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A major developmental defect observed in several Biscayne Bay, Florida, fish species

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Synopsis

Stunted or missing dorsal spines or rays, sometimes accompanied by a depression in the dorsal profile, were found in 10 fish species in six families from North Biscayne Bay. The same morphological abnormality occurred in *Haemulon sciurus, H. parrai, H. plumieri, Lagodon rhomboides, Archosargus rhomboidalis, Diplodus argenteus, Lutjanus griseus, Kyphosus sectatrix, Sphoeroides testudineus,* and *Lactrophyrys quadricornis.* Another morphological abnormality, scale disorientation, was found in six species: *H. parrai, L. rhomboides, A. rhomboidalis, L. griseus,* and *Abudefduf saxatilis.* Pugheadedness, jaw deformities, and other abnormalities also were observed. The occurrence of similar deformities across such a spectrum of fishes from the same location suggests the deformity was induced by something in the environment common to all these species. Although there could be other explanations for the unusual cluster of abnormalities, it is suspected that the same environmental contaminant or group of contaminants is adversely affecting a common developmental pathway of these fishes. Biscayne Bay is an urban estuary that receives agricultural, industrial, and residential run off.

Introduction

Skeletal, fin, and scale abnormalities occur in hatchery-raised fish and in wild fish populations. Comprehensive bibliographies of reported anomalies through 1976 were prepared by Dawson (1964, 1966, 1971) and Dawson & Heal (1976), which listed 1482 citations.

Our emphasis here is on an infrequently described deformity involving the dorsal fin and, sometimes, the dorsal profile. This paper documents the presence of this condition, which we call the 'saddleback syndrome', after Tave et al. (1983), in several fish species from Biscayne Bay. We also document the current presence of 'scale disorientation' in Biscayne Bay fishes roughly 15 years after first observed there (Overstreet 1988, Skinner & Kandrashoff 1988).

Tave et al. (1983) observed abnormalities involving the dorsal fin and dorsal profile in hatchery-raised *Oreochromis aureus* and described them as follows: 'The fish are missing all or part of their dorsal fin. The expression of this character is quite variable and exhibits a continuous distribution ranging from those that lack only the first spine to those that have no dorsal fin.' Pterygiophores associated with

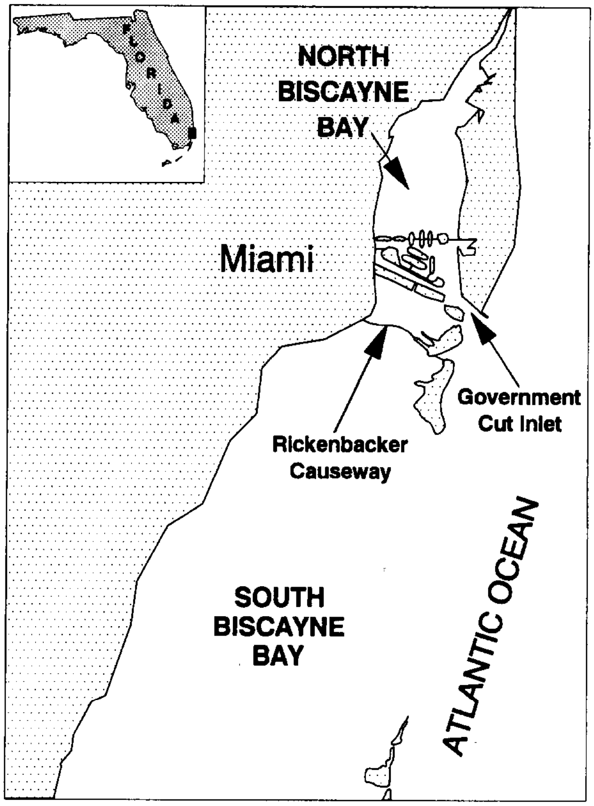

Fig. 1. Map of Biscayne Bay showing location and configuration of North Biscayne Bay.

issing spines or rays also were missing, resulting in a depression in the dorsal profile that inspired the name 'saddleback'. Saddleback in *O. aureus* was produced by an autosomal dominant lethal gene (Tave et al. 1983) with 'incomplete dominant gene action' (Tave 1986).

