EFFECTS OF HURRICANE ISABEL ON FISH POPULATIONS AND COMMUNITIES IN CHESAPEAKE BAY

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ABSTRACT

Trawl surveys throughout Chesapeake Bay documented abundances and distributions of pelagic and bentho-pelagic fishes after Hurricane Isabel. Species richness increased, primarily from occurrences of previously uncommon freshwater species that possibly were transported to the Bay's main stem by high freshwater flow from the Susquehanna River. Abundances of young-of-the-year (YOY) anadromous fishes (e.g., striped bass and white perch) were above the decadal mean for fall trawl surveys, probably more in response to the prevailing "wet" conditions of spring 2003 that favored successful reproduction of anadromous fishes than as a consequence of Isabel. In the lower Bay, a large post-Isabel increase in abundance of adult bay anchovy occurred, likely resulting from post-Isabel migration into the Bay or downriver displacement from tidal tributaries. Young-of-the-year (YOY) Atlantic croaker were remarkably abundant in the post-Isabel survey. Their peak abundance, centered in the lower Bay, was more than 30 times higher than mean abundance for the previous decade, suggesting a large entrainment of croaker larvae from coastal ocean spawning sites in the aftermath of Isabel. The apparent near-term effects of Isabel mostly indicated enhanced abundances and shifts in distributions; no obvious negative effects on fish populations, recruitment of YOY fishes, or fish communities were observed.

INTRODUCTION

Documented effects of hurricanes and tropical storms on fish communities are limited, in part due to the lack of pre-storm data required to conduct before- and after-storm comparisons. Under some circumstances, hurricanes can cause massive mortalities of fish and destruction of their habitats in coastal and estuarine ecosystems [1]. Under other circumstances, the effects may be small [2]. However, storm effects on fish communities typically are described as short term [3, 4, 5]. Observed effects include high mortality, shifts in species composition and biomass, social/reproductive abnormalities, export and loss of egg and larval stages, and a rise in the incidence of fish disease [6, 7, 8, 9, 10, 11].

The Chesapeake Bay has experienced impacts from hurricanes and tropical storm systems in the past. Most notable was Tropical Storm Agnes in June 1972, which resulted in a 100- to 200-year flood [12]. Although Agnes' effects on finfish proved temporary, the storm's impact on shellfish (oyster - *Crassostrea virginica* and soft-shelled clam - *Mya arenaria*) was devastating, with an estimated loss in Virginia of 7.9 million dollars [12].

On 18 September 2003, Hurricane Isabel made landfall east of Cape Lookout, North Carolina as a Category 2 hurricane. The storm center approached from south of the Chesapeake Bay during the afternoon of 18 September and passed to the west of the Bay in the early morning of 19 September as a sub-Category 1 storm. Isabel brought the highest storm surge and wind to the region since Hurricane Hazel in 1954 and the Chesapeake-Potomac Hurricane of 1933 (*www.erh.noaa.gov/er/akq/wx_events/hur/isabel_2003*).

A baywide trawl survey was conducted to evaluate the effects of Hurricane Isabel on fish

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community structure in the Chesapeake Bay. The objectives were to measure and map species distributions and abundances within the Chesapeake's main stem. The results were compared with distribution and abundance data collected 2 to 9 days prior to Hurricane Isabel in a CHESFIMS[1] survey (9–16 September 2003). In addition, results were compared with data from previous fall baywide fish surveys in TIES[2] and CHESFIMS (1995–2002).

MATERIALS AND METHODS

Two post-Isabel trawl surveys were conducted. The first was a BITMAX[3] survey in the upper Bay on RV *Aquarius* from 21–23 October 2003; the second was a survey on RV *Cape Henlopen* from 6–10 November 2003. Together, these surveys sampled the entire Chesapeake Bay main stem (30 trawling stations). Fish were collected at night in an 18-m^2 mouth-opening, midwater trawl (MWT) with 3-mm cod-end mesh. The MWT was fished for 20 minutes in stepwise fashion from surface to bottom. The post-Isabel abundances and distributions were compared with pre-Isabel data from CHESFIMS (September 2003) and earlier years' data from TIES[2] and CHESFIMS[1]

