# Final Report to the VMRC, RFAB, and CFAB

**Project Title:** Towards validation of juvenile indices of abundance for several fish species in Chesapeake Bay

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**Principal Investigators:** Robert J. Latour, Christopher F. Bonzek, Mary C. Fabrizio

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## Introduction

Since the early 1900s, the production and seasonal dynamics of resources indigenous to Chesapeake Bay have supported a variety of fisheries both within the bay and along the Atlantic coast. During the past 50 years, large-scale fisheries have targeted (among others) striped bass (*Morone saxatilis*), weakfish (*Cynoscion regalis*), summer flounder (*Paralichthys dentatus*), spot (*Leiostomus xanthurus*), and Atlantic croaker (*Micropogonias undulatus*). These fisheries have resulted in significant levels of harvesting for several of the aforementioned species, and although trends in the commercial and recreational landings have been quite variable during the last several decades, many species have experienced overexploitation.

Fisheries-independent monitoring programs are designed to provide scientists and managers with information regarding the population dynamics of natural resources. In addition, data collected from these programs are often used to parameterize the stock assessment models from which management regulations are derived. Well-designed monitoring programs are assumed to provide unbiased estimates of population parameters. However, for scientists and managers to have confidence in the data being collected and subsequent modeling results, validation of the survey is required.

In the Chesapeake Bay region, several fisheries-independent surveys are routinely conducted for the purpose of measuring the relative abundance of fishes in the bay. Specifically, the VIMS Juvenile Fish and Blue Crab Trawl Survey is a long-standing survey designed to derive indices of abundance of young-of-the-year (YOY) fishes in the Virginia portion of Chesapeake Bay. Complementing this program is the VIMS beach seine survey, which samples YOY fishes in habitats and regions of the bay where trawl gear cannot be deployed. Collectively, these indices of YOY abundance are used by the Atlantic States Marine Fisheries Commission (ASMFC) to infer recruitment success and assist in the development of management regulations. However, to date, no attempts have been made to formally validate the indices derived from these sampling programs. This project will utilize linear models to attempt to validate survey-based indices of YOY abundance.

## Field methods

*YOY fishes*
The VIMS Juvenile Fish and Blue Crab Trawl Survey is a long-standing (initiated in 1955) fisheries-independent survey designed to sample YOY fishes in the Virginia portion of Chesapeake Bay. Sampling is based on depth strata (1 – 4 m, 4 – 9 m, 9 – 13m and >13 m) each defined within 15 latitudinal mile regions in the mainstem bay (to ensure proper spatial coverage, the mainstem was further divided into eastern and western areas within each latitudinal region) and 10 longitudinal mile regions in the tributaries. Sampling is conducted monthly (with the exception of January and March when only the tributaries are sampled) and a 9 m semi-balloon otter trawl is deployed at 3 – 4 sites within each stratum of each region. The survey employs several fixed sampling locations, while others are randomly selected each month. Once onboard, the catch is sorted by species and individual lengths are recorded. Length frequency analysis is used to discern YOY from older fishes.

The Virginia Juvenile Striped Bass Seine Survey is also a long-standing fisheries-independent survey (conducted continuously since 1980) designed to measure the relative abundance of YOY striped bass in the tributaries of the Virginia portion of Chesapeake Bay. Sampling is conducted biweekly from July through September at 18 historic sites and 22 auxiliary sites along the shores of the James, York, and Rappahannock Rivers. At each sampling location, a 30 m long, 1.2 m deep beach seine is hauled along the shoreline, generally not extending past the 1.2 m depth contour. All fishes collected are sorted by species and counted. All striped bass collected are measured.

*Adult fishes*
The Chesapeake Bay Multispecies Monitoring and Assessment Program (ChesMMAP) is a recently developed fisheries-independent trawl survey (initiated in 2002) designed to sample the adult components of the finfish populations in the bay. Each year five ChesMMAP cruises are conducted (March, May, July, September, and November) and approximately 80 to 90 sites are sampled each cruise within the Virginia and Maryland mainstem portions of Chesapeake Bay. Sampling locations are chosen according to a stratified random design, with strata based on water depth (3 – 9 m, 9 – 15 m, and >15 m) within five 30 latitudinal minute regions of the bay. The number of locations sampled in each stratum of each region is randomly selected in proportion to the area of that stratum. At each sampling location, a 13.7 m 4-seam balloon otter trawl (15.2 cm stretch mesh in the wings and body and 7.6 cm stretch mesh in the cod end) is towed for 20 min at approximately 6.5 km $h^{-1}$. Each catch is sorted and individual lengths are recorded by species or size-class if distinct classes within a particular species are evident. A subsample of each species or size-class is further processed for age determination and diet composition analysis, respectively.

## Statistical methods

*YOY abundance indices*
Methods for calculating YOY abundance indices from the VIMS trawl and seine surveys are long-established and well documented (see Montane and Fabrizio 2006, Hewitt *et al.* 2007). In

short, yearly catch-per-unit-effort (CPUE) calculations yield annual indices of relative abundance for YOY fishes (weighted geometric mean CPUE).