Morphological abnormalities similar to saddleback have been reported in wild populations of cutthroat trout, *Salmo clarki* (Code 1950), sockeye salmon, *Oncorhynchus nerka* (Lewis 1961), southern flounder, *Paralichthys lethostigma* (Dawson 1967), several species in the family Leiognathidae (James & Badrudeen 1968), an Indian glassfish, *Ambassis dayi* (Kurup & Sammuel 1979), ayu, *Plecoglossus altivelis* (Komada 1980), and crucian carp, *Carassius carassius* (Valente 1988). The morphological abnormality we call saddleback should not be confused with the pathogen-associated saddleback disease involving skin discoloration and lesions encircling the fish (Morrison et al. 1981).

Area and methods

Biscayne Bay is a semi-enclosed, subtropical, estuarine lagoon, segmented by islands, causeways, and deep channels (Thorhaug et al. 1976). Shallow reefs (Voss 1988) lie nearby. Many fish species use both reef and estuarine habitat during their life cycle. The most common life-history pattern is one of offshore spawning and subsequent immigration of larvae into the bay, where the juvenile period is spent.

Bay waters are cleaner today than 25 years ago (McNulty 1966, 1970), but pollution sources – agricultural, industrial, and residential runoff – still exist. Heavy metals, phthalic acid esters, and hydrocarbons, including PCBs, have accumulated in sediments[1]. Skinner & Kandrashoff (1988) summarized the recent history of pollutant inputs.

Fish were caught primarily by hook and line (a few were caught in crab traps) during normal operation of a small-boat, full-time commercial fisherman from November 1989, to June 1990. Roughly 43 000 fish were caught and all were scanned for abnormalities. Fishing activity was mainly north of the Rickenbacker Causeway, often referred to as North Biscayne Bay, and in Government Cut Inlet (Fig. 1).

Representative samples of abnormal fish were frozen at the end of each day and transported to the Miami Laboratory of the Southeast Fisheries Science Center, where species identifications and abnormalities were confirmed and recorded. Most fish were measured (fork length) to the nearest millimeter.

Results

Abnormalities were recorded in 17 species from 12 families (Table 1). We grouped the abnormalities into four categories: saddleback syndrome, scale disorientation, deformed snout/mouth (which includ-

[1] Corcoran, E.F., M.S. Brown & A.D. Freay. 1984. A study of trace metals, chlorinated pesticides, polychlorinated biphenyl, and phthalic acid esters in sediments of Biscayne Bay. Report to Metropolitan Dade County Resources Management, Miami. 58 pp.

ed pugheadedness and abnormal jaws), and other (which included scoliosis and missing pectoral fins).

Saddleback was the most common abnormality, noted in 61 of 80 specimens. In our specimens, this syndrome was expressed as an incomplete dorsal fin with one or more missing or stunted dorsal spines, sometimes accompanied by a depression in the upper body profile at the site where the spines were missing (Table 2). The deformity usually involved the anteriormost dorsal spines. Saddleback individuals sometimes had other abnormalities.

Photographs of saddleback specimens, where possible alongside normal individuals, are shown in Figures 2, 3 and 4. Missing or stunted dorsal spines, ith or without the dorsal depression, were noted in nine species: bluestriped grunt, *Haemulon sciurus* (Fig. 2a), sailor's choice, *H. parrai* (Fig. 2b), white grunt, *H. plumieri* (Fig. 2c), pinfish, *Lagodon rhomboides* (Fig. 3a), sea bream, *Archosargus rhomboidalis* (Fig. 3b), silver porgy, *Diplodus argenteus* (Fig. 3c), gray snapper, *Lutjanus griseus* (Fig. 4a), Bermuda chub, *Kyphosus sectatrix* (Fig. 4b), and checkered puffer, *Sphoeroides testudineus.* The scrawled cowfish, *Lactrophrys quadricornis,* a species having only a posterior dorsal fin normally, had a depression in its anterior dorsal profile (Fig. 4c),

Table 1. Summary of abnormal fishes collected November 1989 – June 1990 from Biscayne Bay, Florida, a subtropical estuary.

