Workgroup members

This guide is a product of the expert workgroup discussions on climate change impacts and a monitoring assessment conveyed by IUCN-Med and RAC/SPA. We are grateful to all of them for their advice and guidance:

Aybars Altiparmak , Turkish Ministry of Forest and Water Affairs, Turkey
Marilena Aplikioti , Ministry of Agriculture, Natural Resources and the Environment, Cyprus
Sami Ben Haj , Cabinet Thétis, Tunisia
Jose Carlos García Gómez , University of Sevilla, Spain
José Antonio García Charton , University of Murcia, Spain
Bella S. Galil , National Institute of Oceanography Israel Oceanographic & Limnological Research, Israel
Mª del Carmen García Martínez , Instituto Español de Oceanografía, Spain
Giuseppe di Carlo , WWF Mediterranean Programme Of ce, Italy
Joaquim Garrabou , Institut de Ciències del Mar, Spain
Dan Laffoley , IUCN's World Commission on Protected Areas
Christophe Lejeusne , Estación Biológica de Doñana-CSIC, Spain
Piero Lionello , University of Salento, Italy
Melina Marcou , Ministry of Agriculture, Natural Resources and Environment, Cyprus
Paula Moschella , CIESM
Petra Rodic Baranovic , State Institute for Nature Protection, Croatia
Maria Salomidi , Institute of Oceanography, Hellenic Centre for Marine Research, Greece
Nadia Suda Lanzon , Malta Environment and Planning Authority, Malta
Leonardo Tunesi , ISPRA, Italy
Robert Turk , Institute of the Republic of Slovenia for Nature Conservation, Slovenia
Manuel Vargas , Instituto Español de Oceanografía, Spain
Marcello Vichi , Euro-Mediterranean Centre for Climate Change, Italy

We also thank Diego Kersting (Marine Reserve of Columbretes Islands), Dimitriadis Charalampos (National Marine Park of Zakynthos), Mark Walton (University of Wales, UK), Boris Weitzmann (Medes

improve information and adapt to change. Moreover, information about the impact of climate change on biodiversity will provide the evidence required to justify investment in mitigation and adaptation measures. Finally, climate change monitoring programmes can

Modelling change

Projected change by the end of the century

Most of the models' outcomes for the different scenar

Ocean deoxygenation: the global trend of decreasing oxygen levels as a result of ocean warming and increasing strati cation species has been reported throughout this region, as in the case of the round sardinella Sardinella aurita and one of its predators, the blue sh Pomatomus saltatrix, a migratory coastal pelagic species whose northern boundary was believed to be the southern Catalan coast in the western Mediterranean. Both species have been reported to be increasing in abundance in recent years and expanding northwards into the north-western Mediterranean (Sabates et al., 2006). These changes are believed to be associated with higher spring temperatures, which are crucial for the migration and reproduction of these species. Annual cyclical uctuations related to natural temperature variations could nonetheless have major consequences for the physiology, tness and abundance of these species.

One of the reasons for the successful range expansion of many of these temperature-sensitive species is their abilittthwr thns iue sh abtioou(r)4(, favouring their rapid spread northwards and westwards in the Mediterranean. The fastest reported of these colonizers is the bluespotted cornet sh Fistularia commersonii, which has been able to develop large populations in the warm eastern areas and colonize the entire Mediterranean from there in less than 10 years (Azzurro et al.2012). Other species such as two rabbit shes

Mass mortalities of macrobenthic communities

Unprecedented mass-mortality events and diseases linked to climate warming have been observed in the Mediterranean in recent decades. More than 30 species in Mediterranean hard-bottom communities have been affected by mass-mortality events associated with unusual increases in seawater temperature along thousands of kilometres of coastline, mainly in the north-western Mediterranean (Cerrano *et al.* 2000; Garrabou *et al.*, 2009).

Coralligenous formations, considered one of the richest habitats in the Mediterranean, have suffered most severely. These communities, mostly living in what is essentially a cold-water environment due to the formation of a seasonal thermocline, are adapted to a changing environment produced by intermittent and transitory processes, including upwellings, downwellings, vertical mixing, horizontal advection and heat waves. Conversely, other affected species that live in shallower coastal habitats such as caves and rocky, alga-dominated environments are adapted to a more stable environment during summer periods.

