of each chemical in isolation[4].

How does this issue present an opportunity for Mediterranean wetlands? N/A

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3. Increasing aquacultural production

Supporting information: Aquaculture refers to the farming of aquatic organisms (e.g. fish, crustaceans, molluscs, plants) with regular intervention such as stocking, feeding or protection from predators[1]. By 2004, aquaculture production in the Mediterranean basin had grown to over 1.5 million tonnes.yr^{-1}, over half of which was in fresh and brackish waters[2]. This trend is likely to continue as the human population grows but catches of wild fish are limited by quotas and declining stocks[2] and terrestrial agriculture faces competition from other land uses [e.g. Issue 20]. Increased production may be driven by expansion and/or intensification[3]. Currently, Morocco is investing heavily in both inland and coastal aquaculture[4] and the European Union is supporting aquacultural expansion as a means for rural development in Albania[5]. This issue does not exclude the possibility of local abandonment of aquaculture facilities.

How does this issue pose a threat to Mediterranean wetlands? Expansion: conversion of natural wetland habitats; increased sphere of influence. Unsustainable intensification: pollution to neighbouring wetland habitats; microorganism blooms [Issue 15]; disruption of local food webs in/near stocked wetlands[6]; increased pressure on wild populations, if juveniles for stocking are harvested from the wild[7,8]. Aquaculture facilities can act as source populations of invasive species, which can escape and spread to adjacent natural habitats[6,9–12]. Conflicts between aquaculture and other interests (e.g. bird conservation, fishing, farming[7,13]).

How does this issue present an opportunity for Mediterranean wetlands? Could stimulate restoration/creation of wetlands, providing multiple ecosystem services (e.g. carbon storage, wildlife habitat) alongside aquacultural production[14]. Potential to increase economic value of existing wetlands. It is possible to improve productivity and economic returns, whilst minimising resource inputs and pollution to surrounding wetlands (e.g. nutrients and toxic additives in fish food[15]). For example, shellfish and seaweeds could be placed downstream of fish enclosures, invertebrates (e.g. lobsters or sea urchins) below and/or plants within[16]. Aquaculture may encourage interventions to improve water quality, in the interest of product quality and safety[17]. Stocking with appropriate species at appropriate times may itself improve water quality[18].

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Water and pollution

4. Increasing water abstraction

Supporting information: This issue includes abstraction from both ground and surface water sources. Under a business-as-usual scenario, total water withdrawals are expected to increase across most of the Mediterranean basin through 2050[1]. This will be driven largely by increases in the surface area of irrigated agricultural land [Issue 1], combined with warmer and drier conditions [Issue 10 & Issue 11]. In 2014, irrigated agriculture accounted for 66% of total water consumption in the Mediterranean region, and over 80% in countries such as Greece, Libya and Morocco[2]. Withdrawals are also forecast to increase for domestic, industrial and touristic use[1] – especially in countries with little planned desalination capacity (e.g. Tunisia) and in the eastern and southern Mediterranean where population growth will be most extreme[2].

How does this issue pose a threat to Mediterranean wetlands? Reduced water availability for wetlands near/downstream of abstraction zones: wetlands may experience drastically reduced hydroperiods or completely dry out (e.g. dune ponds in Doñana National Park, Spain[3]; Gerpotamou Basin, Crete, Greece[4]) or experience modifications to water chemistry (e.g. increased salinity[5] or pollutant concentrations[6]). Subsidence[7]. Runoff from irrigated land can also lead to unwanted inputs of fresh water to brackish or saline wetlands[8]. These physical changes will likely affect biodiversity and ecosystem functions[5].

How does this issue present an opportunity for Mediterranean wetlands? Increasing reliance on water abstraction could strengthen arguments to conserve wetlands and water resources. Provides a stimulus to increase water storage, including in artificial or restored wetlands [cf. Issue 5]. In some situations, macrophytes may benefit from reduced water levels in lakes or reservoirs[5].

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5. Accumulation of dams/reservoirs, built for water storage and/or energy production

Supporting information: The number of dams built in Mediterranean watersheds has increased rapidly over the past 70 years, to address increasing demand for water and energy[1] and sometimes to quell social and political tensions[2]. There are currently over 21,000 hydropower plants in Europe, and over 8,700 are planned or in construction – with especially high concentrations in the Balkans and the Alps[3]. Many of these are small projects, driven by financial incentives, which have a small individual impact but a large cumulative impact on downstream systems[4,5]. There is also extensive dam construction, both ongoing and planned, in Turkey[6,7].

How does this issue pose a threat to Mediterranean wetlands? Flooding of existing wetlands upstream of dam. Altered flow and flooding regimes downstream of dam, leading to: water and sediment scarcity[8,9]; increased salinity[10]; shrinking or loss of wetlands (e.g. the closed-basin Burdur Lake, Turkey[11] and early-successional, disturbance-dependent riparian wetlands[12]). Dam is a barrier to movement of aquatic animals, e.g. preventing fish from reaching upstream spawning grounds[13]. Reservoirs may favour invasive alien species, promoting homogenisation of biodiversity within river basins[14] or across the Mediterranean.

How does this issue present an opportunity for Mediterranean wetlands? A reservoir is a large, new, permanent wetland, which may create a novel habitat for wetland species[15] (although these may be invasive aliens[14]), a suitable site for aquaculture[16], and recreational opportunities (e.g. birdwatching in Arrocampo Ornithological Park, Spain and boat tours on Komani Lake, Albania). Dams may allow management of flow and flooding regimes to maintain downstream wetlands, and the services they provide, in the face of threats such as climate change[17].

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6. Increasing agricultural water use efficiency

Supporting information: In 2014, irrigated agriculture accounted for 66% of total water consumption in the Mediterranean region, and over 80% in countries such as Greece, Libya and Morocco[1]. Most irrigation water losses in the Mediterranean are related to inefficient water transport infrastructure[2]. In the south and east Mediterranean, most irrigation systems are not equipped with water-saving technologies[1]. The water use efficiency of irrigated crop production could be improved by, *inter alia*: using pipes and drip feeds rather than sprays and sprinklers; irrigating at night rather than during the day; using more water-efficient crops or varieties; increasing taxes on water use; or installing smart systems with continual monitoring and real-time adjustments to water supply[3]. Mediterranean governments are already beginning to subsidise some of these more efficient irrigation methods[4].

How does this issue pose a threat to Mediterranean wetlands? Improvements may not be sufficient to cope with increased crop water demand due to climate change, and increased production needs for a larger human population[5]. So, there may still be net increase in water abstraction for agriculture [Issue 4]. Increases in efficiency could mask this from the public and political conscious.

How does this issue present an opportunity for Mediterranean wetlands? Could lead to reduced abstraction of water from wetlands and aquifers [cf. Issue 4] – meaning there is more, and better quality, water available for wetlands[6]. Reduced abstraction could compensate for climate change impacts [Issue 10 & Issue 11], maintaining wetlands in a safe operating space[7].

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7. Salinisation of freshwater wetlands

Supporting information: Increased salinity in wetlands can be linked to water abstraction[1] [Issue 4], low river flows [Issue 5], climatic changes [Issue 10 & Issue 11], dust storms [Issue 30], mass clearance of deep-rooted perennial vegetation (which reduces evapotranspiration and causes water tables to rise, leading to concentration of salts near the ground surface[2]) and irrigation (causing water tables to rise, mobilising salts if irrigation water drains through saline sediments[3], adding salts if irrigation water is brackish/saline, or concentrating salts if irrigation water is recycled[2]). In coastal wetlands, storm surges [Issue 12] and sea level rise [Issue 13] are additional drivers of salinisation. Observed cases include the Jordan River in Israel[3], the Revano River in Italy[2], Tablas de Daimiel National Park in Spain[2], and the Axios Delta in Greece[2].

How does this issue pose a threat to Mediterranean wetlands? Altered biogeochemical functions and nutrient cycling, including decreased inorganic nitrogen removal and decreased carbon storage[2]. Reduced habitat suitability for freshwater organisms[2]. Shifts in community composition, with reduced richness and/or biomass of zooplankton, macroinvertebrates and aquatic plants[4–6]. May cause, or contribute to, collapse of fisheries[7].

How does this issue present an opportunity for Mediterranean wetlands? Increased habitat suitability for salt-tolerant organisms, and groups such as small wading birds[8].

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8. Plastic pollution

Supporting information: Globally, the generation of plastic waste is expected to increase approximately five-fold between 2010 and 2050[1]. Assuming waste management trends also continue, roughly 12 Gt of plastic waste will be in the natural environment or landfills by 2050[1]. Wetlands are a natural sink for plastic waste carried by rivers, waves and currents[2], as well as being sites for direct dumping. High population densities, poor waste management schemes, tourism and transport all contribute to plastic pollution in the Mediterranean region[3]. Egypt, Turkey and Italy alone are responsible for two thirds of plastic leakage into nature in the Mediterranean Sea[4], with the River Nile being one of the top 10 rivers in the world for plastic load[5]. This issue includes (a) large plastics such as bags, bottles, fishing nets, face masks and gloves (the latter likely to be a particular problem following the COVID-19 pandemic[6,7]) and (b) microplastics: synthetic polymers ≤5 mm long[8], created when large plastics break down, when laundering synthetic clothes and when tyres wear. Most research into microplastics has been carried out in marine environments, but there is growing evidence of presence and impacts in inland wetlands[9].

How does this issue pose a threat to Mediterranean wetlands? Large plastics: direct impacts on wetland animals, such as entanglement and suffocation. Microplastics: negative impacts on biodiversity (e.g. mortality through ingestion, reproductive disruption, toxicity of chemicals in plastics or adsorbed pollutants[9,10]). Bioaccumulative effects on higher trophic levels, including humans[11,12].

How does this issue present an opportunity for Mediterranean wetlands? Plastic pollution is a visible, tangible, high-profile issue. So, it may provide an opportunity for the public to engage in Mediterranean wetland conservation, interact with wetlands and learn about them.

