the results and observations of cruise in the Northern Arabian Sea during different monsoonal periods. Results and observations obtained from other cruise are also discussed to have better understanding on bacterial carbon demand and carbon budget of the Arabian Sea.

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Herring survival strategy during overwintering in Northern Norway: environment and predators

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The overwintering strategy of Norwegian spring spawning herring (*Clupea harengus* L.) in the fjords of northern Norway is described. Hibernating herring do not feed. In order to reproduce successfully in the spring, they should not only survive, but also spend as little energy as possible on standard metabolic costs, general swimming performance and predator avoidance to maximize the energy invested into the gonads and thereby reproductive success. Herring seem to save energy by staying passively in deep layers in fjords with low current speed, although the water is relatively warm. The herring are subject to a wide variety of predators. Staying in deep layers in low light levels could decrease the risk of predation by killer whales. However, killer whales seem to be an effective predator, and herd schools of herring by co-operative hunting, cutting pieces of the continuous layer of herring and forcing the fish upwards to form schools. The schools are then herded to shallow water where they are heavily predated upon. At this time, other predators such as saithe, gulls and eagles also attack the herring. When compared to other phases in the life history of adult herring, the total predation pressure may be relatively low. The role of vertical migration and distribution in relation to predation are discussed.

Key words: herring, overwintering strategy, predation, energy, ecosystem.

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Simulation of recent changes in the functioning of ecosystem and the upper layer biochemical structure of the Black Sea

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The processes governing the biogeochemical structure of the upper layer water column in the central Black Sea are studied using a coupled physical-biogeochemical model. It considers dynamically a fully coupled system of the processes taking place in the euphotic zone, the oxycline, the suboxic layer and the suboxic-anoxic interface zone. The pelagic food web is represented by two groups of phytoplankton (diatoms and flagellates), three size groups of zooplankton (microzooplankton, mesozooplankton and macrozooplankton). The macrozooplankton group represents essentially a particular gelatinous species group called the medusae *Aurelia aurita*. The model further incorporates the oxygen dynamics and its coupling with the plankton production, particulate matter decomposition and nitrogen transformation, as well as dissolved organic matter generation and bacterial production, denitrification and hydrogen sulphide oxidation processes in the upper layer water column.

The model investigates the role of several factors which led to drastic changes in functioning of the ecosystem within the last three decades in the Black Sea. The simulations reproduce reasonably well the observed, present-day annual plankton structure involving a series of successive phytoplankton and zooplankton peaks over the year. It is shown that these peaks become progressively stronger since 1970's as a result of increased antropogenic nutrient load from the major rivers. As a result of recent increased population of gelatinous carnivores in the system, the yearly phytoplankton distribution is shown to possess more pronounced summer bloom structures due to stronger "top-down" control of these gelatinous carnivores. The position of the nitrate maximum appears to be intimately related with

the location of the onset of trace level oxygen concentrations as they control the lower limit of the nitrification and the onset of the denitrification in the water column. The model successfully simulates the observed seasonal and vertical variations of the dissolved oxygen in response to its atmospheric and photosynthetic productions, and losses during the particulate matter decomposition and nitrogen transformations.

The simulations support the presence of an oxygen deficient zone (the so-called the Suboxic Layer) below the 15.6 sigma-t level within the interior Black Sea. The upper boundary of the suboxic layer varies depending on the two opposing mechanisms; the oxygen consumption in the remineralization and nitrification and the ventilation associated with the vertical diffusive transport from the oxycline. Its lower boundary always coincides with the vanishing H2S concentrations near the 16.2 sigma-t level.

In the case of complete oxygenation of this zone, the SOL disappears all together as the positions of vanishing oxygen and H2S concentrations converge to a common point, implying that their overlapping is not possible under the realistic oxidation rates.

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Modeling trophic interrelations in the Black Sea

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