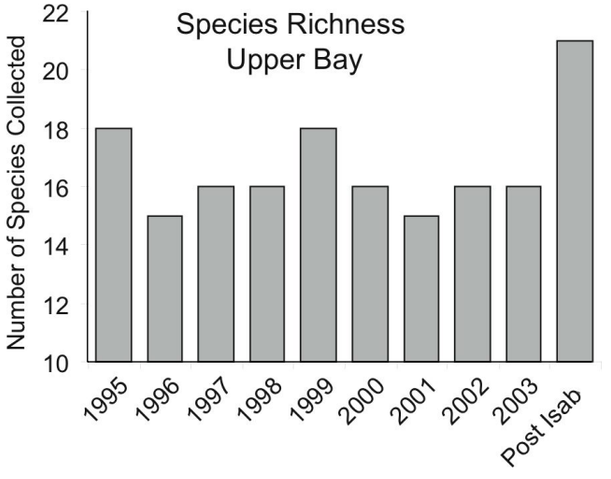

Figure 1. Number of fish species collected in the upper Chesapeake Bay (up-Bay of latitude 39º N) during fall (mid September to early November) surveys, by year. All fish were collected in an 18-m^2 mouth-opening, midwater trawl with 3-mm cod-end meshes.

fall surveys of fishes collected using the same mid-water trawl. The six TIES cruises were conducted in October/November (1995–2000) [13]; the CHESFIMS cruises were conducted in September (2001–2003). In addition, ichthyoplankton and jellyfish were collected in a 1-m^2 Tucker trawl (280-µm meshes) during the post-Isabel cruises (16 stations) and data were compared with similar data from previous TIES collections.

The number of fish species (diversity) in each trawl sample, relative abundances (numbers per 20-min tow), and sizes were recorded and contoured abundance maps produced. Diversity and abundances of key taxa were compared to the decadal means for previous fall cruises and to abundances and distributions found on the CHESFIMS pre-Isabel cruise (9–16 September 2003).

RESULTS AND DISCUSSION

Environmental Data

Substantial declines in salinity and water temperature in the Bay main stem occurred between pre- and post-Isabel cruises, reflecting the normal seasonal pattern from September to early November. Bottom water temperatures ranged from 14º C to 19º C during the post-Isabel survey, increasing from the head down the Bay, a typical early November pattern. The post-Isabel water temperatures were similar to those measured in fall cruises during the TIES years. Baywide, post-Isabel bottom salinities were lower in October and November than in all years since 1995, except for

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[1] *CHESFIMS, Chesapeake Bay Fishery-Independent Multispecies Survey, a project funded by the NOAA Chesapeake Bay Office (Grant NA07FU0534) to survey fish throughout the Bay from 2001 to 2004.*

[2] *TIES, Trophic Interactions in Estuarine Systems, a NSF-funded, multidisciplinary research program (Grant DEB 9412113) that sampled and surveyed the Bay from 1995 to 2000.*

[3] *BITMAX, Biophysical Interactions in the Estuarine Turbidity Maximum, a NSF-funded multidisciplinary research program (Grant OCE 0002543) to sample and survey the upper Bay region near the salt front and estuarine turbidity maximum zone from 2001 to 2003.*

