suggesting that extra-amygdala spread into the ventricles is not responsible for the effects described herein.

Recent reports from other laboratories confirming the presence of norepinephrine in amygdala nuclei of rats (*20*) and studies on the localization and characterization of β-adrenergic receptors in the amygdala complex (*21*) strongly support the possibility that our results indeed reflect the effects of local manipulation of a specific β-adrenergic-sensitive neurochemical system within the amygdala of rats.

Previous observations that low-level electrical stimulation of the amygdala after training disrupts long-term memory formation have implicated this neuroanatomical region in the memory process (*5*).

Furthermore, pharmacological studies have indicated that the integrity of whole brain norepinephrine systems is necessary for long-term memory formation (*6*). Our results thus confirm and extend these previous findings by implicating an amygdala adrenergic system in long-term memory formation.

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Increasing Frequency of Thyroid Goiters in Coho Salmon (*Oncorhynchus kisutch*) in the Great Lakes

Abstract. *Coho salmon collected during the 1976 spawning runs from Lakes Michigan, Ontario, and Erie had overt goiter frequencies of 6.3, 47.6, and 79.5 percent, respectively. These represent significant increases over the frequencies observed in previous years. Epizootiological data suggest that environmental goitrogens (possibly pollutants) may be involved in the etiology of the thyroid disorder.*

Coho salmon (*Oncorhynchus kisutch*) is a highly prized sport and commercial marine fish. In the late 1960's the species was successfully introduced into the Great Lakes (*1*), and it has provided a spectacular multimillion-dollar sports fishery to North American anglers. Since it was introduced into the Great Lakes, several investigators have reported thyroid hyperplasia (goiters) in this species (*2–4*). Recently, Drongowski *et al.* (*3*) and Sonstegard and Leatherland (*4*) described severe hypothyroidism associated with thyroid hyperplasia in coho from Lakes Michigan and Ontario. While the hypothyroid condition (goiters) found in the coho salmon is undoubtedly due in part to the low availability of iodine in the Great Lakes Basin (*5, 6*), we report studies here which strongly suggest the involvement of environmental goitrogens (possibly pollutants) in the etiology of the thyroid disorder. In addition, our data (Table 1) suggest an increase in the frequency of occurrence of overt goiters over that in previous years.

Table 1. Goiter frequencies of Great Lakes coho salmon. Frequencies were determined from sexually mature fish examined during the fall spawning run. The number of fish examined is given in parentheses. Abbreviation: T.R., this report.

Lake	Year	Frequency (%)	Reference
Erie	1972	44 (117)	(*2*)
	1976	79.5 (117)	T.R.
Ontario	1975	24 (51)	(*4*)
	1976	47.6 (63)	T.R.
Michigan	1973	1 (100)	T.R.
	1976	6.3 (111)	T.R.

Sexually mature coho salmon were collected during the fall spawning runs from Lakes Michigan, Ontario, and Erie. The presence of goiters was determined by retracting the operculum of each fish and examining the base of the gill arches for evidence of swelling or nodules (see Fig. 1). Fish with one or more distinct nodules more than 1 cm in diameter were recorded as having overt goiters. The frequency of overt goiters ranged from 6.3 percent in Lake Michigan to 47.6 percent in Lake Ontario to a striking 79.5 percent in Lake Erie.

If low iodine availability were the sole factor contributing to goiter develop-

ment, one would expect goiter frequency to be inversely proportional to lake iodine concentration. However, Lake Michigan has the lowest iodine content (0.9 μg/liter), which is only one-half that of Lake Erie (1.7 μg/liter) and one-third that of Lake Ontario (2.9 μg/liter) (*7*). Conversely, Lake Ontario has nearly 7.6 times and Lake Erie 12.6 times as high an overt goiter frequency as Lake Michigan. A nearly 13-fold difference in goiter frequency between two populations of the same species, age, and state of spawning seems highly unlikely if iodine deficiency is the sole contributor to goiter development.

