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Ichthyotoxicity of a harmful dinoflagellate *Cochlodinium polykrikoides*: Aspect of biochemical and hematological responses of fish exposed to Algal blooms

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To elucidate the ichthyotoxic mechanisms of a harmful dinoflagellate *Cochlodinium polykrikoides*, biochemical and hematological responses of fish exposed to blooms were investigated. Particularly, based on our finding that oxidative damages of gill were associated with fish mortality, dysfunction of ion-transporting enzymes and secretion of gill mucus of fish exposed to this bloom species were examined. The susceptibilities of several fishes to *C. polykrikoides* were different; the active pelagic fishes such as black scraper *Thamnaconus septentrionalis*, red sea *bream Pagrus major*, beakperch *Oplegnathus fasciatus* and seaperch *Malakichthys wakiyae*, were more vulnerable than the benthic fishes, flounder *Paralichthys olivaceus* and *rockfish Sebastes inermis.* In addition, the higher the algal cell density, the higher the fish mortality. When the test fishes were exposed to *C. polykrikoides* of 5000 cells ml^{-1}, the transport-related enzymes, carbonic anhydrase and Na^+/K^+-ATPase activities were significantly decreased. The activity of carbonic anhydrase was decreased with increasing algal cell density and exposure time. The quantity of total polysaccharide in gill mucus is higher in the fish exposed to *C. polykrikoide*s than in the control fish; the magnitudes were higher in the pelagic fishes than that of benthic fishes. Blood PO_2 declined in proportion to the density of algal cells, at which the blood PO_2 of moribund fish was about 40~60% of control test fish. Particularly, the fishes began to be killed when the blood PO_2 fell below 30~40 mmHg. However, the blood pH dropped almost 1.0 unit just before fish kill. Hemoglobin and hematocrit levels of fish exposed to *C. polykrikoides* of 5,000 cells/ml for 24 h and moribund fish did not greatly change. The concentrations of plasma Na^+, K^+ and Cl^- were slightly

elevated to different magnitudes except Ca^{2+}, and plasma osmolality was also increased in *Cochlodinium*-exposed fish. In the plasma cortisol level, these values of moribund flounder and red sea bream were 4~5 times higher than those of control fish, respectively. These results suggest that the inactivation of gill transport-related enzymes activities, abnormal secretion of gill mucus and the fall in blood PO_2 were may be one of the principal causes of fish kill by *C. polykrikoides*, and the changes of other hematological parameters were a secondary responses elicited by the decrease in blood PO_2.