Mass-mortality events in these hard-bottom communities have mainly been observed along the north-western Mediterranean coast, from north-eastern Spain and the Balearic Islands to France and the Ligurian coast of Italy, and to a lesser extent around Corsica. In 1999 and 2003, these events were the most severe ever recorded in the area and affected a wide variety of species and taxa along more than 1,000 km of these coasts down to a depth of 50 m (Garrabou *et al.*, 2009). Other similar events, although at a smaller scale, have been observed in other Mediterranean areas involving other organisms (e.g. bald sea-urchin disease affecting *Paracentrotus lividus*). Many of these mortality events have been linked to a particularly strong summer stratification of the water column and a possible reduction in food resources (Coma *et al.*, 2009).

The impact of mortality events on populations has been severe, especially on Mediterranean gorgonians (*Paramuricea clavata*, *Eunicella singularis*, *E. cavolinii*, *Lophogorgia ceratophyta* and *Corallium rubrum*) and sponges (*Ircinia fasciculata*, *Spongia officinalis* and *S. agaricina*). For example, in some affected areas up to 90% of red gorgonian *Paramuricea clavata* colonies show total or partial mortality. Other species however, such as the yellow gorgonian *Eunicella cavolinii*, seem to be more resistant to these warming events, although the effects on their reproductive biology, vulnerability to disease and growth can still be seen several years after the initial stress, and there may be no significant signs of recovery.

Given that the affected species are in general long-lived organisms characterized by slow population growth and limited larval dispersal, the ability of affected populations to recover is probably quite limited. Habitat-forming species such as these gorgonians provide shade and shelter for other species by means of their skeletal structure. Significant changes in their abundance can therefore have a major effect on the organization and functioning of the community.

Population blooms

Changes in temperature and other conditions have also been linked to increasingly frequent reports of blooms of a variety of organisms.

Several studies have demonstrated a significant increase in jellyfish abundance in different areas of the

Another type of bloom, mucilaginous aggregates, is caused by the proliferation of several phytoplankton species developing seasonally and at different depths. Marine mucilage oating on the surface or in the water column can have a long life span (up to 2–3 months)

Refugia: Physical environments that are less affected by climate change than other areas (i.e., due to local currents, geographic location, etc.) and are thus a "refuge" from climate change for organisms.

The organic deposits in Mediterranean saltmarshes and seagrass meadows, principally those of *Posidonia oceanica*, are an exceptional example of a natural carbon sink ecosystem as they considerably reduce the harmful effects of human carbon emissions by capturing and storing part of the excess carbon dioxide (CO_2). Such carbon that is sequestered, stored and released from coastal ecosystems, including mangrove swamps, is known as 'blue carbon'.

Posidonia oceanica meadows can sequester and store large amounts of organic carbon in sediments and biomass: the average storage rate for the Mediterranean is calculated to be 0.15 to 8.75×10^{6} tC a year, according to several recent studies (Serrano, 2011). Overall, the historical carbon deposits in the mats below Mediterranean seagrass meadows could amount to as much as 2.5 to 20.5×10^{9} tC. Their large capacity together with their extremely long carbon residence time makes *Posidonia* meadows a very important carbon sink relative to the total carbon stored in the oceans (Pergent et al., 2012).

When degraded or disturbed (e.g. by trawling, pollution or other cumulative stressors), however, these habitats can release the carbon dioxide back into the ocean and atmosphere, thus having an adverse effect by increasing greenhouse emissions.

Well represented in many Mediterranean MPAs, these seagrass meadows are highly biodiverse habitats whose conservation helps mitigate climate change effects, in addition to increasing the MPAs' natural resilience. MPA managers can assist by preventing the loss of the carbon that is currently stored in these habitats and improving management to enable the seagrass to retain

MPA CASE STUDY 1

Vulnerability assessment of sea turtle nesting beaches in Zakynthos MPA, Greece

Sea-level rise is likely to dramatically change the Mediterranean coastline, particularly in low-lying areas (Ferreira et al., 2008). Many habitats such as beaches or wetlands may be degraded or destroyed by the rising waters and the overlapping effects of increased precipitation and storm frequency.

In Greece, the National Marine Park of Zakynthos and the University of the Aegean recently conducted a vulnerability assessment to examine the potential climate change impacts and adaptation responses in sea turtle nesting beaches, which in general have not yet been properly examined or fully understood (Fish et al., 2005). The Marine Park, which is situated in the southernmost part of the island of Zakynthos, holds the most important nesting sites for the endangered loggerhead turtle Caretta carettain the Mediterranean. Its management objectives are to preserve the natural environment and conserve the ecological balance of the marine and coastal area of Laganas Bay and the Strophadia Islands, to protect the sea turtles and other species, and to develop conservation activities in Zakynthos.

