

The Mechanisms and Effects of Endocrine Disruption on Infertility in the Bonnethead Shark on Florida's Gulf Coast

Project Scope

Previous studies have demonstrated a high frequency of infertile ova in the uteri of pregnant bonnethead sharks (*Sphyrna tiburo*) from Tampa Bay, Florida, a highly industrialized region on Florida's Gulf Coast. Whereas infertility typically is rare in shark species, its occurrence in approximately 75 percent of pregnant bonnethead sharks examined in recent surveys of affected populations on the Florida Gulf Coast suggests that it may have detrimental effects on population survival.

The main objectives of this research were to:

- Determine the degree to which the infertility observed in the bonnethead shark in the Tampa Bay/Anclote River area of Florida is caused by disruption of the endocrine system;
- Determine the mechanism(s) of endocrine disruption;
- Determine if this infertility is correlated with organochlorine (OC) levels in the serum and/or liver; and
- Estimate the effects that the infertility rates, as well as other possible effects of the contaminants observed in three different geographical areas of the Florida Gulf Coast, may have on maintenance of populations of the species in these different areas.

Grant Title and Principal Investigator

The Mechanisms and Effects of Endocrine Disruption on Infertility in the Bonnethead Shark on Florida's Gulf Coast
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Key Findings

- Infertility rates in bonnethead sharks were significantly higher in the Tampa Bay/Anclote River area than in the less contaminated Florida Bay and Apalachicola Bay areas.
- The ability of female sharks to store spermatozoa prior to fertilization was significantly lower in sharks from the Tampa Bay/Anclote River.
- The reproductive biology of male bonnethead sharks from the three study sites did not differ significantly.
- Differences in female reproduction appear to be related to differences in endocrine function, based on low serum concentrations of 17 β -estradiol measured in Tampa Bay/Anclote River sharks.
- High rates of infertility appear to be associated with elevated concentrations of total PCBs and other OCs in Tampa Bay/Anclote River sharks.
- The high infertility rate in Tampa Bay is unlikely to have a profound effect on population status of the bonnethead shark.

Project Period: January 1998 to December 2001

To address these objectives, trends in individual growth and reproduction and potential rates of population increase were investigated for three separate populations of bonnethead sharks exposed to different levels of OC contamination on Florida's Gulf Coast. Sharks were collected from three geographical regions representing different levels of OC contamination:

- (1) The Anclote River, a site adjacent to Tampa Bay (highly populated, highly industrialized) that is known to contain high levels of OCs and to exhibit high rates of infertility in resident shark populations;
- (2) Apalachicola Bay, a site on the northwest coast of Florida (less populated and non-industrialized) that exhibits moderate levels of environmental contamination and unknown rates of shark infertility; and
- (3) Florida Bay, a site that is known to have relatively low levels of environmental pollutants and low rate of shark infertility.

Relevance to ORD's Multi-Year Research Plan

This project contributes directly to two important long-term goals of the ORD's MYP: (1) to provide a better understanding of the science underlying the effects, exposure, assessment, and management of endocrine disruptors, and (2) to determine the extent of the impact of endocrine disruptors on humans, wildlife, and the environment.

Researchers investigated the relationship between EDCs and reproductive success and endocrine function in bonnethead sharks. They correlated measured blood serum steroid concentrations and OC pesticide concentrations in shark tissues with measures of gonadal development, semen quality, female sperm storage, and fertility. They found that infertility rates and other aspects of female reproduction (e.g., sperm storage) were significantly impacted by exposure to EDCs in the Tampa Bay area of Florida's Gulf Coast. In contrast, the reproductive biology of male bonnethead sharks was not significantly affected. Infertility rates in females were significantly higher in the Tampa Bay/Anclote River area compared to the other study areas with lower OC contamination; however, the high infertility rates did not appear to have a profound effect on population status in the Tampa Bay/Anclote River.