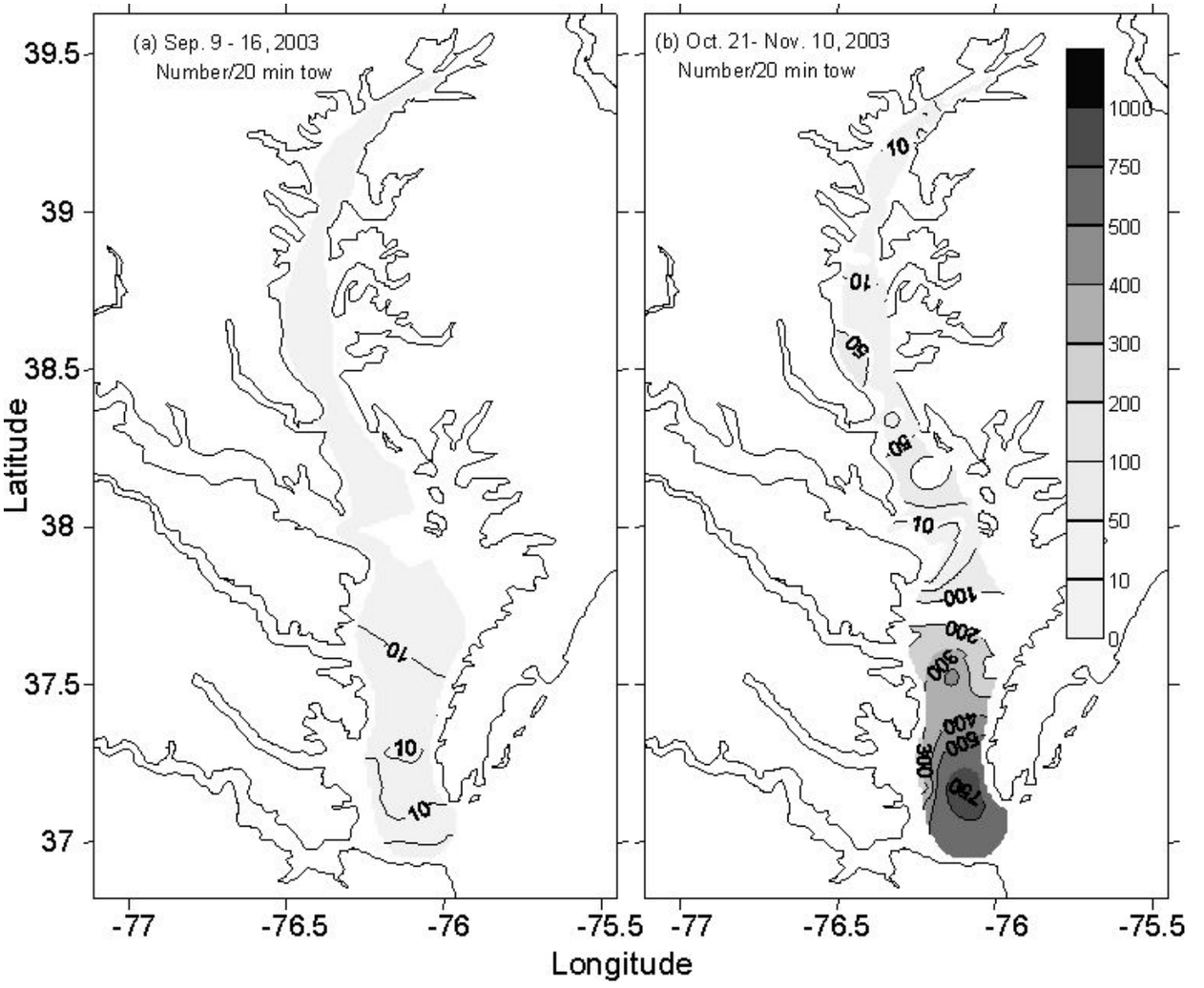

Figure 2. Maps of adult bay anchovy (age 1+) distribution (numbers per tow) from mid-water trawl collections in fall baywide surveys in Chesapeake Bay. Left panel: 9 to16 September 2003 (pre-Isabel); Right panel: 21 October to 10 November 2003 (post-Isabel).

the "wet" year 1996 (TIES[2] and CHESFIMS[1] CTD data). Salinities near the western shore of the Bay were lower than those near the Eastern Shore during the post-Isabel survey, attributable in part to the heavier rainfall and higher tributary flows on the western shore. Bottom salinities in the uppermost Bay increased slightly in the immediate aftermath of the hurricane, but declined substantially in the following weeks (Chesapeake Bay Program monitoring data).

Fishes

A total of 103,392 fish was collected during the post-Isabel survey. Young-of-the-year (YOY) bay anchovy (*Anchoa mitchilli)* dominated catches, contributing 83% to the total number and 32% to the biomass. Relative abundance and biomass (catch-per-tow (CPUE)) of all fish species combined were similar to CPUE levels in previous years, but significantly higher than CPUE for the pre-Isabel cruise in September 2003. Baywide, a total of 35 species was collected in the post-Isabel surveys, three more than the long-term average of 32+ species in previous fall collections (1995–2003).