A rise in sea level would threaten the endangered sea turtle population by reducing the available nesting space on the beaches. Higher temperatures would also affect the growth and sex ratio of the hatchlings. The intensi cation of sand dune erosion, storm surge frequency, urban infrastructure and disturbances from the growing tourist activities would further exacerbate the problem.

Photo: Zakynthos National Park archives

Sea turtle hatchings in the National Marine Park of Zakynthos, Greece

To assess the main effects of climate change on nesting beaches, modeling sea level rise scenarios, beach pro le measurements, meteorological data as well as coastal seabed and water column characteristics have been measured. All these parameters were then related to turtle nesting patterns. The results indicated that higher sea levels would have a considerable impact. In the 0.2 m sea-level rise scenario, it was estimated that the beaches would retreat between 0,8 to 15,9m, whereas in the 0,5 m and 1.0 m scenarios, they could retreat between 4,9-25,2 m and 10,8-37,3 m, respectively. In the worst-case scenario (a 2.0 m storm surge), beach recession was estimated between 23,2 to 80,8 m (Velegrakis et al. 2013).

Beach pro le transects through Gerakas nesting beach. From Vlegrakis et al., 2013.

These estimates suggest that the beach will potentially lose 44–94% of its width in the rst three sea-level rise scenarios, whilst in the worst case of a 2.0 m storm surge it will be entirely inundated. The beach cannot adapt to sea-level rise by transgression, as it is backed by cliffs. The result will be coastal squeezing, which in turn will dramatically reduce the available nesting space and increase con ict related to the recreational use of the beach; it might even force the turtles to nest on other beaches.

Information from this vulnerability assessment will help managers to prioritize conservation efforts, use realistic measures to mitigate potential sea-level threats and establish a long-term monitoring and alarm system. Training for the Park staff in the use of the tools that have been produced will enable them to carry out future vulnerability assessments and develop adaptive planning.

Predicted coastline retreat in Gerakas beach for different sea-level rise scenarios (0.2, 0.5, 1.0, 2.0 m). From Vlegrakis et al., 2013.

Sea turtle hatching of *Caretta caretta*.
Photo: Héctor Garrido, CSIC.

Developing a monitoring and evaluation protocol for the MPA network

Why monitor climate change effects?

Mediterranean MPAs are under growing pressure from both climate change and other anthropogenic in u-ences, particularly coastal development. These pres-sures require that managers understand and are aware of the environmental changes that are currently occur-ring and are likely to manifest themselves in the MPA environment in the near future. Rare, endangered or threatened species or sites and habitats that hold large numbers of species might be particularly vulnerable to climate change, as species will need to move or adapt to the changing environmental conditions. Monitor-ing can be of assistance in identifying these adverse effects and providing early warnings. The inclusion of climate change in standard monitoring programmes would help in assessing and putting in place appropri-ate management actions to protect the most resilient or least susceptible communities, habitats and areas, and in exploring other potential management adapta-tion strategies.

Because MPAs cover relatively undisturbed environtion numbers) in order to keep track of the condition of their marine environment. Building on this information, the monitoring programme should incorporate climate change and its impacts within the standard procedure. The results of climate change monitoring supplemented by observations of coastal and marine condition (i.e. physical and biochemical parameters) can then be used to determine causes and effects when changes in marine biodiversity are found.

Given the great range and diversity of climate change impacts and the usually limited resources available to MPAs, a suite of key indicators is needed that can facilitate monitoring and lead to an understanding of the impact of climate change on their biodiversity.

Within each category several indicators can be used to build the required baseline data for assessing the severity of climate change impact on MPAs.

The choice of which indicators and parameters to monitor to some extent reflects current knowledge and estimates of climate change impacts, and will need to be revised in the future. The selected indicators are therefore not intended to be the only ones that should be used to monitor the response of marine communities; they should in fact form part of a broader MPA monitoring programme based on multiple management objectives.

To be effective sentgrtip611(l)-9(i)-9mhate chane24(,te)-20h5 453-a(17(s)-02(e i)52795 453dw)-12(i)7

Monitoring needs to occur at multiple scales and there is no single method or indicator that ‘ ts all’. Each MPA is unique and represents a particular set of ecosystems, biodiversity, environmental conditions and human uses, all of which result in a speci c degree of vulnerability to conditions associated with climate change. Besides, not all monitoring programmes can be relevant to all MPAs. Within this framework, monitoring will serve two goals:

- For individual MPAs, a monitoring programme will track changes in key ecosystem components within the MPA;

wmrammes can be wet9riewo4ts

- For the network of MPAs, the monitoring pro

1. Physical and biochemical condition

INDICATOR

Since several scientific research institutions are working on these issues, it is advisable to check whether monitoring programmes and/or protocols already exist in or near the MPA waters and whether they have data available. A suite of other physical parameters, such as air temperature, wind speed, etc., collected by various different government agencies and institutions could also be useful for interpreting the results.

