INTEGRATING DATA ON LIFE HISTORY, HEALTH, AND REPRODUCTIVE SUCCESS TO EXAMINE POTENTIAL EFFECTS OF POPS ON BOTTLENOSE DOLPHINS (*Tursiops truncatus*) IN SARASOTA BAY, FLORIDA

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Introduction

Very high concentrations of persistent organic pollutants have been measured in the tissues of some cetaceans, but the identification of cause and effect relationships between these concentrations and health or reproductive impacts has largely eluded scientists to date [1]. Most previous research on environmental contaminants in cetaceans has involved examination of carcasses, with attempts to draw correlations between contaminant concentrations and the cause(s) of death. Such evaluations are imprecise at best, because of the complications provided by animals that may have faced a variety of health challenges near the ends of their lives. Few conclusions can be drawn about possible reproductive effects in such situations.

All mammals do not necessarily respond in the same way to exposure to the same chemicals; thus, it is important to determine which specific pollutants and what concentrations are of greatest concern to cetaceans, how they might impact the health and/or reproductive success of the animals, and how the effects vary with their life history. To these ends, we have implemented a weight of evidence approach that involves long-term monitoring of a living population of bottlenose dolphins (*Tursiops truncatus*) exposed to low to moderate levels of POPs in Sarasota Bay, Florida. This year-round resident community of about 140 dolphins includes at least four generations of identifiable individuals, and has been under study since 1970 [2,3,4,5]. Capture, sample, mark, and release efforts have provided information on age, sex, health, body condition, and tissue residues of environmental contaminants [6]. Observations of the mothers and their offspring over time, along with paternity testing, permit evaluation of reproductive success. In this way, health and reproductive success can be examined relative to sublethal levels of environmental contaminants, taking into account variability in contaminant accumulation and loss related to life history. Most other studies of environmental contaminants in marine mammals have involved animals collected opportunistically, with no knowledge of the history of the animal [7].

Methods and Materials

We have established a "natural laboratory" situation through long-term research in Sarasota Bay, Florida. Sheltered waters and a relatively small home range facilitate monitoring of dolphin occurrence, habitat use patterns, and births and fates of calves. Therefore, for many calves, birth order is known. Shallow waters allow for safe capture-release operations for veterinary examinations and to obtain biological samples for life history and genetic analyses, health assessment, contaminant concentration measurement, and testing potential biomarkers. Dolphins are encircled with a net, and are brought aboard a specially-designed vessel. Body condition is evaluated (weight, lengths, girths, ultrasonic measurement of blubber thickness at selected sites). The animals are given a physical exam, and blood, milk, blubber, urine, fecal, and microbiological samples are collected [6]. Diagnostic ultrasound provides information on health and reproductive condition. Ages of most dolphins are known from documentation of their birth to well-known mothers; unknown ages are determined from growth layer groups in a sectioned and stained tooth [8]. Organochlorine concentrations in blubber, milk, and blood are examined relative to age, sex, body condition, birth order, and health parameters, including immune system function as indicated by lymphocytes [10]. Possible effects on reproductive success are examined through measurement of testosterone concentrations, tracking of paternity patterns as determined from genetic samples, and by tracking individual female calving success through their reproductive lifespan.

Results and Discussion

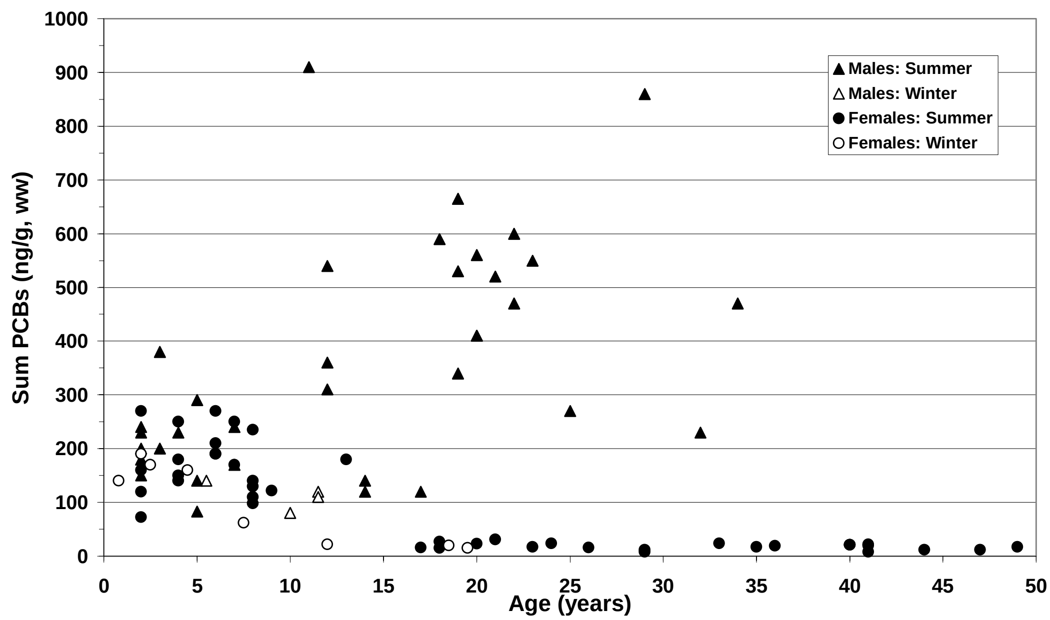
Sample analyses are underway for a variety of compounds, but preliminary results of PCB analyses are available at the time of this writing (Table 1).