In the upper Bay's estuarine transition zone, three more species were collected during the post-Isabel cruise than in any previous fall cruise and

the mean number of post-Isabel species was five more than the long-term fall survey mean (Figure 1). Unusual or uncommon species in the post-Isabel cruise included the brown bullhead (*Ameiurus nebulosus)*, a sunfish (*Lepomis* sp.*)*, a darter (*Etheostoma olmstedi*), and the yellow perch (*Perca flavescens)*, all sampled from the upper Bay. Yellow perch had not been collected in previous fall TIES or CHESFIMS surveys in the mainstem Bay.

Abundances of YOY anadromous fishes in fall 2003 were well above the decadal average for the upper Bay, probably due to the high rainfall and stream discharge in spring 2003, which favor recruitment of these fishes [14]. There were no obvious negative effects of Isabel on YOY anadromous fishes. Comparing distributions in the pre- and post-Isabel cruises, the centers of YOY striped bass (*Morone saxatilis)* and white perch (*M. americana)* abundances shifted slightly down-estuary after the hurricane, apparently in response to a similar down-estuary shift in the salt front. Similar responses were observed after Tropical Storm Agnes [4, 15]. Notably, the post-Isabel distributions of YOY blueback herring, alewife, and shads (*Alosa* spp.) extended into the mid-Bay, a pattern similar to that observed previously only during fall of the wet year 1996.

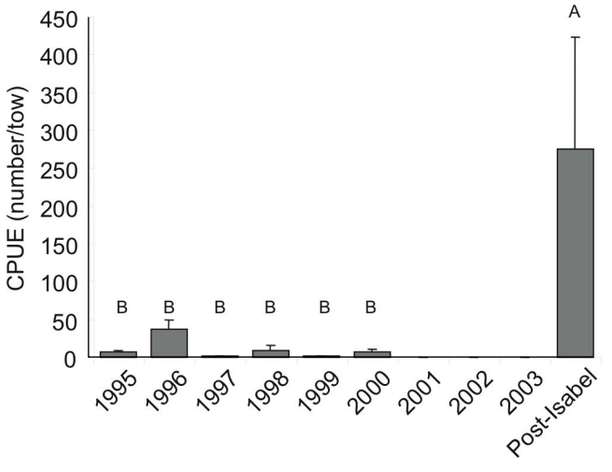

Figure 3. Atlantic croaker young-of-the-year relative abundance (number/tow) in Chesapeake Bay (+/- standard error) from mid-water trawl tows in fall surveys. Means were tested using one-way ANOVA, followed by Duncan's multiple range test. Different letters over a bar indicate significant difference ($p < 0.05$).

A sharp increase in the abundance of adult (age 1+) bay anchovy occurred after passage of Hurricane Isabel (Figure 2), mostly in the lower Chesapeake (pre-Isabel CPUE = 6.2 ±2.0 per tow; post-Isabel CPUE = 192.3 ±44.0 per tow). The apparent influx of adult anchovy may have resulted from entrainment with shelf waters into the lower Bay or possibly flushing from western shore tributaries after Isabel. The YOY bay anchovy were more abundant throughout the Bay following Hurricane Isabel and their center of abundance shifted down-estuary after the hurricane. The elevated abundance and down-estuary shift followed the normal seasonal recruitment pattern in this species [16], however, and probably was not due to the hurricane.

Other key species in fall surveys included Atlantic croaker (*Micropogonias undulatus)*, Atlantic menhaden (*Brevoortia tyrannus)*, and weakfish (*Cynoscion regalis)*. Of these, only YOY Atlantic croaker apparently had a major response to hurricane effects (Figures 3 and 4). Baywide, post-Isabel YOY croaker abundance was more than 30 times higher than in any previous TIES or CHESFIMS fall survey except for 1996 (the abundance was seven times higher after Isabel than in fall 1996). In most years, YOY croaker October/November abundance peaked in the upper Bay, suggesting transport of larvae from spawning grounds on the continental shelf to the Bay mouth and then a rapid, up-estuary transport.