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9. Poor wastewater treatment infrastructure, especially in urban areas

Supporting information: This issue is primarily concerned with domestic and industrial pollution, including raw sewage, untreated wastewater and stormwater runoff[1] (diffuse pollution from agriculture is considered within Issue 2). In the Mediterranean, wastewater treatment plants (WWTPs) are often lacking or substandard: across the region, 37% of large coastal settlements (> 2,000 inhabitants) do not operate a WWTP[2]; in Albania, operational wastewater treatment plants serve only around 13% of the population[3]; in the European Union, many wastewater treatment plants fail to meet regulatory standards[4]. WWTPs may be chronically overwhelmed by urban growth (e.g. in Nador, Morocco[5]), seasonally overwhelmed by an influx of summer tourists (e.g. Marsa Matrouh Lagoon, Egypt[5]), or temporarily overwhelmed by extreme rainfall events [Issue 12]. Discharge of untreated or poorly treated wastewater is a particularly important problem in the Mediterranean, due to (a) high population densities and human activity; (b) hot, dry summers during which natural water sources do not dilute wastewater inputs; and (c) low water renewal in many coastal lagoons and associated wetlands[6]. There is ongoing investment in improving WWTPs, which may ease this problem[3,7] – but only gradually, and in conflict with urban growth [Issue 20] and climate change [Issue 11 & Issue 12].

How does this issue pose a threat to Mediterranean wetlands? Eutrophication[8,9]. Metal pollution[10–12]. Pollution with domestic and medical residues [Issue 28]. Negative impacts on biodiversity (including wildlife diseases[13,14]) and ecosystem services (e.g. safety of water for drinking or recreation, collapse of fisheries[15]).

How does this issue present an opportunity for Mediterranean wetlands? Addition of nutrient-rich sewage could enhance productivity in some naturally nutrient-poor locations[15,16]. Artificial wetlands could be constructed as a cost-effective water treatment solution; these may simultaneously provide wetland habitat[17].

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Physical environment and climate change

10. Increasing average and maximum temperatures

Supporting information: Mean summer and winter temperatures are projected to increase across the Mediterranean region between 2020 and 2050[1]. For example, in 2046–2065, much of the Mediterranean landmass will experience summer temperatures 2–3°C higher than in 1986–2005 (RCP4.5 low-moderate emissions scenario)[1].

How does this issue pose a threat to Mediterranean wetlands? Increased rates of evaporation from wetlands and evapotranspiration from catchments, with effects on the quantity and quality of water in wetlands[2,3]. Increased stress on wetland organisms – many of which are already at their physiological limits in hot Mediterranean summers[4] or will reach their physiological limits at mountain summits[5]. Increased photosynthetic rates could contribute to aquatic plant invasions [Issue 14] and cyanobacterial blooms [Issue 15]. Likely to promote human migration, especially to the cooler northern Mediterranean and coastal regions[6], intensifying human impacts on wetlands in these areas [e.g. Issue 4 & Issue 20].

How does this issue present an opportunity for Mediterranean wetlands? Could increase productivity, especially of photosynthetic organisms[7] – as long as there is sufficient water available [cf. Issue 11].

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11. Declining total precipitation, increased drought severity and desertification

Supporting information: Total precipitation, in both summer and winter, is projected to decline across much of the Mediterranean region between 2020 and 2050 – although in most areas this is within the range of natural variability[1]. The average length of dry spells is expected to increase, especially on the Iberian Peninsula and in the Maghreb[2]. Observed trends of reduced flood discharges are likely to continue[3]. Desertification refers to the process of land degradation in dry regions, resulting from both climatic changes and human actions (e.g. intensive agriculture [Issue 1] and water abstraction [Issue 4]) and involving a persistent reduction in biological productivity[4,5]. Parts of North Africa and southern Europe are likely to be heading towards desertification within the next 30 years[6].

How does this issue pose a threat to Mediterranean wetlands? Precipitation and/or flooding are essential to recharge many wetlands. Wetlands may have reduced water levels, remain drier for longer, or completely dry out[7]; droughts could be used as justification for constructing dams[8] [Issue 5]. Exacerbation of water conflicts between regions or countries, as each attempts to secure its own water supply [Issue 44]. Shift in location of seasonally flooded wetlands, to currently wetter areas[9]. Declines in water quality, because nutrients and pollutants become more concentrated[7]. Salinisation of freshwater wetlands [Issue 7]. Increased fire risk [Issue 31]. Changes in biological communities, reflecting shifts in the competitive balance between species[10,11]. Decline in wetland functions and services[11]. However, there may be some resilience in wetland habitats to reduced annual precipitation, especially where there are local increases in winter precipitation[12].

How does this issue present an opportunity for Mediterranean wetlands? Reductions in runoff could reduce chronic nutrient loading to wetlands[7] – but more extreme storms could lead to acute inputs [Issue 12]. Temporary drying of wetlands could eradicate aquatic invasive species, allowing pre-invasion communities to reassemble[13,14].

1. IPCC (2013) Annex I: atlas of global and regional climate projections. 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
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12. Increasing frequency and intensity of storms

Supporting information: Although the Mediterranean will become drier on average over the next 30 years [Issue 11], storms may become locally more frequent and/or intense. Models suggest that extreme rainfall events will become (a) more frequent in the south and east Mediterranean[1] and in the winter[2], and (b) more intense in southern Europe and Turkey in the winter, and in the Balkans in the summer[3]. Medicanes (Mediterranean hurricanes) are likely to become less common but more intense and longer-lasting[4].

How does this issue pose a threat to Mediterranean wetlands? Possible increased occurrence and intensity of flash flooding[5] (linked also to increasingly sealed surfaces in urban areas[6]). Increased engineering of rivers and floodplains, intended to reduce the risk of floods to humans. Increased inputs of sediment, nutrients and other pollutants to wetlands, in runoff[7]. Excess inputs of fresh water can effectively pollute saline systems. Hydromorphological changes (erosion, elevation of coastal wetlands[8,9]). Mass mortality of biodiversity: in 2008, a severe storm off the coast of Catalonia, Spain, killed around half of the sea urchins in seagrass beds[10].

How does this issue present an opportunity for Mediterranean wetlands? Intense rainfall events could lead to spontaneous restoration of floodplain wetlands. Increased flood risk could discourage development in floodplains and on floodplain wetlands.

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13. Sea level rise

Supporting information: Coastal wetlands are critically important in the Mediterranean, in terms of surface area, biodiversity support and ecosystem service provision[1]. The level of the Mediterranean Sea is predicted to rise by approximately 25 cm, under a range of climate change scenarios, by 2050[2]. Wetlands around the micro-tidal Mediterranean Sea may be particularly vulnerable to sea level rise, compared to wetlands around macro-tidal seas[3]. Flat, low-lying delta areas (e.g. Rhône, Nile, Ebro, Neretva) are at the greatest risk of inundation. Management of coastal land will need to plan for retreat.

How does this issue pose a threat to Mediterranean wetlands? Loss of coastal wetlands through flooding and erosion[3,4], especially where development hinders migration inland [Issue 19 & Issue 20] and sediment supplies are reduced [Issue 5]. Includes damage/loss to cultural landscapes involving wetlands (e.g. Venice and its lagoon, Italy; Po Delta near Ferrara, Italy[5]). Salinisation of inland wetlands, through inundation and intrusion of salt water into aquifers[6].

How does this issue present an opportunity for Mediterranean wetlands? Potential gain of new coastal wetlands further inland, as long as these are not squeezed out by development and sediment supplies are maintained[3,4]. Opportunity for managed retreat, restoration or rewilding of wetlands (e.g. management of sediment inputs to deltas[8]; abandonment of former saltworks in the Camargue, France[8]).

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Biotic environment, ecology, biodiversity

14. Increasing number and expanding distribution of alien species

Supporting information: Globally, the number of established alien species is increasing and shows no sign of slowing[1]. The same is true in many Mediterranean wetlands (e.g. The Camargue, France[2]). Following the opening of the Suez Canal, marine species from the Red Sea have flooded into the Mediterranean[3,4]. New trade links may create more opportunities for invasion[5] (e.g. Morocco opened the Mediterranean's largest container port in June 2019[6]; Turkey, Italy and Tunisia are linked by the ongoing Motorway of the Sea project[7]). Other pathways for introduction include deliberate release (e.g. for angling, for biocontrol, of unwanted pets) and escapes (e.g. from aquaculture facilities or ornamental wetlands)[8,9]. Wetlands disturbed by other forces – such as pollution, fire or storms – may be more vulnerable to invasion[10,11]. Many Mediterranean wetlands occur on islands, and island biodiversity is especially vulnerable to invasive alien species[12,13].

How does this issue pose a threat to Mediterranean wetlands? Some alien species will become invasive and have negative impacts on the environment and/or people. Threats to native species: competition, predation, hybridisation, extinction[14,15]. Formation of harmful microorganism blooms[16] [Issue 15]. Impacts on ecosystem services[17] (e.g. recreation[18] and rice production[19]). Interference with human activities in wetlands (e.g. clogging fishing nets, consuming bait). Loss of heritage value. Management consumes conservation resources, and can have negative side effects (e.g. pesticide toxicity).

How does this issue present an opportunity for Mediterranean wetlands? Possible increases in local species richness – but may not be desirable species, and within the context of reduced diversity at a Mediterranean-wide scale. Alien species may provide novel resources for humans[20] or wildlife[21].

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15. Increased frequency, intensity and distribution of algal blooms

Supporting information: Sudden proliferations of microalgae or cyanobacteria can have a negative impact on human activities and/or biodiversity. The frequency, intensity and distribution of such blooms have increased over recent years, in both coastal and inland wetlands, and are likely to increase further[1–3]. Some wetlands have also experienced shifts from harmless to harmful blooming species[1]. These trends are driven by many of the other issues listed in this document. For example, storms [Issue 12] and urban wastewater [Issue 9] can add nutrients to wetlands, which may become more concentrated due to reduced water availability [Issue 4 & Issue 11]. Expansion of agriculture in watersheds [Issue 1] and increased use of fertilisers [Issue 2] can increase nutrient inputs to wetlands. Increased temperatures [Issue 10] can also favour blooms, by increasing growth rates and expanding the realised niche of bloom-forming algae[4]. Locally, other factors can add nutrients to wetlands and stimulate algal blooms, e.g. guano of gulls feeding in landfills but roosting in Fuente de Piedra Lake, Spain[5].