*Adult abundance indices*
Minimum trawlable fish abundance ($N$) is calculated as:

$$N = \frac{cA}{a} \quad (1)$$

where $c$ is the mean catch per tow (estimated according to the methods of Cochran (1977) for estimating means from stratified random samples), $A$ is the total survey area (mainstem of Chesapeake Bay), and $a$ is the area swept by each tow (calculated using net monitoring gear and GPS). Equation (1) refers to minimum trawlable abundance because it does not account for net efficiency.

Age-specific abundance estimates of bay fish stocks are estimated from the subsample of specimens from which otoliths were removed and analyzed; the number of fish in each age-class is expanded from the number of specimens in the subsample to the total number of specimens captured by ChesMMAP each survey year.

*Relationship of indices*
Simple linear regression models were used to examine the relationship between the recruitment index and age-specific adult abundance derived from Chesapeake Bay monitoring programs. In the context of this study, the model for a simple linear regression is:

$$I_a = \beta_0 + \beta_1 I_{YOY,t} \quad (2)$$

where the dependent variable $I_{YOY,t}$ is the YOY index of abundance in year $t$ and the independent variable $I_a$ is the age-specific estimate of adult abundance obtained from the ChesMMAP survey (see Figure 1 as an example for age 1 striped bass). We applied equation (2) to three species captured in high abundances by the monitoring programs currently in place in Chesapeake Bay. Furthermore, these species exhibit different reproductive strategies that influence their distributions and ultimately, abundance (Atlantic croaker spawn on the continental shelf, weakfish are bay and coastal spawners, and striped bass are anadromous and therefore spawn in freshwater locations). Linear regressions were constructed based on five data points because there are five years of ChesMMAP data available. Although five data points are insufficient to examine the structural relationship between YOY and adult abundance, a linear relationship is assumed. We recommend that this relationship be evaluated in the future as more data on adult fishes become available. Nonetheless, such regressions can be repeated for each age class for which ChesMMAP captures significant numbers of specimens. Strong relationships between juvenile and adult abundance would corroborate the validity and accuracy of the recruitment indices and would provide support for the current approaches and assumptions for calculating the indices. On the other hand, weak relationships would necessitate further investigation as to why the relationships are not supported.

**Results/Discussion**

Using striped bass data, linear regressions were constructed for seven age classes. A one-tailed t-test was used to examine the relationship between estimates of adult age-specific abundance and recruitment indices. The slope of each regression line was examined to see if it was significantly different from 0 at an alpha level of 0.05. Four out of seven slopes were significantly different from 0 ($p < 0.05$) using the recruitment index from the VIMS striped bass seine survey (Figure 2). Regression lines with slopes significantly different from 0 provide support towards validating the recruitment indices with only five years worth of data on adult abundance.

These methods were repeated for weakfish and Atlantic croaker. Age-specific abundances were regressed against recruitment indices derived from the VIMS Juvenile Fish and Blue Crab Trawl Survey for weakfish (Figure 3). The slope of each regression line was examined, and only one out of four slopes was significantly different from 0. The one-tailed t-test could not be applied to age 3 individuals because the slope was negative. The negative relationship between estimates of age 3 abundance and the recruitment indices was unexpected, and further investigation is necessary to elucidate potential reasons for this relationship. For Atlantic croaker, age-specific abundances were regressed against recruitment indices also derived from the VIMS Juvenile Fish and Blue Crab Trawl Survey. For this species, four out of ten slopes were significantly different from 0, with the strongest relationships exhibited for age classes 1, 2, 3, and 6 (Figure 4).

Initially, the results suggest that the recruitment indices can be validated using linear regression analysis for at least several of the species-specific age classes captured in large numbers by the ChesMMAP survey. However, not all age classes exhibited strong linear relationships for which the slope was significantly different from 0. One potential reason for this is that the recruitment indices may not be representative of underlying abundance due to the spatial and temporal factors used in their development. As the next step in our analysis, we modified the spatial and/or temporal information used to develop the recruitment indices in an attempt to increase their accuracy and subsequently, improve the linear relationships between estimates of adult abundance and the recruitment indices.

A modified recruitment index for striped bass was developed by additively combining the VA and MD recruitment indices derived from the individual seine surveys. Age-specific abundances were regressed against the modified striped bass recruitment indices (Figure 5). The $r^2$ values for four age classes improved considerably when the modified index was used (ages 1, 5, 6, and 7). In addition to strengthening the relationship between recruitment indices and estimates of adult abundance, these results indicate that recruitment indices for striped bass could potentially be considered on a Bay-wide scale instead of state-specific. However, further consideration should be given to the effects of migratory and spawning behavior on spatial distributions of striped bass within Chesapeake Bay and subsequently, estimates of adult abundance since the vulnerability of adult striped bass to the trawl survey gear is influenced by the life history of this species.

In an attempt to improve the linear relationships for several of the weakfish age classes, a modified index was developed. The modified index utilized data collected from stations deeper than 30 ft and also expanded the index months to include November, in addition to August through October. Additionally, estimates of adult abundance incorporated data only from the Virginia portions of the mainstem of Chesapeake Bay. The $r^2$ values for three age classes improved when adult abundance was regressed against the modified recruitment index (Figure 6; ages 1, 2, and 4); however, the improvement in $r^2$ for ages 2 and 4 was marginal. These results suggest that extended temporal coverage of the months used to derive the recruitment index may improve the calculation of the weakfish index since YOY weakfish are still caught by the VIMS juvenile fish trawl survey in relatively high abundances in November. Depth may also affect the distribution of juvenile weakfish and should be taken into consideration in the development of recruitment indices, where appropriate. Further research is necessary, however, to substantiate this claim. Depth likely influences prey availability and subsequent biotic processes such as predation, for juvenile weakfish in Chesapeake Bay.