Project Results and Implications

The reproductive competence of mature male and female sharks was evaluated using a variety of indices, including measures of gonadal development, semen quality, female sperm storage, and fertility. The relationship between reproductive success and endocrine function was investigated using measurements of serum steroid concentrations. Associations between reproductive success and levels of environmental contamination were evaluated by measuring the concentrations of OCs and polychlorinated biphenyls (PCBs) in shark tissues. Lastly, differences in population growth were determined by incorporating estimates of natural mortality, age at maturity, lifespan, and fecundity (which is influenced by fertility rate) into demographic models for the three study populations.

Sharks were collected as follows: 178 from the Tampa Bay/Anclote River area (40 immature females, 46 mature females, 44 immature males, and 48 mature males); 155 from the Florida Bay area (41 immature females, 41 mature females, 32 immature males, and 41 mature males); and 92 from the Apalachicola Bay area (34 immature females, 12 mature females, 29 immature males, and 17 mature males). The number of sharks collected from Apalachicola Bay was inadequate to represent each of the different reproductive stages in statistical comparisons with sharks from the other two locations for most reproductive parameters. The difficulty in obtaining sharks from Apalachicola Bay compared with the other two sites relates to their different migratory patterns through the areas.

Infertility rates were significantly higher in the Tampa Bay/Anclote River area than in the Florida Bay area. Researchers found 17 infertile ova distributed among 28 percent of the potentially reproductive females captured in the Tampa Bay/Anclote River area and found only two infertile ova (one each in two females) in sharks from Florida Bay. Figure 1 shows a uterus from a female bonnethead shark from Tampa Bay/Anclote River with three embryos and five infertile ova present. Sperm viability from mated females was observed to be lower in the Tampa Bay/Anclote River population compared with the Florida Bay population, although these differences were not found to be significant due to the high variability of the data. Further observations showed that the ability of female sharks to store spermatozoa prior to fertilization was significantly lower in sharks from the Tampa Bay/Anclote River. The reproductive biology of male bonnethead sharks from the three study sites did not differ significantly.

Differences in sperm storage, fertility, and perhaps other undetected disparities in female reproduction appear to be related to differences in endocrine function, based on low serum concentrations of 17 β -estradiol measured in Anclote River sharks specifically during the period of sperm storage and vitellogenesis. An association between high rates of infertility and levels of contaminant exposure was observed, based on significantly elevated concentrations of total PCBs and more than 10 OCs in Tampa Bay/Anclote River sharks.



Figure 1. Uterus from bonnethead shark from Tampa Bay with three embryos and five infertile ova

Estimated median population growth rates (λ) of bonnethead sharks from the three sites sampled varied from 9% per year in Florida Bay to 18% per year in Tampa Bay, with an intermediate value of 12% per year for Apalachicola Bay. Median values of λ from the three sites were significantly different, and all post-hoc comparisons revealed significant differences between pairs of populations. The risk of having a declining population ($\lambda < 1$) was greater in Florida Bay (23.2%) than in Tampa Bay (7.5%) and Apalachicola Bay (3.9%). Elimination of the infertility rate in the estimation of λ resulted in higher values of λ and a lower proportion of $\lambda < 1$ for each population. The greatest increase in λ and decrease in values of $\lambda < 1$ was for Tampa Bay, where λ increased from 18% to 23% per year and the proportion of $\lambda < 1$ values decreased from 7.5% to 3%. These results indicate that infertility rate in the three populations analyzed, while substantial in Tampa Bay, does not appear to have a profound effect on population growth rates or population status. However, in less prolific species of sharks, the effect may be dramatic.

The assessment of risk for populations of bonnethead sharks in the Florida Gulf coastal areas will allow for the estimation of possible effects on other commercially and ecologically important shark species as well as other marine life and humans that share contaminant exposure with *S. tiburo*. Because of its sensitivity to OCs (related to infertility and other reproductive system-related parameters), the female bonnethead shark could serve as an indicator of changing OC levels and thereby be useful in risk assessment and management in these and other areas where the species occur.

Investigators

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