Family Scientific name	Common name	Number specimens	Size range Fork length (mm)			Abnormality types			
			Min.	Max.	Mean	Saddleback syndrome	Scale disoriention	Deformed snout/mouth	Other
Muraenidae – (Morays)									
Gymnothorax sp.	Moray species	1	NA	NA	NA	0	0	1	0
Carangidae – (Jacks)									
Selene vomer	Lookdown	1	195	195	195	0	0	0	1
Corphaenidae – (Dolphins)									
Coryphaena hippurus	Dolphin	1	NA	NA	NA	0	0	0	1
Lutjanidae – (Snappers)									
Lutjanus griseus	Gray snapper	24	177	231	194	21	2	0	5
Lutjanus synagris	Lane snapper	1	NA	NA	NA	0	0	1	0
Pomadasyidae – (Grunts)									
Haemulon parrai	Sailor's choice	2	140	169	155	1	0	1	1
Haemulon plumieri	White grunt	6	150	200	178	5	2	0	0
Haemulon sciurus	Bluestriped grunt	4	171	224	192	4	0	0	0
Sparidae – (Porgies)									
Archosargus rhomboidalis	Sea bream	15	190	253	214	11	7	0	2
Diplodus argenteus	Silver porgy	3	169	207	183	3	0	0	0
Lagodon rhomboides	Pinfish	12	145	193	180	11	4	5	1
Mullidae – (Goatfishes)									
Pseudopeneus maculatus	Spotted goatfish	1	243	243	243	0	0	0	1
Kyphosidae – (Sea chubs)									
Kyphosus sectatrix	Bermuda chub	3	233	252	240	2	1	0	0
Pomacentridae – (Damselfishes)									
Abudefduf saxatilis	Sergeant major	1	247	247	247	0	1	0	0
Scaridae – (Parrotfishes)									
Sparisoma chrysopterum	Redtail parrotfish	1	209	209	209	0	0	0	1
Ostraciidae – (Trunkfishes)									
Lactophrys quadricornis	Scrawled cowfish	3	190	233	211	2	0	0	1
Tetraodontidae – (Puffers)									
Sphoeroides testudineus	Checkered puffer	1	165	165	165	1	0	0	0
Total		80				61	17	8	14

aking this the tenth species to exhibit the same general type of abnormality.

Some of our specimens differed from Tave et al.'s (1983) in having the first few anteriormost dorsal spines intact and spines posterior to them missing. According to D. Tave (personal communication), none of the saddleback *O. aureus* had intact dorsal spines anterior to missing spines, although he did see this in *O. mossambicus.* The anteriormost spines were affected in many that we catalogued. Individuals both with and without intact dorsal spines anterior to missing dorsal spines occurred within the same species in our collection.

Based on catch records and recollections of M. Kandrashoff, we estimate that the frequency of the saddleback syndrome in the fish we caught was, roughly, as high as 3% in bluestriped grunt and silver porgy and as high as 5% in sea bream and gray snapper. Although the occurrence of saddleback in Biscayne Bay fishes has not previously been published, dated photographs by W. Kandrashoff record its presence in sea bream and pinfish as early as 1975, gray snapper in 1983, and bluestriped grunt in 1984.

Scale disorientation, in which a patch of scales are misaligned, was the second morphological abnormality in interspecies occurrence in our specimens. Asymmetrical scale disorientation was exhibited in six species representing five families: hite grunt, sea bream, pinfish, Bermuda chub, gray snapper, and sergeant major, *Abudefduf saxatilis.*

Discussion

Multi-species occurrence of saddleback syndrome

This is the first report of the saddleback abnormality in wild fish populations from different families from the same area. We know of one report of the abnormality in more than one species, all in the same family, from two locations (James & Badrudeen 1968).

Although we found saddleback in many Biscayne Bay taxa, it may occur infrequently elsewhere. In the 1482 citations of abnormalities catalogued by Dawson (1964, 1966, 1971) and Dawson & Heal (1976), we found only five, all mentioned earlier, describing this particular anomaly. We found three more in our computerized search of *Aquatic Sciences & Fisheries Abstracts* from 1977 through March, 1992.

Dahlberg (1970) examined 20654 fish in Georgia estuaries and found only 12 with anomalies, none saddleback. Of 100000 freshwater fish caught in Washington, 236 abnormal individuals, none with saddleback-like deformities, were discovered (Patten 1968).

Table 2. Types of saddleback syndrome symptoms observed in fishes collected November 1989 – June 1990.