How does this issue pose a threat to Mediterranean wetlands? Impacts on ecosystem service provision and biodiversity related to the large algal biomass: blooms are unsightly, and block out light/reduce oxygen availability with cascading effects through the ecosystem[3,4]. Impacts on ecosystem services and biodiversity related to production of algal toxins[4,6–8]. Likely to act as a co-stressor, especially with climate change[4].

How does this issue present an opportunity for Mediterranean wetlands? N/A

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16. Declining populations, and extinctions, of Mediterranean wetland species

Supporting information: In the Mediterranean, the abundance of wetland-dependent amphibians, reptiles, mammals and fish was around 35% lower in 2013 than it was in 1990[1]. In the Camargue in southern France, amphibians, odonates and orthopterans experienced sharp population declines between the 1970s and the 2010s[2]. Around 36% of species dependent on Mediterranean wetlands are threatened with global extinction[1]. At least 20% of utilised freshwater plants in North Africa are threatened with regional extinction[3].

How does this issue pose a threat to Mediterranean wetlands? Loss of functions and services linked to wetland biodiversity (e.g. pest control, bioindicators, fish stocks[4], cultural and other services associated with waterbirds[5]). Reduced value of wetlands, increasing their vulnerability to conversion to other land uses.

How does this issue present an opportunity for Mediterranean wetlands? Potential to use population declines and extinctions, both observed and potential, as a "call to arms" for wetland conservation[6]. Potential to use rare or threatened species as "flagships" to conserve entire ecosystem (e.g. white headed-duck *Oxyura leucocephala* as a flagship for lake conservation in Turkey and Spain[7]). Wetlands containing rare species may become *more* valuable, for example as birdwatching sites[8].

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17. Fragmentation of wetland habitats

Supporting information: Wetlands may become fragmented (size of individual patches reduced, physical or ecological distance between remaining patches increased[1,2]) by processes such as urbanisation, agricultural expansion, dam construction or climate change. Fragmentation can occur at multiple scales, from loss of wetland area within a wetland complex[3] to division of habitats within an individual wetland (e.g. the road *La Goulette* bisecting Tunis Lagoon, Tunisia[4]). Amongst European countries, Croatia, Portugal and Greece experienced particularly large proportional increases in the area of strongly fragmented landscapes between 2009 and 2015[5].

How does this issue pose a threat to Mediterranean wetlands? Negative impacts on ecosystem functions and services (e.g. fish stocks, pollination, water supply). Smaller, more isolated populations have a greater extinction risk due to environmental, demographic and genetic stochasticity[1,6–8]. Possible extinction of metapopulations[9]. Break up of dispersal or migration corridors[10] due to complete loss of wetlands (wetlands no longer present), shortened hydroperiods (wetlands not present at the right time), changes in water quality (e.g. salinisation), or construction of barriers such as dams (functional connectivity of habitat reduced). These threats apply to both the species dispersing (e.g. waterbirds) and the organisms they transport (e.g. plants)[6]. Increased conflict between humans and wetland wildlife, for example if waterbirds feed in agricultural land instead of wetlands[6].

How does this issue present an opportunity for Mediterranean wetlands? Fragmentation, or the threat of it, could strengthen arguments for protection, restoration or creation of wetlands in strategic sites.

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Ecosystem services and use of wetlands

18. Traditional livelihoods, that use wetlands sustainably, become less common

Supporting information: Across the Mediterranean, traditional and sustainable uses of wetlands are in decline, in favour of intensification or abandonment. This may be related to declining yields and economic returns, emergence of more economically lucrative opportunities, cultural shifts towards a homogeneous global model, increased availability of industrially manufactured alternatives, or environmental changes[1]. For example, in the Macta Marshes, Algeria, conversion of wetlands to agricultural land was associated with a cultural shift from nomadic to sedentary lifestyles[2]. Reed harvesting in the Camargue, France has been increasingly intensified and mechanised to meet increasing demand from northern Europe[3]. Artisanal fisheries in Venice Lagoon, Italy may collapse as valuable target species cannot tolerate warming waters[4].

How does this issue pose a threat to Mediterranean wetlands? Wetland degradation or loss under more intensive management[2,3], or conversion to other land uses after abandonment. For example, when low intensity, nature-friendly salt production in the Ulcinj Salina, Montenegro, stopped in 2013, there was pressure to convert the site into a luxury resort[5]. Loss, or homogenisation, of cultural practices across the Mediterranean[1].

How does this issue present an opportunity for Mediterranean wetlands? Potential for wetland conservation through continued, or resumed, sustainable use (e.g. under the Hima system in Lebanon[6]). May be driven by tourist demand[1].

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19. Increasing tourist numbers

Supporting information: The Mediterranean region is one of the world's tourism hotspots: Mediterranean countries received around 398 million international visitors in 2017 (30% of the world's total)[1]. About half of these arrivals visit coastal areas[2]. In 2018, France and Spain were the two most visited countries in the world, with Italy fifth[1]. Across the Mediterranean, visitor numbers are forecast to reach around 500 million by 2030[2]: around the same size as the resident population[3]. However, note that the COVID-19 pandemic has caused a severe decline in tourism in 2020, which is likely to continue in the short term (months to years)[4–6]. Experiences during the pandemic could encourage people to remain closer to home for vacations when they become commonplace again, tempering the magnitude and seasonality of visitor numbers in the Mediterranean[7].

How does this issue pose a threat to Mediterranean wetlands? Damage to habitats and disturbance of wildlife through construction of tourism infrastructure ("land grabs", especially in coastal areas)[8,9], recreational use[10] and management of natural systems for the benefit of tourists[11]. Pressure on already limited water resources: water is used in tourist accommodation and to maintain infrastructure such as swimming pools, golf courses and water parks[12]. Production of waste (e.g. plastics, sewage), which is not always well managed[12,13]. Exclusion of local people. Reduction in wilderness value, affecting cultural ecosystem services in sites valued for their naturalness (e.g. Palm Island, Lebanon and Wadi Mujib, Jordan[14]). Enhancement of climate change on a global scale, associated with travel (especially flying) and construction of concrete-based infrastructure[15].

How does this issue present an opportunity for Mediterranean wetlands? Revenue from taxes and fees (whether from tourists visiting wetlands or other areas) could support investment in wetland conservation[13]. Potential to develop sustainable tourism activities that value natural and cultural heritage (e.g. creation or infrastructure, or even wetlands, for birdwatchers[16]). Potential to educate tourists about wetlands and inspire them to get involved in wetland conservation. Provides incentive and funding to maintain social heritage of wetlands (e.g. gondolas in Venice Lagoon, Italy). Ensures wetlands have an economic value, as an argument against conversion to other land uses.

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20. Urban growth

Supporting information: This issue is about the increasing area occupied by cities or towns. Urban areas covered over 33,000 ha (1.6%) of the Mediterranean basin in 2000. This is projected to increase to over 127,000 ha (5.9%) by 2030, with the largest increases in the south and east Mediterranean[1] and in coastal zones[2]. Growth of urban areas may be driven by a combination of overall population growth[3] and depopulation of rural areas[4] – which may in turn be linked to climate change and drought (e.g. rural exodus associated with drought conditions in Morocco between 1980 and 1990[5]). The urban population in the Mediterranean is predicted to increase from 315 million in 2010 to 385 million in 2025[3]. Between 2018 and 2030, the fastest growing cities will include: Aleppo, Damascus and Homs in Syria (3.2–4.5% projected annual population increase); Tanger, Morocco (2.6%); Cairo, Egypt (2.0%); Alexandria, Egypt (1.9%); and Antalya, Turkey (1.9%)[6].

How does this issue pose a threat to Mediterranean wetlands? Direct conversion of wetlands (e.g. around Izmir, Turkey[7] and in Tunis Lagoon, Tunisia[8,9]): responsible for 5% of natural wetland conversions across the Mediterranean 1975–2005[2]. Fragmentation of wetland habitats [Issue 17]. Lower quality and quantity of water available for wetlands[10] [Issue 4 & Issue 9]. Increased cover of impermeable surfaces, including on floodplains, exacerbates flash flooding[2,11]. Source of invasive alien species[12] [Issue 14]. Loss of open habitats as shrubs and trees colonise abandoned rural areas (including wetlands), with implications for species dependent on open habitats[13,14]. Loss of wetland cultural landscapes in abandoned rural areas[15].

How does this issue present an opportunity for Mediterranean wetlands? Wetlands can be incorporated into urban areas, providing benefits to both people and nature[16,17]. Reduced pressure on rural areas may open up opportunities there for wetland restoration, creation and rewilding.

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21. Socioeconomic impacts of climate change

Supporting information: The climate has a pervasive influence on human society and economics[1]. In the Mediterranean, higher temperatures [Issue 10] and changes in precipitation [Issue 11 & Issue 12] could reduce economic and agricultural productivity and per capita incomes[1]. Climate change and extreme weather events will displace human settlements – temporarily, if not permanently[2,3] [see also Issue 20]. Socioeconomic instability could lead to increased conflict, migration and state failure[1]. For example, in Syria in the early 2010s, extreme droughts stimulated rural-urban migration, social tensions and the outbreak of civil war[4]. The impact of this issue is likely to be especially strong in the south and east Mediterranean.

How does this issue pose a threat to Mediterranean wetlands? Weakened economies will have fewer resources available for wetland conservation[5]. Faced with instability, national policy and action may focus on proximate human needs and desires (e.g. food supply, economic growth) and areas with the greatest perceived socioeconomic value (e.g. cities), rather than conservation of the environment and wetlands. Migration is likely to increase pressure on coastal areas, where the Mediterranean population is already concentrated[6].

