Microcontaminants and Reproductive Impairment of the Forster’s Tern on Green Bay, Lake Michigan—1983


*U.S. Fish and Wildlife Service, Habitat Enhancement Field Office, University of Wisconsin-Green Bay, Green Bay, Wisconsin 54302, USA; **University of Wisconsin-Green Bay, Sea Grant Institute, Green Bay, Wisconsin 54302, USA; ***U.S. Fish and Wildlife Service, National Fisheries Contaminant Research Center, Route 1, Columbia, Missouri 65201, USA; †U.S. Fish and Wildlife Service, National Wildlife Health Center, 6006 Schroeder Road, Madison, Wisconsin 53711, USA; and ‡University of Wisconsin-Green Bay, Richter Museum of Natural History, Green Bay, Wisconsin 54302, USA

Abstract. For the 1983 nesting season, Forster’s tern (Sterna forsteri) reproductive success was significantly impaired on organochlorine contaminated Green Bay, Lake Michigan compared to a relatively uncontaminated inland location at Lake Poygan, Wisconsin. Compared with tern eggs from Lake Poygan, eggs from Green Bay had significantly higher median concentrations of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), other polychlorinated dibenzo-p-dioxins (PCDDs), total polychlorinated biphenyls (PCBs), total (three congeners) non-ortho, ortho’ PCBs, five individual PCB congeners known to induce aryl hydrocarbon hydroxylase (AHH) and several other organochlorine contaminants. Conversions of analytical concentrations of TCDD and PCB congeners based on relative AHH induction potencies allowed for estimation of total 2,3,7,8-TCDD equivalents. Two PCB congeners, 2,3,3′,4,4′- and 3,3′,4,4′,5-pentachlorobiphenyl (PeCB) accounted for more than 90% of the median estimated TCDD equivalents at both Green Bay and Lake Poygan. The median estimated TCDD equivalents were almost 11-fold higher in tern eggs from Green Bay than in eggs from Lake Poygan (2175 and 201 pg/g). The hatching success of Green Bay sibling eggs from nests where eggs were collected for contaminant analyses was 75% lower at Green Bay than at Lake Poygan. Hatchability of eggs taken from other nests and artificially incubated was about 50% lower for Green Bay than for Lake Poygan. Among hatchlings from laboratory incubation, those from Green Bay weighed approximately 20% less and had a mean liver weight to body weight ratio 26% greater than those from Lake Poygan. In both field and laboratory, mean minimum incubation periods were significantly longer for eggs from Green Bay compared to Lake Poygan (8.25 and 4.58 days, respectively). Mean minimum incubation time for Green Bay eggs in the field was 4.37 days longer than in the laboratory. Hatchability was greatly improved when Green Bay eggs were incubated by Lake Poygan adults in an egg-exchange experiment, but was sharply decreased in Lake Poygan eggs incubated in Green Bay nests. Nest abandonment and egg disappearance were substantial at Green Bay but nil at Lake Poygan. Thus, not only factors intrinsic to the egg, but also extrinsic factors (parental attentiveness), impaired reproductive outcome at Green Bay. The epidemiological evidence from this study strongly suggested that contaminants were a causal factor. AHH-active PCB congeners (intrinsic effects) and PCBs in general (extrinsic effects) appeared to be the only contaminants at the concentrations measured in eggs, capable of producing the effects that were observed at Green Bay.