The post-Isabel, YOY croaker abundance was centered in the lower Bay. Mean length of measured YOY croaker was significantly smaller (ANOVA, $p<0.0001$) in the post-Isabel survey (33.0±0.4 mm) than the overall mean length for 1995–2000 fall surveys (43.0±1.4 mm). Field notes taken during the post-Isabel survey indicated unprecedented numbers of croaker <20 mm long (not fully vulnerable to the trawl) that escaped cod-end meshes, spilled onto the deck when the trawl was brought on board, and were not counted or measured. The high abundance and small size in the lower Bay indicated a massive and recent import

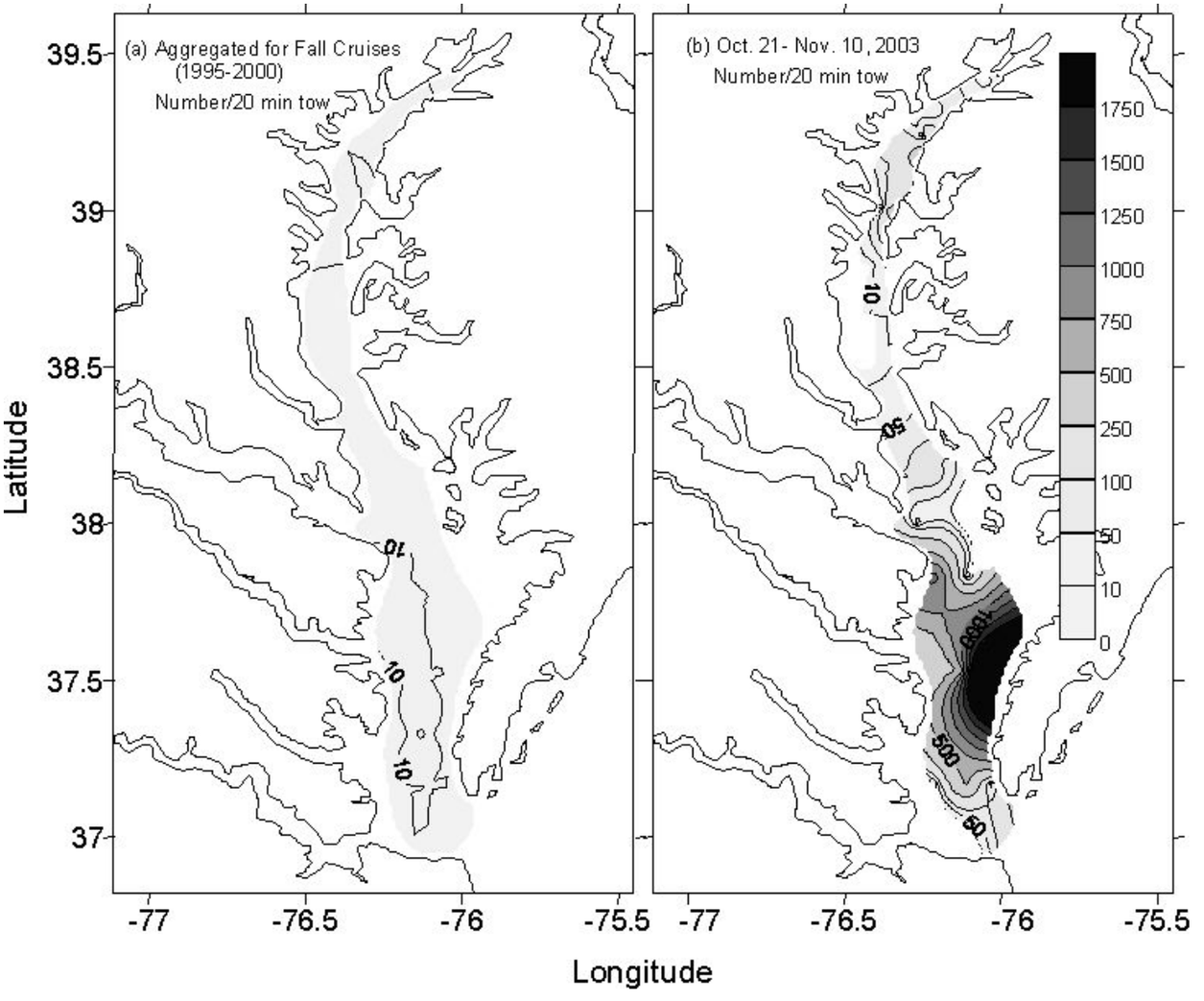

Figure 4. Distribution and abundance (number/tow) of young-of-the-year Atlantic croaker in Chesapeake Bay in the post-Isabel survey (21 October to 10 November 2003) compared to the mean for fall surveys from previous TIES[1] years (1995 to 2000).

of croaker larvae from offshore, possibly from above-average, cross-shelf transport after Isabel and subsequent up-estuary advection in bottom waters with enhanced estuarine circulation. Monthly trawl-survey results in the Virginia portion of Chesapeake Bay also indicated unprecedented numbers of YOY croaker in the October to December 2003 period attributed to the effects of Hurricane Isabel [17, 18].

Hurricane Isabel crossed the Bay region during the summer/fall transition season after most estuarine-spawning fishes had completed spawning; consequently, YOY juveniles were abundant but eggs and larvae were uncommon. In contrast, Tropical Storm Agnes hit the Bay region in late June 1972 during the peak spawning season of bay anchovy, naked goby (*Gobiosoma bosc)*, weakfish, and other species. Their eggs and larvae were absent or rare in the post-Agnes surveys [6], suggesting disruption of spawning, mortality, or export from tidal tributaries and perhaps from the Bay itself. Hoagman and Merriner [7] estimated losses of $>10^8$ eggs and larvae from the Rappahannock and James rivers in the two weeks following Agnes. In our post-Isabel surveys, there was no evidence of catastrophic displacement or

mortality of YOY juveniles of anadromous and estuarine-spawning fishes. Larvae of the ocean-spawning Atlantic croaker also apparently experienced a massive import into the Bay.

Jellyfishes