How does this issue present an opportunity for Mediterranean wetlands? As tangible social and economic impacts of climate change develop, the perceived value of wetlands for climate change adaptation and mitigation increases[7]. Increased opportunity to sell wetlands as nature-based solutions to climate change.

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Governance

22. Weak and ineffective governance

Supporting information: Governance is about "who decides and how"[1]. Who are the authorities in a country or region? How, and how effectively, do they manage policies, institutions, processes and power? To varying degrees across the Mediterranean, environmental conservation is limited by political structures (e.g. centralisation of power and weak local departments, or poor integration of environmental and other ministries), ineffective decision-making mechanisms, complex bureaucratic procedures, corruption, unenforced laws and protections, and a weak civil society that cannot hold the authorities to account[2–5]. In 2018, three Mediterranean countries ranked amongst the top 50 (and two amongst the top 13) in the world for perceived corruption in the public sector[6]. Efforts to coordinate environmental governance at a supranational level, for example in the context of the Barcelona Convention (1976) and its Protocols, can be hampered by ideological divisions between countries (e.g. debates over migration policy or national borders)[7,8].

How does this issue pose a threat to Mediterranean wetlands? Poor environmental governance can lead to over-use, illegal use, inequitable distribution and general mismanagement of resources[4] – including water, wetland habitats and wetland biodiversity. For example, along the Alfeios River in Greece, illegal gravel extractions are facilitated by poor law enforcement at weekends and cartel pressure on local politicians[9]. A recent global analysis found that effective governance was strongly related to the effectiveness of waterbird conservation actions[10].

How does this issue present an opportunity for Mediterranean wetlands? Civil society can take responsibility for conservation of Mediterranean wetlands, leading to a sense of community ownership that may improve long-term conservation success[11,12].

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23. Creation of weak laws regarding conservation or wise use of Mediterranean wetlands

Supporting information: Environmental laws may be weak or toothless if they are fragmented, incomplete, outdated or littered with loopholes and exemptions[1]. General environmental legislation may not refer specifically to wetlands, fostering uncertainty amongst wetland owners, managers and users[1]. In some cases, weak laws may reflect a lack of knowledge and data about wetlands. In other cases, weak laws may be created deliberately, perhaps driven by conflicting interests of governments. For example, it has been suggested that the Turkish Draft Act on Nature and Biodiversity Conservation was "cynically and decidedly pro-development"[2]. Even in the EU, a need for compromise amongst member states means that environmental laws can contain loopholes and exemptions, to allow local interpretation of the law[3,4]. Note that this issue refers to the *creation of inherently weak laws*, rather than *poor enforcement* of laws [cf. Issue 22].

How does this issue pose a threat to Mediterranean wetlands? Weak laws offer little real protection even if enforced. Threats (e.g. hunting, development) are allowed to continue, with the excuse that they are legal.

How does this issue present an opportunity for Mediterranean wetlands? N/A

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24. Subsidies, even those intended to be environmentally beneficial, encourage degradation or conversion of Mediterranean wetlands

Supporting information: Financial subsidies can contribute to environmental degradation and over-exploitation of resources[1,2]. For example, the EU Common Agricultural Policy encourages conversion of wetlands to land in "good agricultural condition" in order to receive subsidies (Regulation (EU) 1307/2013). Seventy per cent of the cost of wetland drainage in France during the 1970s was met by EU agricultural support grants[3]. Some subsidies intended to benefit the environment can damage it in practice. The EU Renewable Energy Directive 2009/28/EC set a target of 10% biofuels in transport fuels by 2020, potentially encouraging growth of biofuel crops in wetlands or displacing food crops into wetlands. In France, tax exemptions for land planted with trees could encourage drainage and afforestation of wetlands[4]. In the future, it is not unlikely that new subsidies harmful to wetlands will be created (e.g. for large-scale afforestation aiming to combat climate change[5]) or that existing subsidies become damaging (e.g. if incentives lag behind stocks and/or demand). Vested interests may underpin the creation of environmentally-damaging subsidies[2].

How does this issue pose a threat to Mediterranean wetlands? Subsidies could encourage wetland degradation or loss. Perverse subsidies, which have adverse *economic* effects as well as adverse *environmental* effects[1], could reduce the perceived value of wetlands to local people.

How does this issue present an opportunity for Mediterranean wetlands? N/A

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Management and monitoring

25. Artificialisation of Mediterranean wetlands

Supporting information: This issue includes changes to wetland hydrology and/or structure, through human interventions such as increased water management, channelisation, diking, inlet construction, harbour construction, and conversion to rice fields, fish ponds or salt pans[1–3]. Loss of natural wetland area in the Mediterranean has been accompanied by parallel increase, of similar magnitude, in the area of artificial wetlands[4]. Currently, around 23% of Mediterranean wetlands are entirely artificial (approximately twice the global average)[4]. However, most Mediterranean wetlands are arguably already artificial to some extent, given widespread management or alteration of hydrology[5]. Issue 1 and Issue 20 relate to the conversion of wetlands to non-wetland land uses.

How does this issue pose a threat to Mediterranean wetlands? Loss of wetlands (e.g. floodplain wetlands along diked rivers). Disruption of natural systems (e.g. pools outside Doñana National Park, Spain, are unnaturally wet due to irrigation whereas those in the park are unnaturally dry due to groundwater depletion[6]; hydrological and sediment regimes in Nador Lagoon, Morocco were altered by construction of new inlets[7]). Reduced value of remaining wetlands for wildlife and people: artificial or artificialised wetlands may support smaller populations, fewer species and different communities compared to natural wetlands[8–10]. Artificial wetlands can favour alien species, and facilitate their spread to natural wetlands[11,12].

How does this issue present an opportunity for Mediterranean wetlands? Increased provision of some ecosystem services (e.g. if wetlands become more accessible for recreation). Potential for increased resilience against climatic changes, as long as management continues. Artificial wetlands may provide complementary habitats to natural wetlands[4,13]. They could provide refuges from climate change and extreme weather events[14].

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25 OVERLOOKED ISSUES

Agriculture and aquaculture

26. Increasing regulation (e.g. bans) on pesticide use

Supporting information: Increasing recognition of the negative impacts of pesticides (e.g. herbicides, insecticides, bactericides) on human health and non-target biodiversity may lead to introduction or strengthening of regulation against their use. The EU currently outlines eight principles of integrated pest management, including use of less, and less harmful, pesticides[1]. In Israel, several harmful chemicals have been phased out in recent years[2]. Note that regulation differs between Mediterranean countries, and may be weak [Issue 23] or poorly enforced [Issue 22] even where it does exist[3].

How does this issue pose a threat to Mediterranean wetlands? Agricultural production quality and/or yield may be reduced, which may encourage expansion of agriculture into wetlands to maintain profits and meet demand[4].

How does this issue present an opportunity for Mediterranean wetlands? Assuming regulations are strong and are enforced: reduced inputs of pesticides into wetlands, via runoff from agricultural, domestic and recreational areas. This would reduce the negative impacts of pesticides on water quality and wetland biota[5] [cf. Issue 2]

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Water and pollution

27. Increasing desalination capacity

Supporting information: The number and capacity of desalination plants in the Mediterranean is likely to increase over the next 30 years, as countries attempt to secure fresh water supplies for a growing population in the face of climate change[1]. Desalination may be particularly important on islands and in the south and east Mediterranean[1,2], but even Spanish policy has shifted towards desalination rather than river regulation or water transfers[2,3]. Israel expects desalination to meet 40% of national drinking water demand by 2025, and 60% by 2050[4]. However, note that uptake may be limited by the high financial cost (of raw materials and energy[1]) and concerns over waste brine disposal[2].

How does this issue pose a threat to Mediterranean wetlands? Pollution from warm, concentrated brine in coastal/marine wetlands[5,6]. Potential construction of hydropower facilities to help meet the high energy demand of desalination plants[7] [see Issue 5]. Illusion of water abundance could reduce uptake of water-saving practices. Reduced area of brackish/saline wetlands, if attempts are made to convert these into freshwater wetlands using desalinised water.

How does this issue present an opportunity for Mediterranean wetlands? Reduced pressure on depleted surface and underground fresh water resources[8] [Issue 4]. Potential to use desalinised water, in emergencies, to supplement existing freshwater wetlands.

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5. Alshahri F (2017) Heavy metal contamination in sand and sediments near to disposal site of reject brine from desalination plant, Arabian Gulf: assessment of environmental pollution. Environ Sci Pollut Res 24:1821–1831
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8. Milano M, Ruelland D, Fernandez S, Dezetter A, Fabre J, Servat E, et al. (2013) Current state of Mediterranean water resources and future trends under climatic and anthropogenic changes. Hydrol Sci J 58:498–518

28. Increasing concentrations of domestic and medical pollutants in Mediterranean wetlands

Supporting information: Includes (a) common domestic chemicals such as caffeine and triclosan, (b) chemicals with medicinal uses, such as testosterone[1], oestrogen, statins, anti-inflammatories (e.g. ibuprofen), antidepressants (e.g. fluoxetine), anticonvulsants (e.g. carbamazepine) and chemotherapy agents, and (c) illicit drugs[2]. Increasing use related to growing populations, ageing populations (increased use of medicines[1,3]), socioeconomic status (e.g. increased drug use after economic crisis in Greece[4]), war/conflicts (increased availability of illicit drugs), and behavioural changes during or following the COVID-19 pandemic (e.g. increased use of disinfectants/hand sanitiser). These chemicals may not be removed by water treatment processes, and may persist in wetlands[5]. Examples in the Mediterranean include legal and illegal drugs in the wastewater of Athens, Greece[4] and pharmaceuticals beyond toxic concentrations in sediments in Doñana National Park, Spain[6]. This issue interacts with water availability [Issue 4 & Issue 11]: less water in wetlands will mean chemicals are more concentrated.

