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Regime shifts at multiple trophic levels of the Black Sea pelagic ecosystem

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Functioning of the Black Sea ecosystem has profoundly altered starting by the early 1970s. The most striking changes occurred during the 1980s and the early 1990s under a complex system of trophic interactions imposed simultaneously by bottom-up controls of eutrophication and cooling and top-down controls of overfishing and population outburst of gelatinous carnivores. Phytoplankton biomass increased four-to-five folds with respect to those in the pristine state. Large pelagics and other predator fishes became extinct, and small pelagic fishes started acting as the top predator in the food web. As their stocks rose by three-fold, they were continually overexploited and finally collapsed during the late 1980s. High stocks of herbivorous zooplankton and gelatinous carnivores immediately filled the niche vacated by small pelagics. By the early 1990s, this over-productive state changed to its moderate-to-low eutrophic environment under reducing anthropogenic supply, climatic warming and diminishing effect of gelatinous carnivores. The total small pelagic fish stock and herbivorous zooplankton recovered up to their level observed around the mid-1970s. Applying a set of criteria to the ecological time series data, the present study demonstrates the existence of successive discontinuous regime shifts between alternate states. For the lower trophic level, unequivocal evidence of these shifts is found in phytoplankton biomass,. The first shift abruptly changed the “low production” state to the “high production” state during the mid-1980s in response to cumulative effects of the anthropogenic nutrient load and cooling. Following a decade-long persistence, the “high production” state switched back to its background state by another discontinuous regime shift towards the end of 1990s. The Secchi disk depth, oxic-anoxic interface zone dissolved oxygen and hydrogen sulphide concentration data exhibit similar features and shows tight coupling between lower trophic level and biogeochemical processes in terms of regime shift events. In the higher trophic level, total small pelagic fish stock experi-

enced three consecutive discontinuous regime shifts; first from the low to high stock regime during the mid-1970s, then from the high to low stock regime at the end of the 1980s and back towards the high stock regime at the end of the 1990s. They are primarily triggered by pronounced changes in the fishing pressure (within the range 0.3-0.9). Distinct features of these regime shifts are their (i) reversible character, (ii) existence at multiple trophic levels, (iii) multiple controls imposed by nonlinearly interacting external forcing. The regime shifts linked a decade-long degraded state of the 1980s to the former pristine state and the new restored state started at the end of the 1990s. The regime shift analysis suggests a trend towards rehabilitation of the ecosystem during the present decade.