Two modified recruitment indices were developed for Atlantic croaker. The first modified recruitment index uses the months April, May, and June to calculate the index instead of the original months, May through August. We hypothesized that the selected months more appropriately reflect YOY recruitment during spring. The second modified index utilizes the same months as the first modified index; however, for this index, only YOY abundance data collected from stations shallower than 30 feet were used. Here, we expected to determine if depth influences Atlantic croaker YOY abundance and ultimately, the recruitment index. The results show substantial improvement in $r^2$ values for six of the ten age classes when age specific abundance was regressed against the first modified index (Figure 7; ages 2, 4, 5, 7, 9, and 10). These results indicate that the months of April, May, and June more appropriately reflect YOY abundance than the original months. Overall, there is a marginal difference between the use of the first and second modified recruitment indices. Therefore, selecting the appropriate months used to derive the recruitment index for Atlantic croaker appears to be more important than the depth from which specimens were collected.

The results of this study demonstrate the utility of linear regression models for validating recruitment indices and emphasize the need for further evaluation of criteria used to develop indices of relative abundance for other species captured in high abundances by the VIMS juvenile fish monitoring programs. Based on the results, there is substantial support that validates the recruitment indices for striped bass and Atlantic croaker; the results for weakfish, however, are equivocal. Weakfish populations are currently listed as depleted with estimated spawning stock biomass declining steadily since 1998 (ASMFC 2006). Our findings, including the negative relationship between estimates of age 3 abundance and recruitment indices, are difficult to interpret in light of the paucity of information that exists on weakfish population dynamics and their current population status. Beyond the first age class, a lack of strong linear relationships could indicate that older weakfish are occupying habitats where sampling does not occur. Further investigation is needed to resolve whether it is a sampling-related issue, or a population dynamics issue. Nevertheless, we can conclude that the spatial and temporal information used to derive recruitment indices should be given careful consideration with respect to each species. By modifying the spatial and temporal criteria used to develop the recruitment indices, the accuracy of the recruitment indices may improve, thus, more appropriately reflecting recruitment to the juvenile stage. For the future, we also recommend a comprehensive investigation into the appropriate methods for estimating adult abundance. In this study, minimum trawlable abundance was used. However, due to time constraints, we were unable to assess whether or not this is the optimal method for deriving estimates of adult abundance.

**Dissemination of results**

This research has contributed, in part, towards the M.S. thesis research of J. Woodward. Preliminary results from this study were presented at the following:

Sept. 2006 Annual Meeting of the American Fisheries Society in Lake Placid, NY
Paper presentation: C. Bonzek

Mar. 2007 VIMS Fisheries department seminar series
Seminar: J. Woodward

Sept. 2007 Annual Meeting of the American Fisheries Society in San Francisco, CA
Poster presentation: J. Woodward

Upcoming presentations that will incorporate findings from this study include:

April 2008 VIMS Fisheries department seminar series
Seminar: J. Woodward

August 2008 Annual Meeting of the American Fisheries Society to be held in Ottawa, Canada
Paper presentation: J. Woodward

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**ChesMMAP Trawl Survey**: Captain Durand Ward, James Gartland, RaeMarie Johnson, Eric Brasseur, Melanie Chattin

**VIMS Juvenile Finfish and Blue Crab Trawl Survey**: Wendy Lowery, Hank Brooks, Aimee Halvorson, Amanda Hewitt

**VA Striped Bass Seine Survey**: Amanda Hewitt, summer field crews

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Cochran, W. G. 1977. Sampling Techniques. John Wiley and Sons, New York. 3rd edition.

Hewitt, A.H., J.K. Ellis, and M.C. Fabrizio. 2007. Estimation of juvenile striped bass relative abundance in the Virginia portion of Chesapeake Bay, January 2006-December 2006. Annual Progress Report to Virginia Marine Resources Commission, 31 p.

Montane, M.M. and M.C. Fabrizio. 2006. Estimating relative abundance of recreationally important finfish and crustaceans in the Virginia portion of Chesapeake Bay, Project # RF 05-15, June 2005 - May 2006. Annual report to the Virginia Marine Resources Commission Marine Recreational Fishing Advisory Board. Virginia Institute of Marine Science, Gloucester Point, VA.