How does this issue pose a threat to Mediterranean wetlands? Potential impacts on behaviour, physiology, reproduction and survival of aquatic organisms[7–9]. These impacts, the doses needed to cause them, and the interactive effects of an ever expanding cocktail of chemicals remain poorly understood[10]. Development of antimicrobial resistant organisms [Issue 33].

How does this issue present an opportunity for Mediterranean wetlands? N/A

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3. Sutherland WJ, Aveling R, Bennun L, Chapman E, Clout M, Côté IM, et al. (2012) A horizon scan of global conservation issues for 2012. Trends Ecol Evol 27:12–18
4. Thomaidis NS, Gago-Ferrero P, Ort C, Maragou NC, Alygizakis NA, Borova VL, et al. (2016) Reflection of socioeconomic changes in wastewater: licit and illicit drug use patterns. Environ Sci Technol 50:10065–10072
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29. Deliberate dumping of solid waste in or near Mediterranean wetlands

Supporting information: This issue is concerned with unregulated waste dumping in Mediterranean wetlands or their catchments. There are low rates of formal waste collection in many Mediterranean countries (e.g. 5% and 15% of rural waste in Tunisia and Egypt, respectively, and 31% of urban waste in Tangier, Morocco[1]), which can encourage people to dump waste in natural areas. Approximately 53% of waste in the Middle East and North Africa is disposed of in open dumps (as opposed to regulated landfill, recycling or composting)[1]. Unregulated waste dumping may decline in the long term, for example through improved waste management systems, education, or enforcement [Issue 48], but waste and associated contaminants can persist in the environment. Episodes of political and socioeconomic stability can also lead to breakdown of waste management systems [Issue 37]. Mediterranean wetlands affected by unregulated waste dumping include the Monegros Playa Lakes, Spain[2] (waste stones from agricultural land), Büyükçekmece Lake, Turkey[3] (chemical waste dumped within the watershed), the Ghadir River in Beirut, Lebanon[4] (household waste thrown in river due to lack of tips nearby) and Sebkhet Karkura, Libya[5] (unspecified waste dumping).

How does this issue pose a threat to Mediterranean wetlands? Chemical pollution, e.g. from industrial waste[3]. Physical pollution, e.g. from glass and plastics [Issue 8]. Reduced aesthetic/recreational value of wetlands. Smothering of vegetation[2].

How does this issue present an opportunity for Mediterranean wetlands? N/A

1. Kaza S, Yao L, Bhada-Tata P, Van Woerden F (2018) What a waste 2.0: a global snapshot of solid waste management to 2050. Urban Development Series. International Bank for Reconstruction and Development/The World Bank, Washington, DC
2. Castañeda C, Herrero J (2008) Assessing the degradation of saline wetlands in an arid agricultural region in Spain. CATENA 72:205–213
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Physical environment and climate change

30. Increased frequency of dust storms

Supporting information: In several locations around the Mediterranean, from Spain to Israel, the frequency of dust intrusions increased over the second half of the twentieth century[1]. Dust storms are likely to become even more common in the Mediterranean due to land degradation and desertification[2]. Drivers of land degradation include climate change [Issue 10 & Issue 11], water abstraction [Issue 4] and intensive agriculture [Issue 1]. Drained or desiccated wetlands can themselves become a source of dust[3].

How does this issue pose a threat to Mediterranean wetlands? Risk of eutrophication in wetlands, because dust deposition adds nutrients to aquatic environments[4,5]. Increase in wetland pH[4,5]. Addition of toxic chemicals such as heavy metals and polyaromatic hydrocarbons to wetlands where dust is deposited; these chemicals may be present in the dust source (e.g. sediment of a desiccated wetland[1]) or can accumulate in the dust cloud as it is moves across the landscape[6]. Salinisation of freshwater wetlands, if dust originates from salt-rich sediments (e.g. North African chotts)[7].

How does this issue present an opportunity for Mediterranean wetlands? Increased productivity of algae and phytoplankton could increase the value of Mediterranean wetlands as carbon sinks[5]. Dust particles can act as condensation nuclei[8], stimulating local precipitation events that would add water to wetlands.

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6. Guo J, Rahn KA, Zhuang G (2004) A mechanism for the increase of pollution elements in dust storms in Beijing. Atmos Environ 38:855–862
7. Abuduwaili J, Liu D, Wu G (2010) Saline dust storms and their ecological impacts in arid regions. J Arid Land 2:144–150
8. Levin Z, Ganor E, Gladstein V (1996) The effects of desert particles coated with sulfate on rain formation in the Eastern Mediterranean. J Appl Meteorol 35:1511–1523

31. Increased fire risk within Mediterranean wetlands and their watersheds

Supporting information: The Mediterranean is likely to experience more frequent and more widespread fires in the future[1–3]. This is related to climate change (hotter, drier summers), abandonment of rural land and reduced grazing pressure (meaning increased fuel loads), expansion of pine and *Eucalyptus* plantations, and increasing sources of ignition (increasing urban-wildland interface, and increased visitor numbers). Fires may occur within wetlands (e.g. seasonally flooded wetlands) or elsewhere in wetland watersheds.

How does this issue pose a threat to Mediterranean wetlands? Fires within wetlands: effects on soil chemistry, nutrient availability, exposure to solar radiation, water infiltration[4,5]. Implications for wetland organisms (e.g. vegetation composition) and aesthetic value. Fires within watersheds: reduced water quality due to inputs of ash and soil/sediment (increased erosion and runoff from burned slopes)[5–7].

How does this issue present an opportunity for Mediterranean wetlands? Fires may help to control vegetation succession, maintaining a more open habitat that favours annual species. Otherwise, abandoned [Issue 18] or nutrient-enriched [Issue 2 & Issue 30] wetlands may become dominated by woody species[5].

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2. Turco M, Rosa-Cánovas JJ, Bedia J, Jerez S, Montávez JP, Llasat MC, et al. (2018) Exacerbated fires in Mediterranean Europe due to anthropogenic warming projected with non-stationary climate-fire models. Nat Commun 9:3821
3. Ruffault J, Curt T, Moron V, Trigo R, Mouillot F, Koustias N, et al. (2020) Increased likelihood of heat-induced large wildfires in the Mediterranean Basin. Sci Rep 10:13790
4. Kotze D (2013) The effects of fire on wetland structure and functioning. Afr J Aquat Sci 38:237–247
5. Zacharias I, Zamparas M (2010) Mediterranean temporary ponds. A disappearing ecosystem. Biodivers Conserv 19:3827–3834
6. Nunes JP, Keesstra S, Doerr S, Pulquério M (2018) Policy brief: impacts of fires on water quality. Results from the Connecteur/PLACARD workshop on fire impacts on water quality, 14–16 February 2018, Lisbon
7. Morán-Ordóñez A, Duane A, Gil-Tena A, Cáceres MD, Aquilué N, Guerra CA, et al. (2020) Future impact of climate extremes in the Mediterranean: soil erosion projections when fire and extreme rainfall meet. Land Degrad Dev 31:3040–3054

Biotic environment, ecology, biodiversity

32. Spread of novel wildlife pathogens and diseases

Supporting information: This issue refers to wildlife diseases new to the Mediterranean region, or whose range expands in response to environmental changes or human activities[1,2]. Examples of pathogens currently present in the Mediterranean include chytrid fungus *Batrachochytrium dendrobatidis*[3], crayfish plague *Aphanomyces astaci*[4] and canker stain of plane trees *Ceratocystis platani*[5]. Bacteria, viruses, flatworms, roundworms and myxozoa can also be high-impact pathogens. Pathogens are often overlooked when horizon scanning for alien and invasive species[6].

How does this issue pose a threat to Mediterranean wetlands? Large decline or extinctions of single species, which may be ecologically, culturally or economically important[7]. Cascading effects on food webs and ecosystem functions.

How does this issue present an opportunity for Mediterranean wetlands? Pathogens are important components of healthy ecosystems[2]. Novel/alien pathogens might help to restore balance to systems invaded by alien species[8].

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2. Okamura B, Feist SW (2011) Emerging diseases in freshwater systems. Freshw Biol 56:627–637
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5. Ocasio-Morales RG, Tsopelas P, Harrington TC (2007) Origin of *Ceratocystis platani* on native *Platanus orientalis* in Greece and Its impact on natural forests. Plant Dis 91:901–904
6. Roy HE, Hesketh H, Purse BV, Eilenberg J, Santini A, Scalera R, et al. (2017) Alien pathogens on the horizon: opportunities for predicting their threat to wildlife. Conserv Lett 10:477–484
7. Gozlan RE, Peeler EJ, Longshaw M, St-Hilaire S, Feist SW (2006) Effect of microbial pathogens on the diversity of aquatic populations, notably in Europe. Microbes Infect 8:1358–1364
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33. Development of antimicrobial resistance within Mediterranean wetlands

Supporting information: Wetlands may be crucial to the evolution of antimicrobial resistance (AMR) and the transmission of resistant organisms to humans[1,2]. Wetlands often receive sublethal quantities of antimicrobials and other pollutants that can drive evolution of AMR[1–3], and may even receive resistant organisms or resistant genes directly in household, hospital or agricultural waste[4]. Wetlands are also spaces where wild animals, domestic animals and humans mix, facilitating transmission of resistant organisms[1,5,6]. AMR surveillance systems, critical for facilitating rapid remedial intervention, are missing or weak in several countries[7]. Recent records of resistant organisms in Mediterranean wetlands include bacteria from a river, lake and lagoon near Montpellier, France[8], streams in Catalonia, Spain[9], and water-treatment wetlands in Sicily, Italy[10]. Locally, antimicrobial usage may increase in the near future, for example to increase agricultural production in the face of rising demand[11,12].

How does this issue pose a threat to Mediterranean wetlands? Could encourage direct management of wetlands (e.g. chemical application, drainage[13]) or vectors (e.g. killing or scaring waterbirds[13,14]), in an attempt to control development or transmission of resistant microorganisms. Even if these actions are not effective, they may be implemented on the basis of misguided policies, or to satiate media or public appetite for intervention[13]. Reduced value of wetlands for recreation. Collapse of aquaculture facilities (and the economic value they give to wetlands) if they are a source, or perceived source, of resistant microorganisms.