Species	Common name	Saddleback syndrome symptoms			
		Missing dorsal spines	Dorsal spine depression	Deformed stunted spines	Total fish
Archosargus rhomboidalis	Sea bream	8	3	2	11
Diplodus argenteus	Silver porgy	3	1	0	3
Haemulon parrai	Sailor's choice	1	0	0	1
Haemulon plumieri	White grunt	1	4	1	5
Haemulon sciurus	Bluestriped grunt	4	3	0	4
Kyphosus sectatrix	Bermuda chub	2	2	0	2
Lactophrys quadricornis	Scrawled cowfish	0	2	0	2
Lagodon rhomboides	Pinfish	10	2	0	11
Lutjanus griseus	Gray snapper	19	0	3	21
Sphoeroides testudineus	Checkered puffer	0	1	0	1
Total		48	18	6	61

Saddleback syndrome as an induced developmental defect

Although James & Badrudeen (1968) thought that injury caused saddleback in their specimens, we could see no indication of injury such as scars or regenerated scales associated with saddleback syndrome in the Biscayne Bay fishes. Fish pathologist J. Ziskowski (personal communication) visually examined four saddleback gray snapper specimens and saw no sign of physical injury or injury from infection or parasites.

Valentine (1975) suggested that the high incidence of various gross skeletal abnormalities in barred sea bass from southern California might result from a dysfunction in calcium metabolism. He noted that certain heavy metals, PCBs, and other chlorinated hydrocarbons interfere with calcium metabolism.

Lerner (1954) proposed that a lack of genetic heterogeneity such as one might find in small, isolated populations or in hatchery stocks can cause developmental instability, leading to morphological abnormalities. This hypothesis has been supported by recent studies using bilateral asymmetry as an index of developmental instability (Leary et al. 1984, 1985). If Biscayne Bay fish populations have declined to the extent that genetic variability has been substantially reduced, this might be the mechanism by which saddleback is being produced. Bilateral asymmetry is known to be present in Biscayne Bay fishes in the form of scale disorientation and missing pectoral fins on one side (Table 1). One might wonder, however, if decreased genetic variability alone could cause the taxonomically widespread occurrence of one particular abnormality in Biscayne Bay that seems uncommon elsewhere.

The presence of the same deformity in many species from Biscayne Bay suggests that something in the environment common to all the species may have caused the deformity. PCBs, other chlorinated hydrocarbons, and certain heavy metals found in Biscayne Bay have been associated with skeletal deformities in laboratory studies (Valentine & Soule 1973, Weis & Weis 1989). The frequency of abnormalities have been shown to be higher in more polluted or chemically contaminated waters