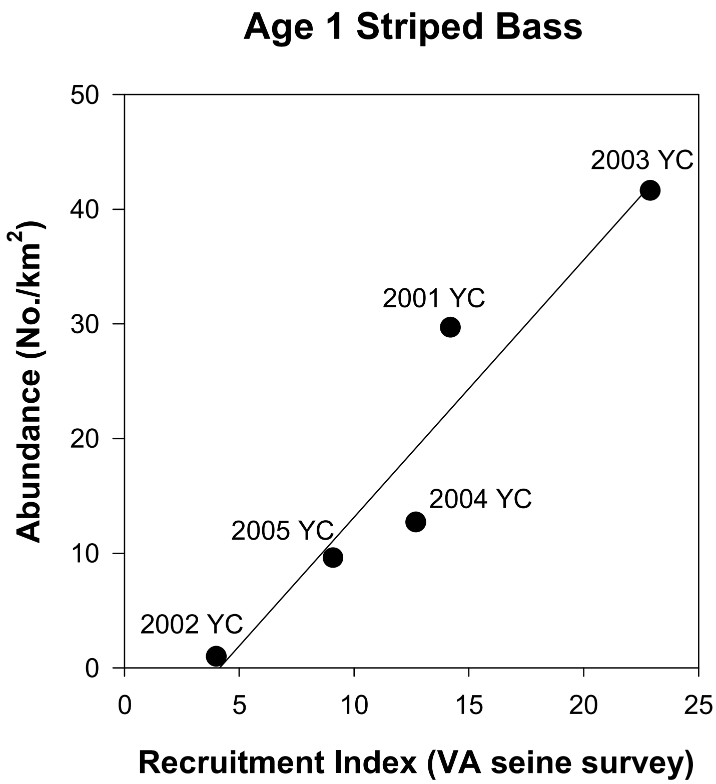


**Figure 1**. Age-1 abundance of striped bass derived from the ChesMMAP survey regressed against the recruitment index derived from the VA seine survey. Year classes are identified by year.

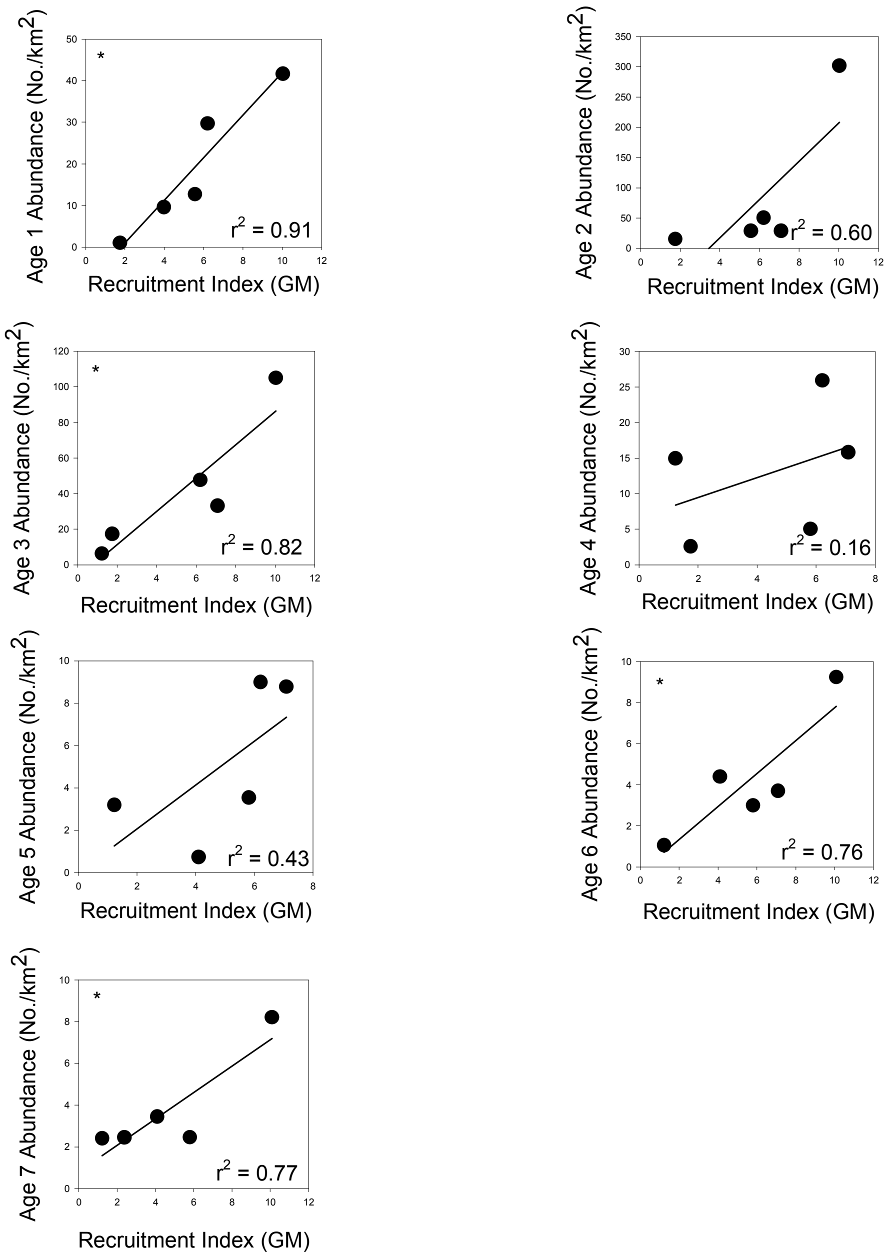


**Figure 2**. Age-specific minimum trawlable abundance of striped bass regressed against recruitment indices (expressed as a geometric mean, GM, catch per haul) from the VIMS striped bass seine survey. Significant results are indicated with an asterisk in the upper left corner.