PROPOSED MONITORING PROCEDURE

MPA sampling is crucial for comparing local variability with the regional observations made by research institution monitoring stations. Wh166 Tw - Tw - Tw -to ceaecOTw - -14(n)-9(d13(r)-1(e)-m)th3f oiond132(omp)4mm2(r)9(i)3(d)6(y r)i(i)2r

2. Changes in reproduction and breeding dates of key species

Increasing seawater temperature affects physiological

Flowering events of *Posidonia oceanica* meadows

Another key parameter to monitor could be the occurrence of Posidonia owering and seed production. The Mediterranean seagrass Posidonia oceanicaexhibits both vegetative and sexual reproduction. Sexual reproduction in this species is considered a rare and sporadic phenomenon, although some episodic owering has been observed associated with extreme summer temperatures (Diaz-Almela et al., 2007). Flowering of Posidonia meadows takes place in autumn, in September–October

ni[(1(a)---1.8 321(pla)ma-10((m)-)91(r)](g)-1 m)(d a r)-7(at)111()1333(tr)01(28)y 2(e)(r)3 ET Twr

3. Episodic events

Since the mid-1970s, large-scale episodic events such as disease epidemics, mass mortalities and biological population blooms have been occurring in marine environments with increasing frequency, intensity, variety and range (Harvel et al., 1999; Hayes, 2001). There is some evidence that climatic anomalies are the underlying (direct or indirect) cause of many of these events (Harvel et al., 1999, 2002). Episodic weather events such as storms change freshwater ows and the export of nutrients to coastal waters, and also affect the salinity of coastal ecosystems. Temperature anomalies, even of short duration, can also trigger population explosions

MPA CASE STUDY 3

Cladocora caespitosa is the only colonial coral native to the Mediterranean that lives in permanent symbiosis with microscopic algae within the living coral. Its colonies may join to form reef-like structures up to several square

INDICATOR

Mass-mortality events

In recent years, rocky coastal habitats have been badly hit by several mass-mortality events. The most severe reported events affected large areas (more than 1,000 km of coastline) and the populations of some 40 macrobenthic species belonging to several different phyla (sponges, cnidarians, bryozoans, molluscs and ascidians) in the north-western Mediterranean. There have been reports of similar happenings in other parts of the Mediterranean. Habitat-forming species, including gorgonians and sponges, have suffered the worst impact down to depths of 45 m.

In general, these events have been associated with an anomalous rise in seawater temperatures in late summer and early autumn. Under these conditions organisms have suffered from a variety of stressors, including energetic constraints, physiological stress, reaching thermal tolerance limits and development of thermo-dependent pathogens, leading to the observed mortality events.

PROPOSED MONITORING PROCEDURE

In order to monitor the effects of mass mortalities within MPAs, scuba diving surveys carried out by techni

(tr)-1(e)-17(s((143 Two51143 Two51143 ((143 TwNs1(e w)3(o)-10(r)-14(s)-7(t i)-8(m.567 143 Two7(t i)-(TJ 0 Tc 0 Tw as)-7(T

4. Shifts in species distribution patterns

Rapid and signi cant shifts in the ranges of non-native shes, crabs and other invertebrates have been recorded in the Mediterranean in recent decades (CIESM, 2008). Native species are also moving northwards and/or to greater depths in response to warmer waters. Besides, the Mediterranean is threatened by introduced non-native species. Some of these species have warm-water af nities and the rising temperatures could be favouring their spread (see Case study 4). Overall the fo[illegible]

MPA CASE STUDY 5

Shifting spatial distribution of marine species

4. Using decision support tools for adaptive management and dialogue

Decision support tools for MPA managers, such as vulnerability and risk assessments, strategic habitat conservation approaches and scenario planning, can be created in pilot projects to help improve the understanding of adaptation options and assist decision making under uncertain conditions. Existing knowledge should be collated, the climate analysed and data integrated to produce readily usable information, which can help managers to rapidly assess climate change impacts, facilitate the adaptation of individual species, increase habitat
--e0(19-11(7(a)-7(c)-10(ts)4(, f)-6(a)-7(c-9(e hr)-10(a)-7(g)]Tm -24.d)4(ri-7e)-16)-8(m)-11(p)-7(t 7i)n)-9(d r)-k