The usual response to a low iodine concentration in the environment is compensatory thyroid hyperplasia; the mechanism for this is thought to involve stimulation of the pituitary-hypothalamic axis as a negative feedback response to low levels of circulating hormones [thyroxine (T_4) or triiodothyronine (T_3) (*5, 8, 9*)]. Therefore, one might expect to find a correlation between low hormone levels and high goiter frequency. Our data (Table 2) do not indicate such a relationship. It is of interest that salmon from Lakes Michigan and Erie have extremely low (nearly undetectable) T_4 concentrations and yet represent the extremes of goiter frequency. In view of the iodine concentrations in the lakes and the fact that Lake Erie salmon are from Lake Michigan egg stock, it is difficult to explain this difference in terms of a greater demand for thyroid hormones by Lake Erie fish. In addition, Lake Ontario salmon had nearly four times as much T_3 and T_4 as Lake Michigan fish, and yet had eight times the goiter frequency. The data on serum hormone concentrations are, in some respects, at variance with data from Lakes Michigan and Ontario in previous years (*3, 4*), which may indicate that goiter frequency is a better criterion than absolute hormone levels for thyroid dysfunction in these fish. This hypothesis is supported by the report of Sonstegard and Leatherland (*4*), who found no correlation between thyroid hormone levels and goiter occurrence in Lake Ontario coho salmon. These observations further suggest that other factors, in addition to iodine deficiency, are involved in the etiology of the goiters. Considering the increasing goiter frequency, it appears that these factors are becoming of greater significance. Seasonal or yearly fluctuations of iodine levels are highly unlikely in the Great Lakes Basin, and it is doubtful whether they could account for the annual differences in frequency observed.

Table 2. Serum thyroxine and triiodothyronine concentrations in spawning coho salmon. Thyroxine and triiodothyronine were determined as described by Sonstegard and Leatherland (*4*). Values are mean ± standard error of the mean; in each case the sample was ten fish.

Lake	Thyroxine (μg/100 ml)	Triiodothyronine (ng/100 ml)
Ontario	1.2 ± 0.4	636.8 ± 69.4
Michigan	0.3 ± 0.1	159.4 ± 51.4
Erie	0.1 ± 0.1*	84.3 ± 25.9

*Undetectable.

The Great Lakes have been polluted with a vast array of chemicals which, either alone or in concert with one another, may act as goitrogens, augmenting the development of goiters in a low-iodine environment. Organochlorines (polychlorinated biphenyls, DDT, dieldrin, and mirex) have a widespread distribution in the Great Lakes and have been reported to alter thyroid activity in fish (*4, 10, 11*), birds (*12*), and mammals (*13*). There is a growing body of data that suggest many parallels between teleosts, birds, and mammals in the roles of thyroid hormones, which are known to be important regulators of growth and reproductive physiology in higher vertebrates (*8, 9*). Significant reductions in fertility, fecundity, and growth rates could have a devastating effect on an already fragile salmon industry.

The evidence reported here suggests that the goiters in the coho salmon may be environmentally induced. Coho salmon, because of their position in the food cycle, may be exposed to considerably higher concentrations of waterborne or dietary pollutants than are other animals. In addition, they may be unusually responsive to environmental insults and may therefore provide a sentinel species for the detection of goitrogens. Waterborne or dietary goitrogens are important because the fish are consumed by humans and the lake water is increasingly being utilized for drinking. The apparent increase in goiter frequency in the coho salmon may reflect an increase in the concentrations, types, or effects of environmental goitrogens.

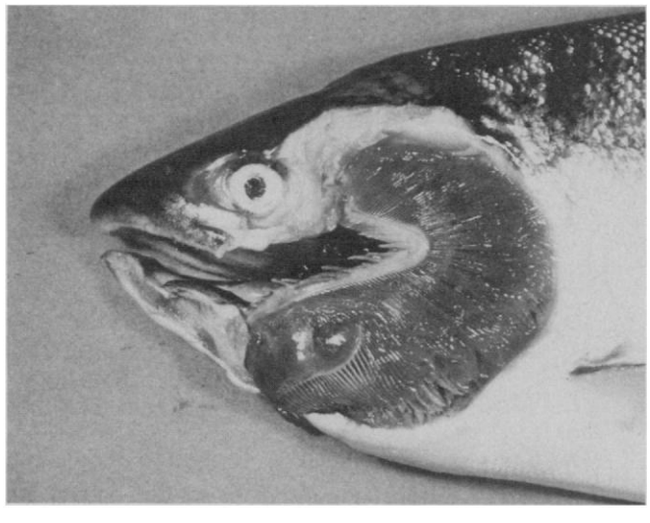

Fig. 1. Coho salmon with overt thyroid goiter on the base of the gill arch. Epizootiological studies suggest that the frequency of occurrence of goiter is increasing in Great Lakes coho salmon and that environmental factors (possibly pollutants) are involved in the etiology of the disease.

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