How does this issue present an opportunity for Mediterranean wetlands? Awareness of the links between wetland pollution and public health (via AMR) could encourage action to reduce pollution (e.g. improved wastewater treatment). Artificial wetlands may be constructed to treat wastewater (remove antimicrobials or AMR genes[15,16]), but these can also provide habitat for wetland organisms.

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2. Taylor NGH, Verner-Jeffreys DW, Baker-Austin C (2011) Aquatic systems: maintaining, mixing and mobilising antimicrobial resistance? Trends Ecol Evol 26:278–284
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10. Russo N, Pino A, Toscano A, Cirelli GL, Caggia C, Arioli S, et al. (2019) Occurrence, diversity, and persistence of antibiotic resistant enterococci in full-scale constructed wetlands treating urban wastewater in Sicily. Bioresource Technol 274:468–478
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15. Chen J, Liu Y-S, Su H-C, Ying G-G, Liu F, Liu S-S, et al. (2015) Removal of antibiotics and antibiotic resistance genes in rural wastewater by an integrated constructed wetland. Environ Sci Pollut Res 22:1794–1803
16. Liu X (2019) A review on removing antibiotics and antibiotic resistance genes from wastewater by constructed wetlands: performance and microbial response. Environ Pollut 254:112996

34. Spread of mosquito-borne diseases

Supporting information: The human health risk posed by mosquito-borne diseases is likely to increase in parts of the Mediterranean over the next 30 years. The region is already home to mosquito vectors[1,2] and mosquito-borne pathogens (e.g. dengue[3], malaria[4] and West Nile virus[5]). However, there is a risk of mosquitoes and/or pathogens spreading to and within the Mediterranean due to climatic changes, and movement of goods and people[4,6]. Where mosquito-borne diseases already circulate, transmission risk may also be increased by climatic changes and their effects on the duration of incubation and transmission periods (e.g. on parts of the North African coast[3] and in southern Europe[4,7]).

How does this issue pose a threat to Mediterranean wetlands? Human health problems fuel negative attitudes towards wetlands. Direct management of wetlands (e.g. drainage, filling or hydrological modifications[8]) or vectors (e.g. spraying insecticides to kill mosquito larvae, introduction of larvivorous fish[9]) in an attempt to control zoonotic diseases. Direct and indirect effects of control measures on non-target wetland organisms[9–13]. Interventions may be carried out to alleviate public fear even if not genuinely effective. Interventions with damaging side effects for wetlands may be carried out if ecological concerns are trumped by immediate public health concerns[14].

How does this issue present an opportunity for Mediterranean wetlands? May provide an incentive to reduce pollution to Mediterranean wetlands: mosquitoes may benefit from pollution because they are more tolerant of it than many of their natural predators[15] or because it can stimulate development of insecticide resistance[16].

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16. Oliver SV, Brooke BD (2018) The effect of metal pollution on the life history and insecticide resistance phenotype of the major malaria vector *Anopheles arabiensis* (Diptera: Culicidae). PLOS ONE 13:e0192551

35. Development of insecticide resistance in mosquitoes

Supporting information: Mosquitoes may develop resistance to insecticides, through mutation and selection, if one class of insecticides is used repeatedly but each treatment doesn't kill all mosquitoes in the population[1,2]. Insecticide resistance will become a more important issue with the spread of serious mosquito-borne diseases [Issue 34].

How does this issue pose a threat to Mediterranean wetlands? Increased management of mosquitoes in wetlands, potentially with methods that are more environmentally damaging[3,4]. Ecological concerns may be trumped by immediate public health concerns[5].

How does this issue present an opportunity for Mediterranean wetlands? Could encourage more judicious application of available insecticides, as part of integrated pest management strategies[6]. Could provide a stimulus to develop alternative control/mitigation technologies with fewer side-effects for wetlands: CO_2-based traps[7]; genetic engineering/CRISPR (releasing sterile males or introducing a gene for flightless females[8]); lasers[9]; wearable devices that emit electromagnetic signals to mimic storms and repel mosquitoes[9]. May provide an incentive to reduce general pollution to Mediterranean wetlands, because pollution can stimulate development of insecticide resistance[10].

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Ecosystem services and use of wetlands

36. Sand and gravel extraction

Supporting information: This issue includes extraction from Mediterranean wetland watersheds or the wetlands themselves. Rivers in particular are a major source of aggregates for construction, since they contain pre-ground and sorted, angular material, often close to human settlements[1]. Sand and gravel extraction is often poorly regulated, leading to overexploitation of these open, common resources[2]. For example, on the Alfeios River in Greece, legal gravel abstractions are supplemented by illegal mining: at the weekend when authorities are not fully operational, or due to cartel pressure on local politicians[3]. Along the Sebaou River, Algeria, the number of illicit sand and gravel extraction sites increased dramatically between 1987 and 2016[4]. In Egypt, domestic extraction of non-metallic minerals (including sand and gravel) increased over five-fold between 1970 and 2010[5]. Demand for aggregates is likely to increase in the future[5], linked to economic growth, population growth, and construction of urban infrastructure [Issue 20].

How does this issue pose a threat to Mediterranean wetlands? Habitat loss. Changes in wetland morphology, downstream sediment transport, water quality, water levels, flow regimes[1,4,6]. In Terga, Algeria, sand extraction has affected the stability of the surrounding wetland ecosystem, including an increased flood risk due to widening of the bed of the El Maleh wadi[7]. Where downstream sediment supply is reduced[8], accretion in coastal wetlands may suffer, increasing the risk from erosion and submergence[9]. Note also indirect impacts to surrounding/downstream wetlands, even when material is extracted from non-wetland areas[1,4]. For example, extraction of beach sand in Morocco exposes coastal wetlands to sedimentation, salinisation and waves[10].

How does this issue present an opportunity for Mediterranean wetlands? New wetland habitats could be created by depositing spoil in deep waters[11] or by flooding upland extraction pits[12].

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Socioeconomics

37. Political and socioeconomic instability

Supporting information: Political and socioeconomic instability in the Mediterranean may be related to global economic crises (e.g. 2008 Global Economic Crisis; recession associated with the COVID-19 pandemic[1]), political tensions (e.g. demands for Catalan independence) or conflicts (e.g. Syrian Civil War 2011–present; Libyan Civil War 2014–present). For socioeconomic effects of climate change, see Issue 21.

How does this issue pose a threat to Mediterranean wetlands? Breakdown of environmental governance at a national scale [cf. Issue 22]. Difficulties coordinating governance at a supranational scale [cf. Issue 44]. Unregulated waste disposal in wetlands and their watersheds, due to collapse of waste management systems or poor waste management infrastructure in refugee camps[2]. Persistent pollution from toxic munitions residues, which can contaminate groundwater[2]. Collapsed professional industries replaced by substandard civilian operations, leading to pollution (e.g. oil waste entering rivers during ongoing Syrian Civil War[2]). Wetland or water infrastructure deliberately and tactically damaged (e.g. missile attacks on water treatment infrastructure in Israel, 2014; attack on a reservoir near Zintan, Libya, 2015[3]). Ransacking of protected areas, which are seen as symbols of oppressive government regimes (e.g. in Tunisia, during the Arab Spring[4]). Resources (money and time) are diverted away from wetland conservation towards more immediate human needs[5–7].

How does this issue present an opportunity for Mediterranean wetlands? Sustainable development and wise use of wetlands could be promoted as cost-effective solutions to social, environmental and economic problems[6,8]. New environmental networks and NGOs may emerge after periods of unrest[4,9].

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7. Theys J (2020) COVID 19 et Méditerranée: les trois temps de la crise. Plan Bleu, Sophia Antipolis
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38. Poverty, especially in south and east Mediterranean countries

Supporting information: Poverty occurs when a person cannot meet a minimum living standard, compared to other people living in the same place and at the same time. Poverty levels are high in some Mediterranean countries/regions (e.g. Syria: 35% of population living below national poverty line according to most recent data available in 2007; West Bank and Gaza: 29% in 2016; Egypt: 28% in 2015; Croatia: 19% in 2017)[1]. Likely to increase with climate change, water shortages and conflicts. Poverty can lead to social marginalisation and socio-political instability[2] [Issue 37].

How does this issue pose a threat to Mediterranean wetlands? Governments might prefer to spend limited money on economic development than conservation[3], or prefer to exploit species and habitats for short-term gain; traditional conservation using protected areas is often perceived as competing with economic activities. Water resources may be a focus for development (e.g. the Southeastern Anatolia Project in Turkey, where the construction of 22 dams, 19 hydroelectric plants and numerous irrigation systems on the Tigris and Euphrates Rivers has been written into law[4]), with impacts on wetlands upstream and downstream [cf. Issue 5]. Poverty-environment trap: a feedback loop between poverty and environmental overexploitation[5].

How does this issue present an opportunity for Mediterranean wetlands? Potential to promote sustainable development and wise use of wetlands, simultaneously tackling the problems of biodiversity conservation and poverty[6]. This assumes that conservation of wetlands, which are mostly situated in rural areas, benefits people in urban areas[7].

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39. Development of a "blue economy" focused on sustainable use of the Mediterranean Sea

Supporting information: The term "blue economy" refers to ocean-based economic development, usually with a focus on environmental sustainability and social equity[1]. There are numerous projects and commitments to development of the blue economy in the Mediterranean[2,3]. This will involve activities such as tourism, industrial shipping, offshore wind farming, fishing, harvesting of other biological resources (e.g. algae and bacteria), and aquaculture [Issue 3].

How does this issue pose a threat to Mediterranean wetlands? Increased development of coastal areas. Increased exploitation of the coastal/marine environment, even if it has sustainable ambitions, will have effects on coastal wetlands. Additional burdens on already stressed systems, new forms of development with unknown risks, cumulative impacts of new and existing uses of the coast/sea, and interactions with other stressors such as climate change[1]. Risk that local people are excluded from wetlands if the blue economy focuses more on economic results than sustainability[4].