Medes Islands MPA. Photo: J. A. González Nieto

In conclusion

There are still large gaps in our knowledge about the future impact of climate change, but we can already see some early signs of its effects on marine communities in the Mediterranean. Climate change is likely to have drastic effects on the habitat of the flora and fauna of MPAs but the impact will vary between different Mediterranean regions and between individual MPAs within each region. MPAs located in the more northerly Mediterranean areas could have an important role to play in preserving endemic and native species as they shift their ranges with warming temperatures. Local hydrodynamic conditions or other factors might also result in different vulnerabilities for the marine communities within those MPAs. Overall, this makes it difficult to delineate specific adaptation approaches for the entire MPA network. Effective management will thus require a flexible approach, in which capacity building and monitoring will be crucial for understanding the changes that occur and informing the conservation approaches to be adopted, which will have to be adjusted as new information becomes available.

For further reading

Allen Consulting, 2005. 'Climate Change Risk and Vulnerability'; Final report to the Australian Greenhouse Of ce by The Allen Consulting Group, March 2005, 159 pp.

Azzurro, E., Moschella P., Maynou F., 2011. Tracking Signals of Change in Mediterranean Fish Diversity Based on Local Ecological Knowledge. PLoS ONE 6(9): e24885. doi:10.1371/journal.pone.0024885.

Azzurro, E., Soto S., Garofalo G., Maynou, F., 2012. Fistularia commersonii in the Mediterranean Sea: invasion history and distribution modeling based on presence-only records Biological Invasions, DOI 10.1007/s10530-012-0344-4.

Ben Rais Lasram, F., Guilhaumon, F., Mouillot, D., 2010. Global warming and exotic shes in the Mediterranean Sea: introduction dynamic, range expansion and spatial congruence with endemic species. In: Golani D, Appelbaum-Golani B (eds) Fish invasions of the Mediterranean Sea: change and renewal. Pensoft Publishers, So a-Moscow, pp 35–56.

Bensoussan, N., Linares, C., Cebrian, E., Crisci, C., Kipson, S., Teixido, N., Romano, J.C., Bianchimani, O., Kersting DK., Lorente, A., Riera i Arago, V., Cadene, F., Laffon, J.F., Payrot, J., Bpasi6272(.)38(,)]3(c)-., L.(va)-12(s11-16(r)-16(r5n)-12(-16(i)-11(a)-1Z10(o)2(f)-32(.)38(, R22(.

Coll, M., Piroddi C., Steenbeek J., Kaschner K., Ben Rais Lasram F., et al., 2010. The Biodiversity of the Mediterranean Sea: Estimates, Patterns, and Threats. PLoS ONE 5(8): e11842. doi:10.1371/journal.pone.0011842

Coma, R., Ribes M., Serrano, E., Jiménez E., Salat J., Pascual J. 2009. Global warming-enhanced strati cation and mass mortality events in the Mediterranean. Proc. Natl. Acad. Sci. USA 106:6176–6181.

Crisci, C., Bensoussan, N., Romano J.-C., Garrabou J., 2011. Temperature Anomalies and Mortality Events in Marine Communities: Insights on Fac tors behind Differential Mortality Impacts in the NW Mediterranean. PLoS ONE 6(9): e23814. doi:10.1371/journal.pone.0023814.

Critto, A., Gallina, V., Torresan, S., Rizzi J., Zabeo, A., Harmelin, J.G., Robert, P., Cantou, M., Harmelin-Vivien, M., 2007. Long term changes in the dusky grouper (*Epinephelus marginatus*) population from a rk12(e)-15(l30(g t)12(e)d [(N) U)12312k -41Bg teito7.03.G, M. m8(, 10(i)7(ce)s)-16iu75 10(i) 3515(o) d-3(x)-16a-10(i-12.316 -1.1

Intergovernmental Panel on Climate

International Global Climate Observing System (GCOS) and the Global Ocean Observing System (GOOS)

http://www.wmo.int/pages/prog/gcos/index.php?name=AboutGCO

GCOS is an internationally coordinated network of ob

CLIM-RUN

http://www.climrun.eu/

The MedPAN collection

The MedPAN collection is a series of publications designed
to provide Marine Protected Areas (MPA) managers and other
stakeholders in the Mediterranean, guidance, practical and useful

t61 -2.t6114 1 088 47-2..95 Areanetworkcu6v7(guidan) pnce, An