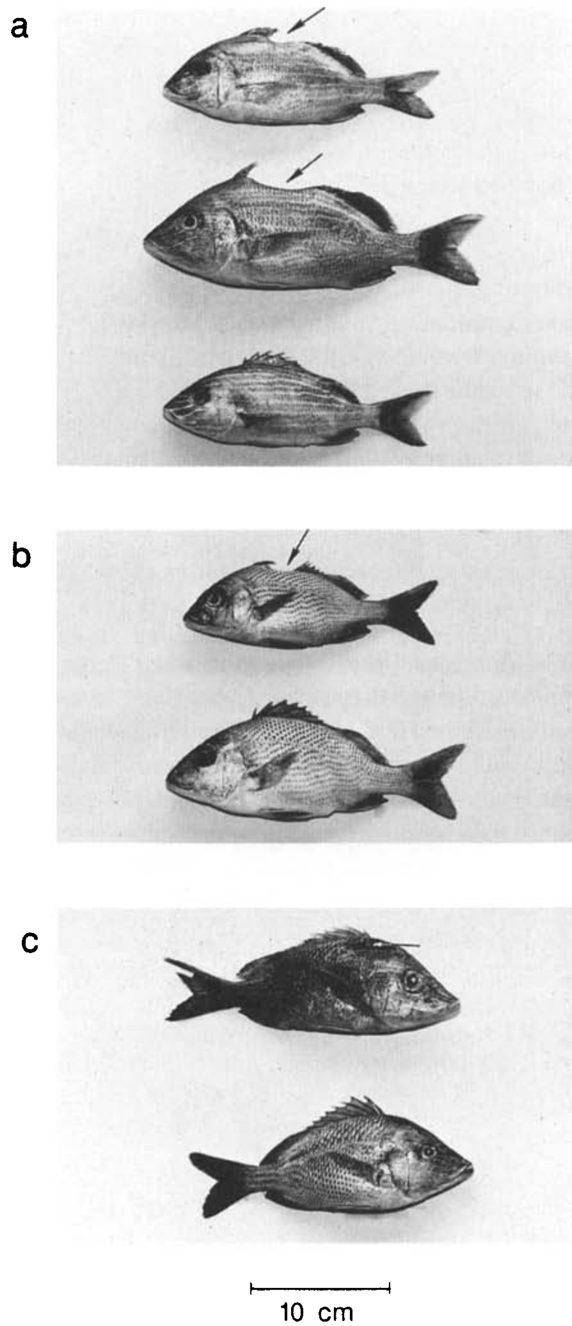

Fig. 2. Saddleback and normal specimens in the family Haemulidae: a – bluestriped grunt, *Haemulon sciurus*, b – sailor's choice, *Haemulon parrai*, and c – white grunt *Haemulon plumieri*. The bottom fish in each photograph is the normal individual.

than in nearby waters (Valentine & Bridges 1969, Valentine 1975, Cameron et al. 1992). The evidence for a relationship between pollution and fish diseas-

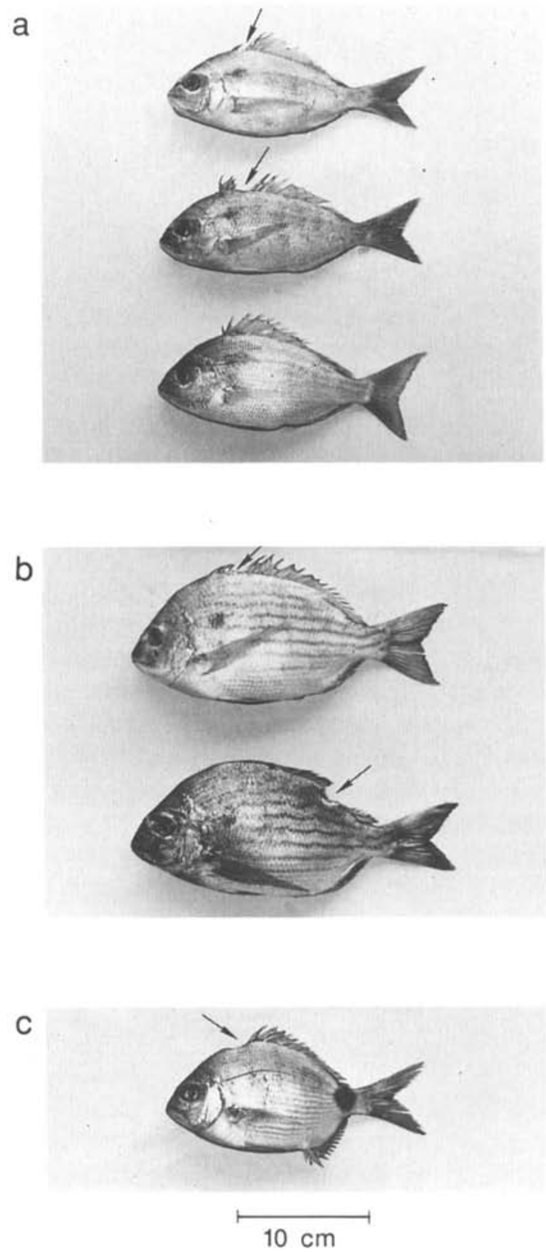

Fig. 3. Saddleback specimens in the family Sparidae: a – pinfish, *Lagodon rhomboides* (bottom individual is normal), b – sea bream, *Archosargus rhomboidalis*, and c – silver porgy, *Diplodus argenteus*.

