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Nonlinear controls of anchovy stock and anchovy-gelatinous regime shift in the Black Sea: A modeling study

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A one-dimensional bi-directionally coupled model of lower trophic food web and bioenergetics-based anchovy population dynamics for the Black Sea was used to elucidate *the effects of fishing, environment and mechanisms that control* three sharp changes of anchovy stock between the low, moderate and high quasi-stable regimes *and accompanying changes of gelatinous predator zooplankton biomass.* The first *transition* was a two-fold shift of anchovy stock from its low ($\sim$ 300 kt) to moderate ($\sim$ 700 kt) regime due to weakening piscivores predation pressure *and competitive exclusion of gelatinous carnivores* during the late 1960s. After maintaining the moderate regime until 1978, another two-fold shift to the high stock regime ($\sim$1400 kt) took place during 1979 – 1980 in response to moderate nutrient enrichment of the upper layer water column due to growing effect of eutrophication. *This transition and subsequent high stock phase was accompanied with a low-to-moderate gelatinous biomass (< 1 gC m^{-2}).*This phase was ended by a third regime shift that brought anchovy stock temporarily back to the low regime during 1989-1990 and concurrently proliferated the gelatinous species, *Mnemiopsis*, biomass up to 3.0 gC m^{-2} as an alternative predator. The anchovy-*Mnemiopsis* regime shift was *primarily* linked to excessive nutrient enrichment of the system, but increasing fishing pressure further aggravated the anchovy stock collapse. *As often observed at highly productive intraguild systems, the third shift identifies a transition from the resource (herbivory) – consumer (anchovy) - predator (gelatinous carnivory) coexistence regime to the resource - predator*

only regime. These transitions illustrate nonlinear response of the system to multiple density-independent exogenous controls and their density-dependent feedback mechanisms.