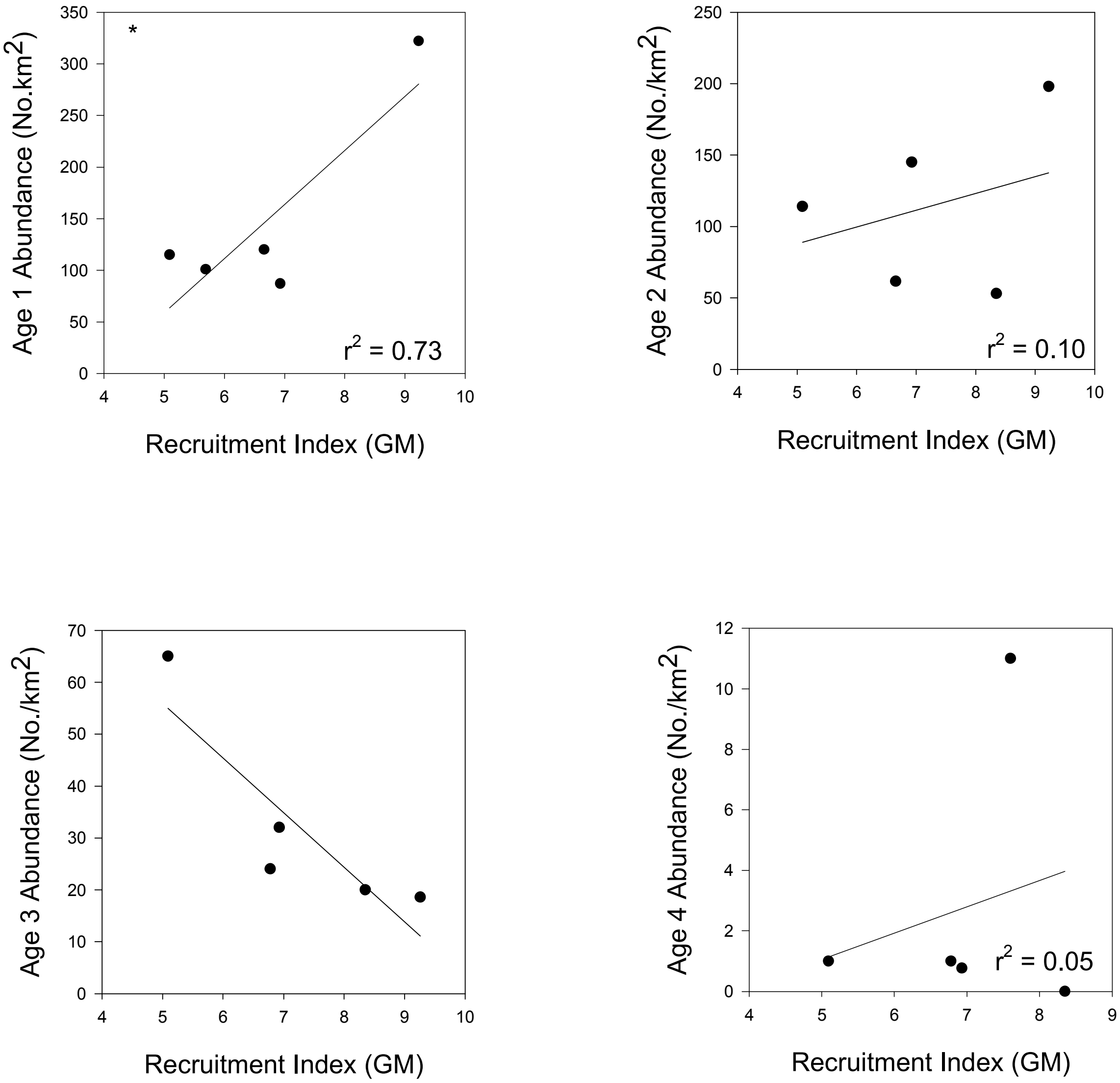


**Figure 3**. Age-specific abundance of weakfish regressed against recruitment indices (expressed as a geometric mean, GM, catch per haul) derived from the VIMS Juvenile Fish and Blue Crab Trawl Survey. Significant results are indicated with an asterisk in the upper left corner.