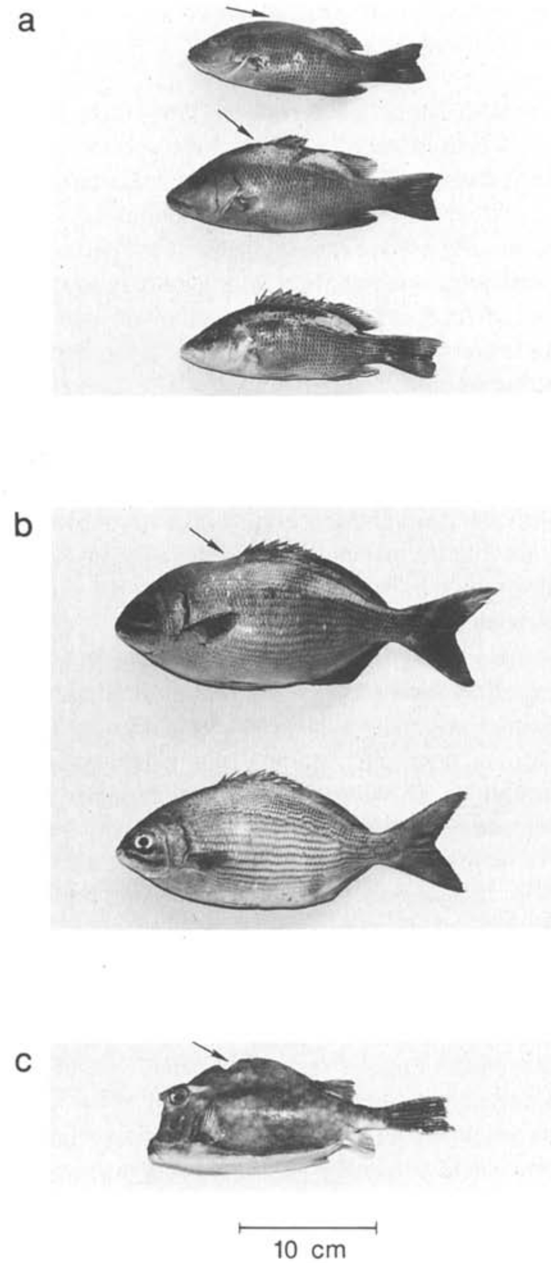

Fig. 4. Additional saddleback specimens: a – gray snapper, *Lutjanus griseus* (bottom individual is normal), b – Bermuda chub, *Kyphosus sectatrix*, and c – scrawled cowfish, *Lactrophrys quadricornis*.

es and deformities is accumulating (Sindermann 1979, 1992).

The breeding study of Tave et al. (1983) demonstrated that saddleback in hatchery-raised *O. aureus* had a heritable basis. Saddleback in Biscayne Bay fishes may have arisen through the environmental induction of mutation at some labile genetic locus shared by all fish groups. Regulatory genes directing the differential development of body sectors are now known to be similar across widely divergent taxonomic groups (Gehring 1987). Germline mutations in fish have been produced in the laboratory by environmental agents (Chakrabarti et al. 1983). Dominant lethal mutations, such as that described by Tave et al. (1983), generally are associated with gross chromosomal change (Newcombe & McGregor 1967). Longwell et al. (1992) have associated mitotic irregularities and chromosome abnormalities in fish with environmental contamination of reproductive tissue.

The similarity of our saddleback syndrome to the heritable one described by Tave et al. (1983) does not necessarily mean that the syndrome we describe also is heritable. An environmental agent does not have to induce germline mutation in order to produce a morphological abnormality that resembles an heritable one. Phenocopies, or morphological abnormalities resembling those caused by known mutants, have been induced experimentally by subjecting embryos during early development to various environmental factors, including chemicals (Scharloo 1991).

Implications of the Biscayne Bay findings

If it can be linked to contaminants or environmental disturbance, saddleback might make a powerful environmental quality index. The defect is easily recognized, interspecific, and present in definitive phenotypes (juveniles, adults). Measurable biological responses are needed to adequately assess the quality of aquatic habitat because some chemicals have biological effects in quantities below detection levels and certain chemicals act synergistically, multiplying their effects. Therefore, water chemistry alone is an incomplete indicator.

Saddleback, if induced by an environmental agent through germline mutation, could also be valuable in developmental genetics research. Definition of the role of homeotic genes in body pattern formation during development has largely depended upon research with *Drosophila* because of the availability of associated mutations (Raff & Kaufman 1983). Developmental models with appropriate mutations are lacking for vertebrates (Fjose et al. 1990).

The presence of the saddleback syndrome will lower the reproductive potential of wild fish populations if survival and disease resistance are affected as in Tave et al.'s (1983) hatchery-raised stock. If the condition is heritable as in *O. aureus*, then the smaller and more isolated the population, the greater the potential influence of deleterious genes (Maynard Smith 1989).

The prevalence, causal agent, and mechanisms involved in saddleback malformations in Biscayne Bay fishes should be explored. Potential results may have application not only to Biscayne Bay restoration but also in developmental genetics and environmental quality monitoring.

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