Impact of Predation by Salmon Sharks (*Lamna ditropis*) and Daggertooth (*Anotopterus nikparini*) on Pacific Salmon (*Oncorhynchus* spp.) Stocks in the North Pacific Ocean

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Various species of fishes, seabirds and marine mammals are known as predators of Pacific salmon (*Oncorhynchus* spp.) in the North Pacific Ocean. However, there is little quantitative information about impact of predation by such predators on Pacific salmon populations. In this paper, we focus on predation by salmon sharks (*Lamna ditropis*) in oceanic offshore waters of the North Pacific Ocean and report on possible substantial impact of their predation on salmon stocks, based on the recent increase in salmon shark abundance on the high seas of the North Pacific Ocean. Also, we discuss predation impact by daggertooth (*Anotopterus nikparini*, formerly *A. pharao*) on salmon stocks, based on current information on their abundance and frequency of occurrence of slash marks on the lateral side of high-seas salmon caused by the attack of daggertooth.

We calculated annual CPUE (number/1000 tan of surface gillnets) of salmon sharks using the data collected by Japanese salmon research vessels that operated in the western and central North Pacific Ocean from 1972 to 2000. Salmon shark CPUE was low from 1984 to 1993 but increased sharply in 1996 and thereafter remained at a high level. A similar increase in salmon shark abundance has been reported from the Gulf of Alaska (Wright and Hulbert 2000). These results indicate that the North Pacific salmon shark population has recovered since the mid- or late 1990s. We estimate that the loss of high-seas salmon due to salmon shark predation was approximately $73\text{-}146\times10^6$ salmon ($113\text{-}226\times10^3$ metric tons) in 1989 when salmon shark CPUE was low (Nagasawa 1998). Thus, there is a possibility that the current increase in salmon shark abundance in the whole region of the North Pacific has increased mortality of salmon during the high-seas phase of the life history.

Daggertooth is a species that has been recently noticed as a predator of offshore salmon (Welch et al. 1991; Radchenko and Semenchenko 1996). Current Russian surface trawl surveys indicate that the abundance of daggertooth is not low in the western North Pacific and that it feeds on large numbers of salmon (Melnikov 1997). Slash marks from daggertooths are not frequently but sometimes found on salmon from high seas and coastal waters. The incidence of slash marks on salmon is usually low, ranging from less than 1% to 4 or 5%, in offshore waters (Ishida et al. 1991) but slightly higher (up to 12%) in coastal waters (Gilhousen 1989; Henderson et al. 1990). The species is widely distributed in offshore waters of the North Pacific Ocean (Nagasawa 1992), and its abundance seems to have been increasing since the early 1990's. Based on this information, we can regard daggertooth as significant salmon predators as well.

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