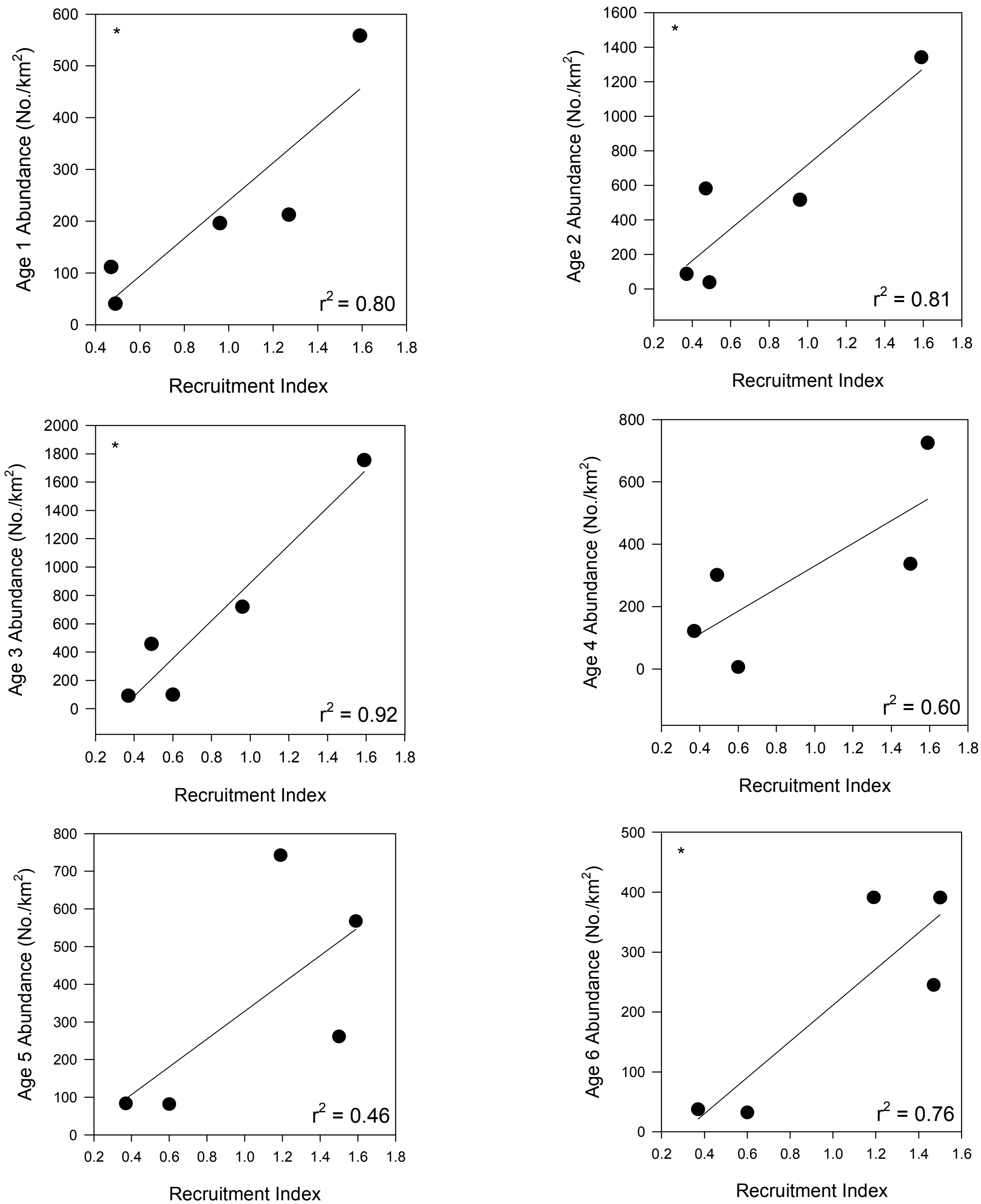


**Figure 4**. Age-specific estimates of Atlantic croaker abundance regressed against recruitment indices (expressed as a geometric mean, GM, catch per haul) derived from the VIMS Juvenile Fish and Blue Crab Trawl Survey. Significant results are indicated with an asterisk in the upper left corner.