How does this issue present an opportunity for Mediterranean wetlands? Formal policies and agreements for the sustainable use of coastal wetlands could bring them into the conservation policy and political arenas. The blue economy model could drive economic growth to meet the needs of a growing population with minimal environmental damage, as long as sustainability is maintained as a key principle. There is a role for protection and restoration of coastal wetlands in a sustainable blue economy[5], both to support other activities and as an economic activity in its own right[6]. Mediterranean countries can unite around a tangible, shared resource [cf. Issue 44].

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6. Okafor-Yarwood I, Kadagi NI, Miranda NAF, Uku J, Elegbede IO, Adewumi IJ (2020) The blue economy–cultural livelihood–ecosystem conservation triangle: the African experience. Front Mar Sci 7:586

40. Changing attitudes to economic development, with increasing priority to social and natural capital over financial capital

Supporting information: It is possible that Mediterranean countries will realign their development plans to place greater value on the environment – including wetlands as ecosystem service providers and nature based solutions to future challenges. There is an increasing realisation that continued economic growth is not environmentally sustainable[1]. Around the world, countries have shifted away from economic growth as the sole measure of success: Bhutan publishes an annual Gross National Happiness Index[2] and in 2019 New Zealand produced its first Wellbeing Budget[3]. The COVID-19 pandemic may offer an opportunity, and a stimulus, to drastically change development pathways in the Mediterranean[4–6].

How does this issue pose a threat to Mediterranean wetlands? N/A

How does this issue present an opportunity for Mediterranean wetlands? Policies favouring social and natural capital in Mediterranean countries could reduce threats to wetlands, e.g. from tourism [Issue 19] and urban growth [Issue 20]. They could also create opportunities for wetland conservation, based on arguments about their ecosystem services and contributions to people[7].

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2. Center for Bhutan Studies (2020) Gross National Happiness. http://www.grossnationalhappiness.com/. Accessed 25 April 2020
3. Government of New Zealand (2019) The Wellbeing Budget. https://treasury.govt.nz/publications/wellbeing-budget/wellbeing-budget-2019. Accessed 25 April 2020
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6. Sandbrook C, Gómez-Baggethun E, Adams WM (in press) Biodiversity conservation in a post-COVID-19 economy. Oryx

7. Millennium Ecosystem Assessment (2005) Ecosystems and human well-being: wetlands and water synthesis. World Resources Institute, Washington, DC

41. Limited funding for conservation of Mediterranean wetlands, especially research and monitoring

Supporting information: Generally, there is not enough money to support all the actions conservationists want to do[1–3]. Underfunding – relative to the area needing conservation, threatened biodiversity, costs and GDP – is particularly severe in Algeria, Morocco, Jordan and France[2]. Funding for conservation may be strongly affected by the COVID-19 pandemic, due to regional or national economic recessions and new, competing priorities for financial resources[4–6].

How does this issue pose a threat to Mediterranean wetlands? Limited funding for inventories of wetlands or wetland species makes planning for conservation or wise use difficult[7,8]. If there is a lack of robust research into the effectiveness of conservation interventions, it is more likely that ineffective or even harmful interventions will be carried out.

How does this issue present an opportunity for Mediterranean wetlands? May encourage more judicious use of available, limited funding. e.g. focus on proactive rather than reactive intervention, developing and using only effective and efficient interventions, and implementing interventions only when really necessary.

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2. Waldron A, Mooers AO, Miller DC, Nibbelink N, Redding D, Kuhn TS, et al. (2013) Targeting global conservation funding to limit immediate biodiversity declines. Proc Natl Acad Sci USA 110:12144–12148
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4. Bakker VJ, Baum JK, Brodie JF, Salomon AK, Dickson BG, Gibbs HK, et al. (2010) The changing landscape of conservation science funding in the United States: conservation science funding. Conserv Lett 3:435–444
5. Sandbrook C, Gómez-Baggethun E, Adams WM (in press) Biodiversity conservation in a post-COVID-19 economy. Oryx
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7. Mace GM (2004) The role of taxonomy in species conservation. Phil Trans R Soc Lond B 359:711–719
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Governance

42. Missing or inadequate national wetland policies

Supporting information: A policy is a collection of principles outlining intended and acceptable activity, and future direction, for an organisation or government[1]. Parties to the Ramsar Convention should create national wetland policies to support, promote and direct wetland conservation and wise use[1]. In 2016, only 12 of 26 Mediterranean countries (with adequate data) had adopted a specific national wetlands strategy[2]. Even when wetland policies are created, they often fail to consider key elements that affect wetlands (perception of survey respondent). For example, it is important that policies are linked to all activity sectors that affect wetlands, including transport, housing, industry and agriculture[3].

How does this issue pose a threat to Mediterranean wetlands? In the absence of a national wetland policy, wetland management (including conservation, wise use, and research) is likely to be uncoordinated, poorly prioritised, ineffective and wasteful[1]. Wetlands become forgotten under national resource management policies with a wider remit e.g. for water, sustainable development or nature conservation[1].

How does this issue present an opportunity for Mediterranean wetlands? N/A

1. Ramsar Convention Secretariat (2010) National wetland policies: developing and implementing national wetland policies. Ramsar Handbooks for the Wise Use of Wetlands, 4th edition, Vol. 2. Ramsar Convention Secretariat, Gland
2. MWO (2018) Mediterranean Wetlands Outlook 2: solutions for sustainable Mediterranean wetlands. Mediterranean Wetlands Observatory, Arles
3. Anon (1997) ENTREVISTA/INTERVIEW Mike Smart, Ass. Secretay General, Ramsar Bureau. Boletín SEHUMED 1:1–2

43. Improved communications bring Mediterranean wetlands on to the policy agenda

Supporting information: To date, Mediterranean wetlands have largely been overlooked by policy, due to *inter alia* poor communication about wetland protection and wise use, the scarcity of wetlands in terms of surface area, and the perception of natural resources (including water) as free capital for development[1]. Well-framed[2,3], well-timed (e.g. taking advantage of policy windows[4]) messages delivered through appropriate channels may help bring wetlands into the focus of policymakers. Well-framed messages might communicate the value of wetlands to development and as solutions to societal challenges[1,5]. An example of a recent, large-scale communication project was the MedWet-led 'Off Your Map' Campaign[6].

How does this issue pose a threat to Mediterranean wetlands? N/A

How does this issue present an opportunity for Mediterranean wetlands? Increased protection and funding for Mediterranean wetland conservation.

1. MWO (2011) Mediterranean wetlands monitoring situation and needs assessment (March 2009–June 2011). Mediterranean Wetlands Observatory, Arles
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3. Durham E, Baker H, Smith M, Moore E, Morgan V (2014) The BiodivERsA stakeholder engagement handbook. BiodivERsA, Paris
4. Rose DC, Mukherjee N, Simmons BI, Tew ER, Robertson RJ, Vadrot ABM, et al. (2017) Policy windows for the environment: tips for improving the uptake of scientific knowledge. Environ Sci Policy 113:47–54
5. IUCN French Committee (2019) Nature-based solutions for climate change adaptation & disaster risk reduction. International Union for Conservation of Nature, Paris
6. MedWet (2020) 'Off Your Map' communication campaign on Mediterranean coastal wetlands. https://medwet.org/off-your-map-communication-campaign-on-coastal-wetlands/. Accessed 25 November 2020

Management and monitoring

44. Management of transboundary wetlands

Supporting information: Several important Mediterranean wetlands or watersheds cross national borders: the River Nile flows through multiple African countries; Lake Prespa straddles Greece, Albania and North Macedonia; Lake Skadar is shared by Albania and Montenegro; the Hutovo Blato-Neretva Delta crosses Bosnia-Herzegovina and Croatia; the Rivers Tigris and Euphrates run through Turkey, Syria (and Iraq); and the Jordan River Basin is shared between Jordan, Lebanon, Syria, Palestine and Israel. In other cases, collections of wetlands across multiple countries form critical landscapes for biodiversity (e.g. wetlands of Tunisia and Libya[1]). Countless Mediterranean wetlands are shared between multiple regions or provinces *within* countries.

How does this issue pose a threat to Mediterranean wetlands? Transboundary Mediterranean wetlands or water resources often lack collaborative management plans[2]. Successful management in one country or region could be negated by the actions of their neighbours. For example, Ethiopia's Grand Renaissance Dam will affect water levels in the River Nile downstream, with implications for irrigation, transport and hydropower production[3]. Linguistic, political, legal, economic, cultural and psychological barriers may complicate coordinated conservation efforts[4–6]. Wetlands may be managed for political gain, with disregard for biodiversity or ecosystem service provision: in May/June 2014, Turkey reduced the flow of the Euphrates into Syria, starving Lake Asad of 1.6 billion m^3 of water and reducing hydropower production[7].

How does this issue present an opportunity for Mediterranean wetlands? Potential to foster cooperative research and management to benefit wetlands and all concerned countries or regions[8]. For example, coordinated conservation between all countries containing the Nile Basin could reduce conservation spending by > $80 million compared to an uncoordinated, business-as-usual scenario[9]. Transboundary control of issues such as water abstraction, pollution, fire and poaching can be highly effective[5]. Potential to conserve large wetland landscapes to maintain connectivity and metapopulations.