In comparing distributions and abundances of two common jellyfishes—the lobate ctenophore (*Mnemiopsis leidyi)* and the sea nettle medusa (*Chrysaora quinqecirrha)*—from TIES fall surveys in 1995–2000 and the post-Isabel surveys in October–November 2003, no evidence was seen of a hurricane effect. Distributions, abundances, and biovolumes of these jellyfishes were highly variable among years and regions in fall cruises; the post-Isabel distributions and abundances were not anomalous.

SUMMARY

In summary, based on comparison of pre- and post-Isabel survey data, the Bay's fish community apparently responded to hurricane effects although the high freshwater flow to the Bay throughout 2003 adds uncertainty to the results. The increase in species richness observed post-Isabel in the upper Bay included many freshwater species previously uncommon or unobserved in mid-water trawl surveys in the Bay's main stem. These species possibly were flushed into the Bay from the Susquehanna River after Isabel. A pulse of freshwater from Isabel and the overall high freshwater flow to the Bay in 2003 also could explain the post-Isabel, down-estuary shift in YOY *Alosa* species distributions, a pattern only observed previously in the wet year of 1996. Results from fish surveys on the James, York, and Rappahannock rivers in July 1972, following Tropical Storm Agnes, support the finding that downstream displacement of juvenile fishes occurs following the passage of strong storm systems [4, 15]. A surge of ocean water into the lower Bay associated with Hurricane Isabel may have promoted immigration of adult bay anchovy into the Bay. The same mechanism could explain the extraordinary abundance of YOY Atlantic croaker in Isabel's aftermath.

Our post-Isabel sampling was conducted 5 to 7 weeks after Hurricane Isabel passed through the Bay region, which limited our ability to observe or interpret the immediate impacts of the hurricane on the Bay's fish community. Despite this constraint, it was possible to document shifts in distributions and abundances of fishes apparently attributable to the hurricane. Observed near-term effects were mostly indicative of enhanced abundances (e.g., YOY Atlantic croaker and adult bay anchovy) [18]. No observed, obviously negative effects of Isabel on fish populations or communities in the Bay were noted.

ACKNOWLEDGMENTS

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