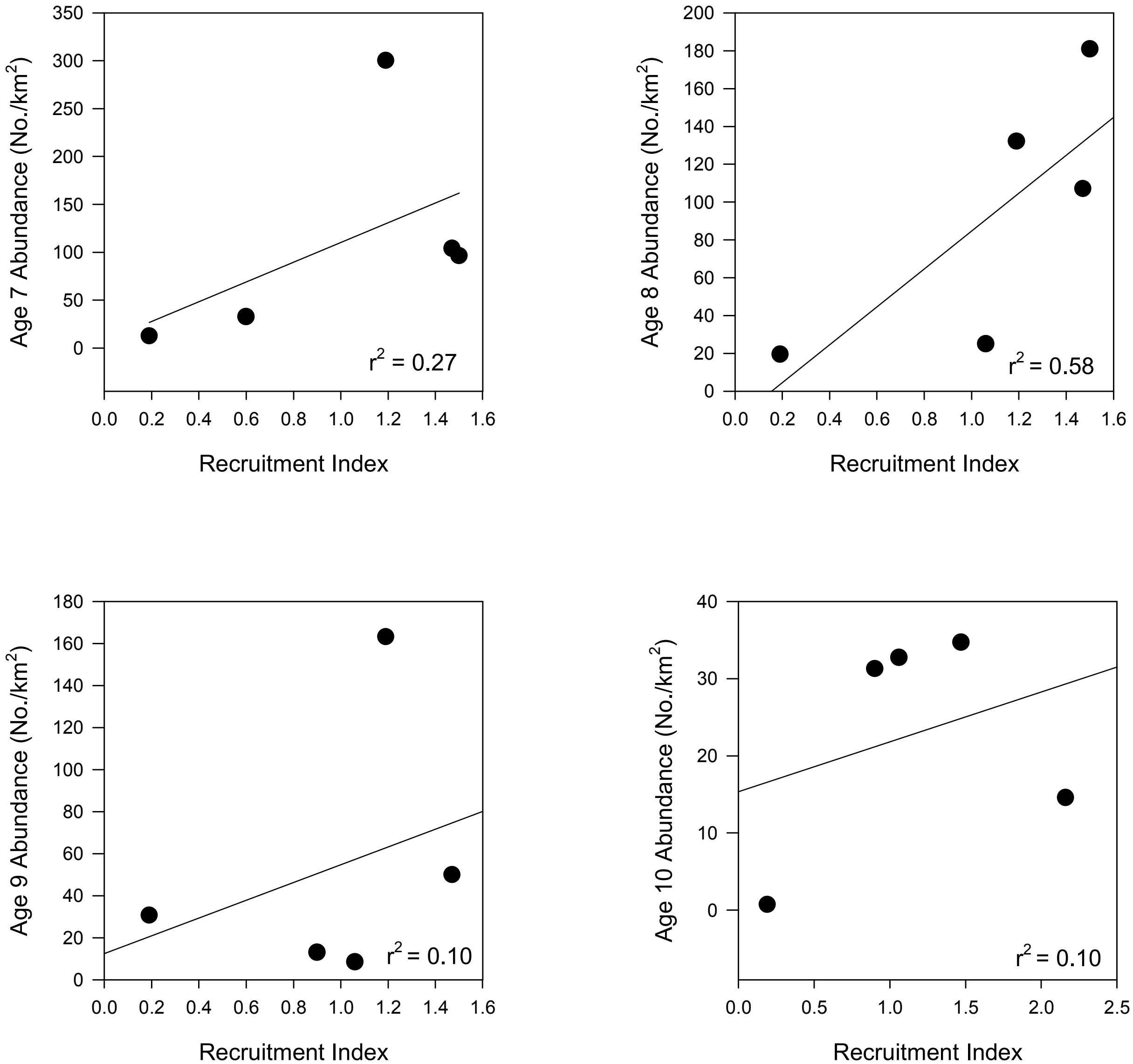


**Figure 4 (cont.)**. Age-specific estimates of Atlantic croaker abundance regressed against recruitment indices (expressed as a geometric mean, GM, catch per haul) derived from the VIMS Juvenile Fish and Blue Crab Trawl Survey. Significant results are indicated with an asterisk in the upper left corner.