1. CEPF (2017) Ecosystem Profile: Mediterranean Basin Biodiversity Hotspot. Critical Ecosystem Partnership Fund, Arlington, VA
2. Mansourian S (2012) Natural resource governance in North Africa: challenges and opportunities. IUCN Social Policy and IUCN Mediterranean Programme

3. Mutahi B (2020) Egypt–Ethiopia row: the trouble over a giant Nile dam. https://www.bbc.com/news/world-africa-50328647. Accessed 25 April 2020
4. Ganoulis J (2006) Water resources management and environmental security in Mediterranean transboundary river basins. In: Morel B, Linkov I (eds) Environmental security and environmental management: the role of risk assessment. Kluwer Academic Publishers, Dordrecht, pp 49–58
5. PAP/RAC (2019) The governance of coastal wetlands in the Mediterranean: a handbook. Priority Action Programme/Regional Activity Centre, Split
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7. Dohrmann M, Hatem R (2014) The impact of hydro-politics on the relations of Turkey, Iraq, and Syria. Middle East J 68:567–583
8. Kark S, Levin N, Grantham HS, Possingham HP (2009) Between-country collaboration and consideration of costs increase conservation planning efficiency in the Mediterranean Basin. Proc Natl Acad Sci USA 106:15368–15373
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45. Development of eDNA and eRNA technology for monitoring Mediterranean wetlands and their biodiversity

Supporting information: eDNA and eRNA refer to DNA and RNA, respectively, that is free in the environment and so can be obtained from environmental samples[1,2]. These molecules can provide information on species, populations and communities[1]. eRNA is stable enough in the environment to be sampled, but less stable than eDNA meaning it is less prone to contamination and may offer a better indication of the living organisms present in the local environment[2]. Some remaining methodological and conceptual issues remain to be resolved before either molecule becomes a viable, widespread tool[1]. The development and implementation of eRNA technology currently lags behind that for eDNA[2].

How does this issue pose a threat to Mediterranean wetlands? N/A

How does this issue present an opportunity for Mediterranean wetlands? Allows thorough monitoring of biological communities and functions[1]. Potentially more cost-effective than other sampling methods[3]. Avoids need for destructive sampling (e.g. killing hosts to survey their parasites[4]). Especially useful for species that are difficult to sample using traditional means (e.g. species in inaccessible habitats[5], rare species[6], cryptic species). Opportunity for citizen engagement during sampling[7].

1. Thomsen PF, Willerslev E (2015) Environmental DNA – an emerging tool in conservation for monitoring past and present biodiversity. Biol Conserv 183:4–18
2. Cristescu ME (2019) Can environmental RNA revolutionize biodiversity science? Trends Ecol Evol 34:694–697
3. Smart AS, Weeks AR, Rooyen AR, Moore A, McCarthy MA, Tingley R (2016) Assessing the cost-efficiency of environmental DNA sampling. Methods Ecol Evol 7:1291–1298
4. Hartikainen H, Bass D, Briscoe AG, Knipe H, Green AJ, Okamura B (2016) Assessing myxozoan presence and diversity using environmental DNA. Int J Parasitol 46:781–792
5. Reinhardt T, Schingen M, Windisch HS, Nguyen TQ, Ziegler T, Fink P (2019) Monitoring a loss: detection of the semi-aquatic crocodile lizard (*Shinisaurus crocodilurus*) in inaccessible habitats via environmental DNA. Aquatic Conserv: Mar Freshw Ecosyst 29:353–360
6. Jerde CL, Mahon AR, Chadderton WL, Lodge DM (2011) "Sight-unseen" detection of rare aquatic species using environmental DNA: eDNA surveillance of rare aquatic species. Conserv Lett 4:150–157
7. Biggs J, Ewald N, Valentini A, Gaboriaud C, Dejean T, Griffiths RA, et al. (2015) Using eDNA to develop a national citizen science-based monitoring programme for the great crested newt (*Triturus cristatus*). Biol Conserv 183:19–28

46. Use of artificial intelligence/machine learning to process data

Supporting information: Artificial intelligence (AI) refers to the use of computers to mimic the cognitive functions of humans. Machine learning is a subset of AI, and involves software modifying algorithms in response to data and feedback it receives[1]. AI can allow rapid, consistent processing of large amounts of interconnected data[2,3].

How does this issue pose a threat to Mediterranean wetlands? AI algorithms are a black box (the internal workings are not always clear or easy to understand), increasing the risk of misinterpreting the outputs and engaging in ineffective or damaging conservation practice (e.g. overlooking rare species[4]). Inadequate or biased training data can generate biased or misleading ouputs[4]. Increased access to AI-based information could drive overexploitation of resources[3].

How does this issue present an opportunity for Mediterranean wetlands? Increased capacity for analysis of large, interconnected databases to develop holistic solutions to environmental problems[3]. Applications relevant to Mediterranean wetland conservation include: mapping wetlands[5]; identifying priority wetlands for restoration[6]; automatically detecting illegal activities in real time (e.g. fishing https://www.oceanmind.global/ and poaching[7]); guiding precision agriculture to reduce water and chemical inputs (e.g. https://analytics.ag/); monitoring and modelling urban watersheds to reduce pollution [Issue 47]; and literature searching (e.g. for reviews and horizon scans[8]). AI can support progress towards many of the Sustainable Development Goals[3].

1. Venkatesan M (2018) Artificial Intelligence vs. Machine Learning vs. Deep Learning. https://www.datasciencecentral.com/profiles/blogs/artificial-intelligence-vs-machine-learning-vs-deep-learning. Accessed 25 April 2020
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47. Smart urban water management

Supporting information: Smart or intelligent urban water management will integrate data monitoring, transmission, management and use to improve the efficiency of water management[1]. Smart urban areas will be equipped with numerous advanced sensors (e.g. for water flow through pipes, water levels in tanks, pollutant concentrations, precipitation). The data from these sensors can be fed into high-resolution, self-learning models which produce near real-time outputs[2]. Development of these systems is/will be facilitated by improvements in sensor, communication and computing technology[2,3]. Smart urban water management will become more important as the urban population grows [Issue 20], water becomes more scarce [Issue 10 & Issue 11] and as storms become more frequent and/or intense [Issue 12]. Smart water management systems are currently in place, at various stages of development, in many urban areas around the Mediterranean including Jerusalem, Israel[1], Cascais, Portgual[1] and Madrid, Spain[4]. In the future, they will likely expand in range and effectiveness across the Mediterranean.

How does this issue pose a threat to Mediterranean wetlands? N/A

How does this issue present an opportunity for Mediterranean wetlands? Real-time monitoring and modelling allow effective, proactive intervention (e.g. diverting stormwater to parts of sewer system with lower flows[5]) or rapid reactive intervention (e.g. following alerts to blockages in sewers[5], pollution events[3], leaks in pipes[1,4] or abnormal water usage[1,4]). This could minimise impacts on wetlands or water supplies.

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48. Increasing quality and declining cost of drones

Supporting information: Drones (also known as unmanned vehicles or remotely operated vehicles) offer a relatively risk-free and low-cost option to rapidly and systematically generate high quality data on natural phenomena[1]. Thus, they have become popular tools in environmental research and management[1,2]. "Increasing quality" refers to factors such as improved image resolution, multispectral sensors, and longer operation times[2].

How does this issue pose a threat to Mediterranean wetlands? Disturbance of wetland animals[3,4]. Visual and acoustic disturbance of local people or tourists, reducing the value of wetlands for them.

How does this issue present an opportunity for Mediterranean wetlands? Drone surveys can be carried out more quickly and more regularly than manual surveys. Drones allow easier monitoring of areas that are tricky to access by foot/vehicle, such as wetlands. Applications relevant to Mediterranean wetlands include law enforcement, monitoring invasive species, monitoring breeding birds, monitoring water quality, monitoring the effects of restoration interventions, mapping underwater topography, firefighting, distributing seed for restoration and development of educational tools[1,5,6].

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49. Use of social media for tracking human interaction with environment

Supporting information: Media such as Twitter, Facebook, Instagram and Flickr can be used to track human activities in nature, as well as discourse and debates about the environment[1,2]. For example, in the context of fisheries, social media data could be used to track fish population trends, fishers' behaviour, and fishers' attitudes towards management initiatives[3]. Social media data are a rich source of information (e.g. text, likes, photographs, timestamps, networks), but are often heavily biased towards certain user groups and geographic locations[1,4]. New technologies, such as underwater wireless connections, could increase the amount and quality of data available from wetlands[3].

How does this issue pose a threat to Mediterranean wetlands? Could lead to incorrect conclusions and misguided management if biases are not controlled for. Potential for conflicts between wetland researchers/managers and the public, if the latter feel their privacy is compromised by analysis of social media data. Digital data can reveal sensitive information such as the precise location of rare or threatened species, which could facilitate poaching[3].

How does this issue present an opportunity for Mediterranean wetlands? Could allow better understanding of how people use and value Mediterranean wetlands, then adjustment of management methods and/or marketing messages to maximise their effectiveness[5]. Particularly useful in wetlands, where research may be hindered by limited accessibility and low detectability of species[3]. Studies using existing social media data may be less costly than field sampling or social surveys[3].

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50. Development of regional networks for sharing knowledge about Mediterranean wetland management

Supporting information: This issue includes both physical and virtual networks. These incorporate a range of stakeholders, from researchers to governments and civil society organisations[1]. Knowledge sharing is facilitated by improvements in communication technologies: video calls, webinars, social media, co-working software. Examples of existing networks relevant to Mediterranean wetlands include:

- MedWet (http://metwet.org),
- the Mediterranean Wetlands Alliance (https://tourduvalat.org/en/mediterranean-wetlands/the-mediterranean-alliance-for-wetlands/),
- the Mediterranean Institute for Nature and Anthropos (https://med-ina.org/),
- the Mediterranean Waterbird Network (https://www.medwaterbirds.net/),
- the Network of Mediterranean Plant Conservation Centres (http://www.genmeda.net/),
- the Union for the Mediterranean (https://ufmsecretariat.org/),
- the Network of Mediterranean Experts on Climate and Environmental Change (https://www.medecc.org/).

How does this issue pose a threat to Mediterranean wetlands? Risk of excluding local or traditional knowledge from high-level networks, and alienating local people.

How does this issue present an opportunity for Mediterranean wetlands? Networks allow sharing of knowledge and experience about what exists where, and about what works and what doesn't. This can increase both efficacy and efficiency of management. Ability to coordinate landscape-scale conservation actions[1]. Ability to match issues or threats with the institution most capable to address them[2].

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