Relatively low reproductive success has been recorded for the Forster’s tern (Sterna forsteri) over a number of years (Harris and Trick 1979; Trick
This fish-eating colonial bird has congenital anomalies, including crossed bills, at Green Bay (Roznik 1978; Trick 1982). Hays and Risebrough (1972) and Gochfeld (1975), who reported similar types of bill defects in the common tern (Sterna hirundo) and roseate tern (S. dougallii), suggested that polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), polychlorinated biphenyls (PCBs) and mercury were the cause. High incidences of bill defects in fish-eating birds were also recorded on Lake Ontario in the early 1970’s by Gilbertson (1983), who reported that retrospective chemical analysis of archived eggs of the herring gull (Larus argentatus) revealed the presence of 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD). Similar deformities have been found in the herring gull, common tern, double-crested cormorant (Phalacrocorax auritus) and Virginia rail (Ralus virginianus) in the Green Bay ecosystem (Toxic Substances Task Force 1983). Two black-crowned night herons (Nycticorax nycticorax) from Green Bay found moribund in 1978 and chemically characterized in 1982 contained various PCDDs including 2,3,7,8-TCDD and non-ortho, ortho’ substituted PCBs. Furthermore, 2,3,7,8-tetrachlorodibenzo Furan (2,3,7,8-TCDF) was found in one bird (Stalling et al. 1985). The 2,3,7,8-TCDD congener serves as the prototype compound for a series of structurally related halogenated aromatic hydrocarbons or isosteres that share similar biologic and toxic properties (Goldstein 1980; Parkinson et al. 1980a, 1980b; 1983; Poland and Knutson 1982; Sawyer and Safe 1982; Safe 1984). Close correspondence is observed between the toxicities of these compounds and their capacities to induce aryl hydrocarbon hydroxylase (AHH) (Poland and Glover 1973; Goldstein 1980; Leece et al. 1985; Safe 1987). All of the identified AHH-active congeners whose toxicities have been investigated produce syndromes in mammalian and avian species manifested by weight loss, edema, hepato-toxicity, thymic atrophy, hyperkeratosis (mammals only), mortality and reproductive impairment (Ax and Hansen 1975; Yamamoto et al. 1976; Goldstein 1980; Leece et al. 1985; Safe 1987).

Recent studies have identified several PCDD, PCDF and PCB congeners in environmental samples (Giesy et al. 1986; Stegeman et al. 1986; Tanabe et al. 1987a, 1987b; Van den Berg et al. 1987); however, no comprehensive search has been undertaken that identified and quantified these isosteres, in addition to other organochlorine contaminants, where reproductive performance in a wild bird population was determined. Knowledge of the occurrence of these isosteres could aid in an assessment of potential contributing toxicity where the characteristic reproductive pathology is evident. Attempts have been made to estimate the combined risk of PCDDs and PCDFs, but not PCBs, using the concept of the “2,3,7,8-TCDD equivalent” (USEPA 1987; Ontario Ministry of the Environment 1985; Milby et al. 1985; Eadon et al. 1986). Recent work by Leece et al. (1985) and Safe (1987) have shown the utility of this approach for PCBs as well.

The concern for the low reproductive success of Forster’s terns located on lower Green Bay and the possible involvement of 2,3,7,8-TCDD, its isosteres and other organochlorine pollutants, was heightened by the knowledge that an inland colony of Forster’s terns was flourishing at Lake Poygan, Wisconsin (Hale 1982). This colony was located upstream from the major potential sources of the suspected microcontaminants (Sullivan and Delfino 1982; Toxic Substances Task Force 1983; Marti 1984; DeVault 1985). Lengthened incubation periods, dead young and nest abandonment were observed at a colony on Longtail Point on lower Green Bay in 1982 (T. J. Kubik and T. C. Erdman, unpublished data).

A study was initiated in 1983 to determine whether reproductive success and egg contaminant levels of the lower Green Bay Forster’s terns differed from inland, Lake Poygan terns and whether the recognized pathologic effects of organochlorine contaminants were present (Harris et al. 1985). These effects attributed to a variety of organochlorine compounds include embryotoxicity (Verret 1970; Flick et al. 1972; Vos 1972; Tumasonis et al. 1973; Cecil et al. 1974; Ax and Hansen 1975); teratogenicity (Verret 1970; Cecil et al. 1973; McKinney et al. 1976); edema (McLaughlin 1963; Verret 1970; Flick et al. 1965, 1972; Firestone 1973; McKinney et al. 1976); growth retardation, McLaughlin et al. (1963) and McKinney et al. (1976); and aberrant parental behavior during incubation (Peakall and Peakall 1973; Fox et al. 1978). AHH induction, teratogenicity, bone development and disease influence, which were among those effects investigated as part of this study, were reported by Hoffman et al. (1987). The expanded results of the original study are reported in this paper.

Materials and Methods

Forster’s tern colonies monitored during the 1983 nesting season were located in northeastern Wisconsin on the shore of Green Bay (South Oconto Marsh and Longtail Point) and at Lake Poygan (Figure 1).