Table 1. PCB analytes: A) in blubber samples collected during 1997-1999 (G. Mitchum, NOS); B) in blubber samples collected during 2000-2001 (A. Borrell, U. of Barcelona); C) in plasma, milk, and blubber samples collected during 1988-1999 (W. Jarman, U. of Utah).

A			B		C				
18	101	169	28	183	3/30	52	99	151	187
28	105	170/190	52	128	5/8	60	101	153	189
44	118	180	95	174	15	64	105	156	194
49	126	183	101	156	17	66	110	157	195
52	128	187	151	180	18	70	118	158	196
66	138	194	149	170	27	74	128	167	198
77	149	195	118	201	28	84	132	170	200
87	151	201	153	195	29	85	137	174	203
95	153	206	105	194	31	87	138	177	206
99	156	209	138	206	44	89	141	178	209
			187	209	46	95	146	180	
					49	97	149	183	

The dolphins of Sarasota Bay demonstrate expected patterns of accumulation and depuration of the organochlorines examined to date, (Figure 1). Males appear to accumulate some compounds through their lives, whereas females begin to depurate with their first calf, reaching an apparent equilibrium between contaminant intake and loss through lactation [9]. Apparent seasonal variations in contaminant concentrations in plasma are suggestive of a pattern of deposition in lipid-filled tissues during winter, when blubber thickness increases, and mobilization of these contaminants in spring as blubber thins, but samples from winter are too few to be conclusive at this time. Unusually high rates of first-born calf mortality are correlated with higher concentrations of contaminants measured in blood and blubber of primiparous females; this finding is further supported through a risk assessment analysis [5,10]. Subsequent calves have a higher probability of success. Males, with their inability to depurate and continuing accumulation through life, have a shorter life span than females, living only into their early 40s rather as compared to maximum female ages of 53 years or more [5]. One preliminary study demonstrated decreased immune system function with increasing concentrations of organochlorines in Sarasota Bay male dolphins [11]. Though some males have been found to sire calves when in their 40s, testosterone concentrations begin to decline by the time they reach their mid-20s. Such declines have been hypothesized in other cases to be related to organochlorine concentrations [12].

Figure 1: Plasma PCBs (sum of 60 congeners, Table 1) relative to sex, age, and season.



The possible relationships between any of these biological findings and environmental contaminant concentrations must be considered tentative pending completion of current analyses and evaluation of the weight of evidence. Even at the current early stages of analysis, it seems clear that, in combination, long-term observational monitoring and periodic biological sampling provide a potentially powerful, non-lethal approach to understanding the correlations of organochlorine concentrations and health or reproductive parameters in coastal dolphins, thereby providing critical information for hazard and risk assessment in marine mammals.

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References

1. O'Shea, T.J. (1999) in: Biology of Marine Mammals (Reynolds, J.E., III and Rommel, S.A, Eds.), Smithsonian Institution Press, ISBN 1-56098-375-2
2. Irvine, A.B., Scott, M.D., Wells, R.S. and Kaufmann, J.H. (1981) Fish. Bull. U.S.79, 671-688
3. Scott, M.D., Wells, R.S., and Irvine, A.B. (1990) in: The Bottlenose Dolphin (Leatherwood, S. and Reeves, R.R., Eds.), Academic Press, ISBN 0-12-440280-1
4. Wells, R.S. (1991) in: Dolphin Societies: Discoveries and Puzzles (Pryor, K. and Norris, K.S., Eds.), University of California Press, ISBN 0-520-06717-7
5. Wells, R.S. (2003) in: Animal Social Complexity: Intelligence, Culture, and Individualized Societies (de Waal, F.B.M. and Tyack, P.L., Eds.), Harvard University Press, ISBN 0-674-00929-0
6. Wells, R.S., Rhinehart, H.L., Hansen, L.J., Sweeney, J.C., Townsend, F.I., Stone, R., Casper, D., Scott, M.D., Hohn, A.A. and Rowles, T.K. (in press) Ecology and Health
7. Aguilar, A. (1985) Residue Reviews, 95, 91-114
8. Hohn, A.A., Scott, M.D., Wells, R.S., Sweeney, J.C. and Irvine, A.B. (1989) Marine Mammal Science 5(4):315-342.
9. Cockcroft, V. G., DeKock, A.C., Lord, D.A. and Ross, G.J.B. (1989) S. Afr. J. Mar. Sci. 8, 207-217
10. Schwacke, L.H., Voit, E.O., Hansen, L.J., Wells, R.S., Mitchum, G.B., Hohn, A.A. and Fair, P.A. (2002) Environmental Toxicology and Chemistry 21, 2752-2764
11. Lahvis, G.P., Wells, R.S., Kuehl, D.W., Stewart, J.L., Rhinehart, H.L., and Via, C.S. (1995) Environmental Health Perspectives, 103, 67-72
12. Subramanian, A., Tanabe, S. and Tatsukawa, R.. (1987) Proc. NIPR Symp. Polar Biol 1:205-216