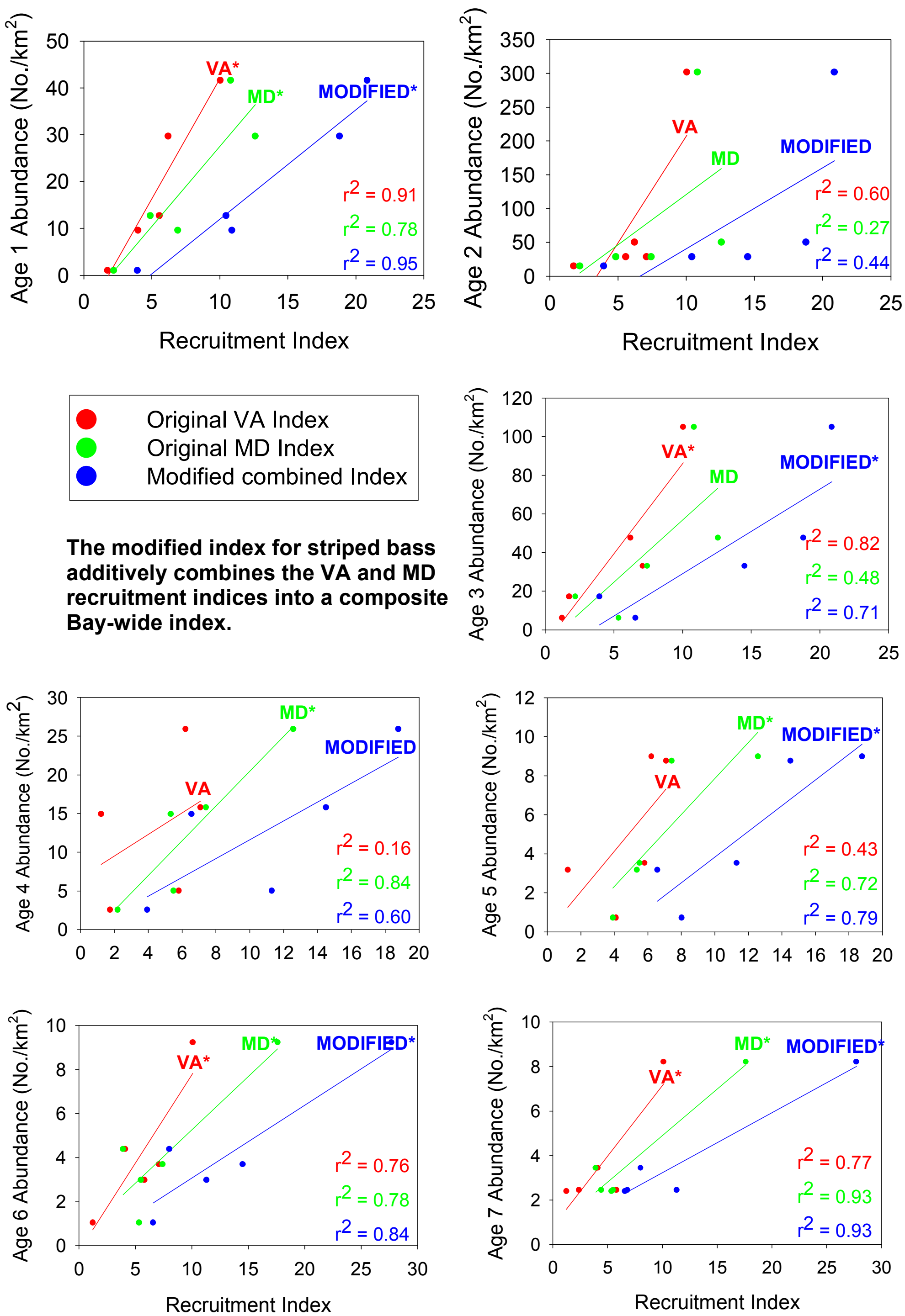


**Figure 5**. Age-specific abundances regressed against recruitment indices for striped bass ages 1-7. Linear regressions constructed with the original VA and MD seine survey recruitment indices are shown in red and green, respectively. The modified index additively combines the VA and MD recruitment indices into a Bay-wide index. Significant results are indicated with an asterisk.

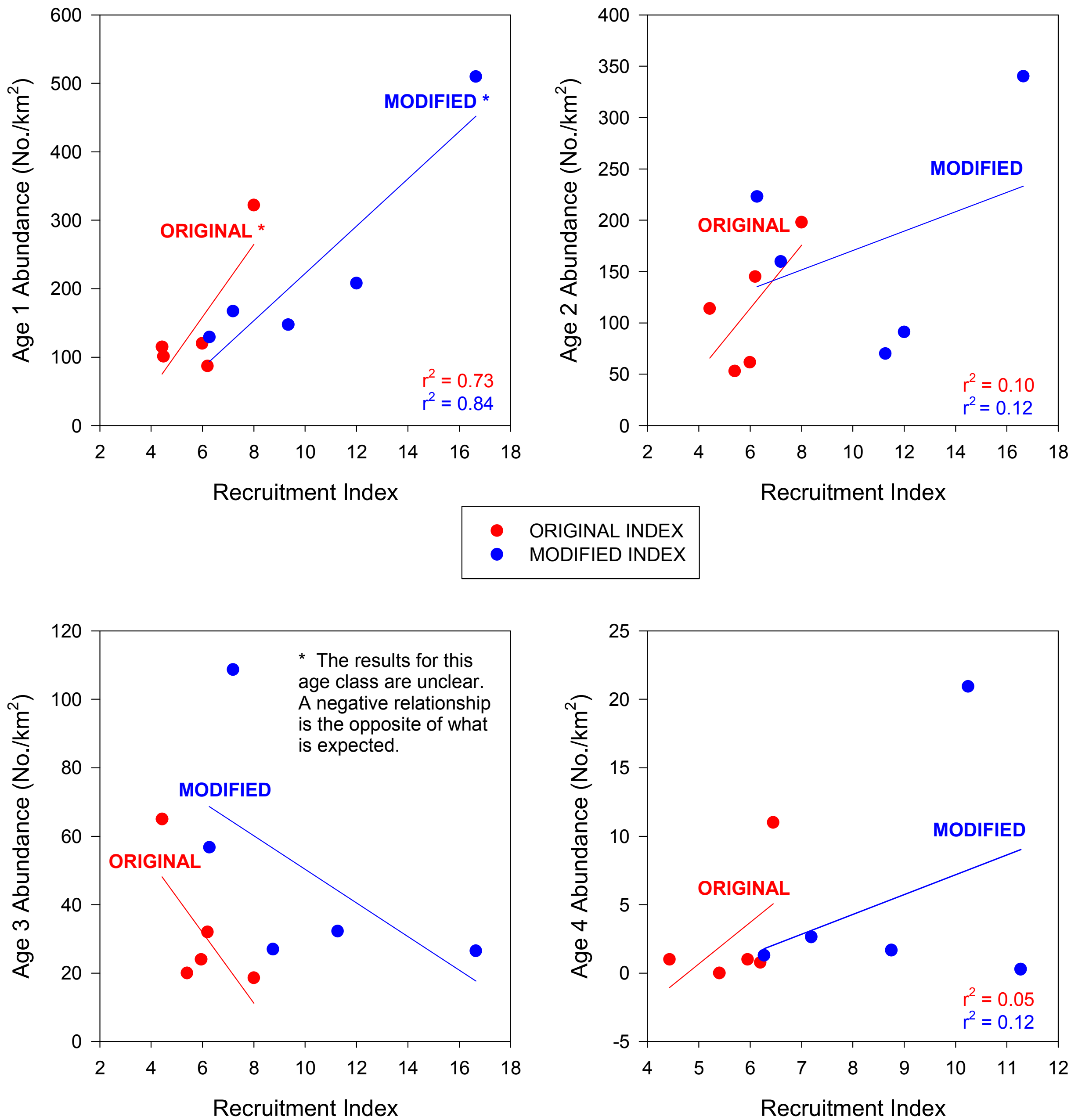


**Figure 6**. Age-specific abundances regressed against recruitment indices for weakfish ages 1-4. The modified index for weakfish uses data from stations deeper than 30 ft for the recruitment index and also includes the month of November in the index calculation. Estimates of age-specific adult abundance are from Virginia portions of Chesapeake Bay only. Significant results are indicated with an asterisk.

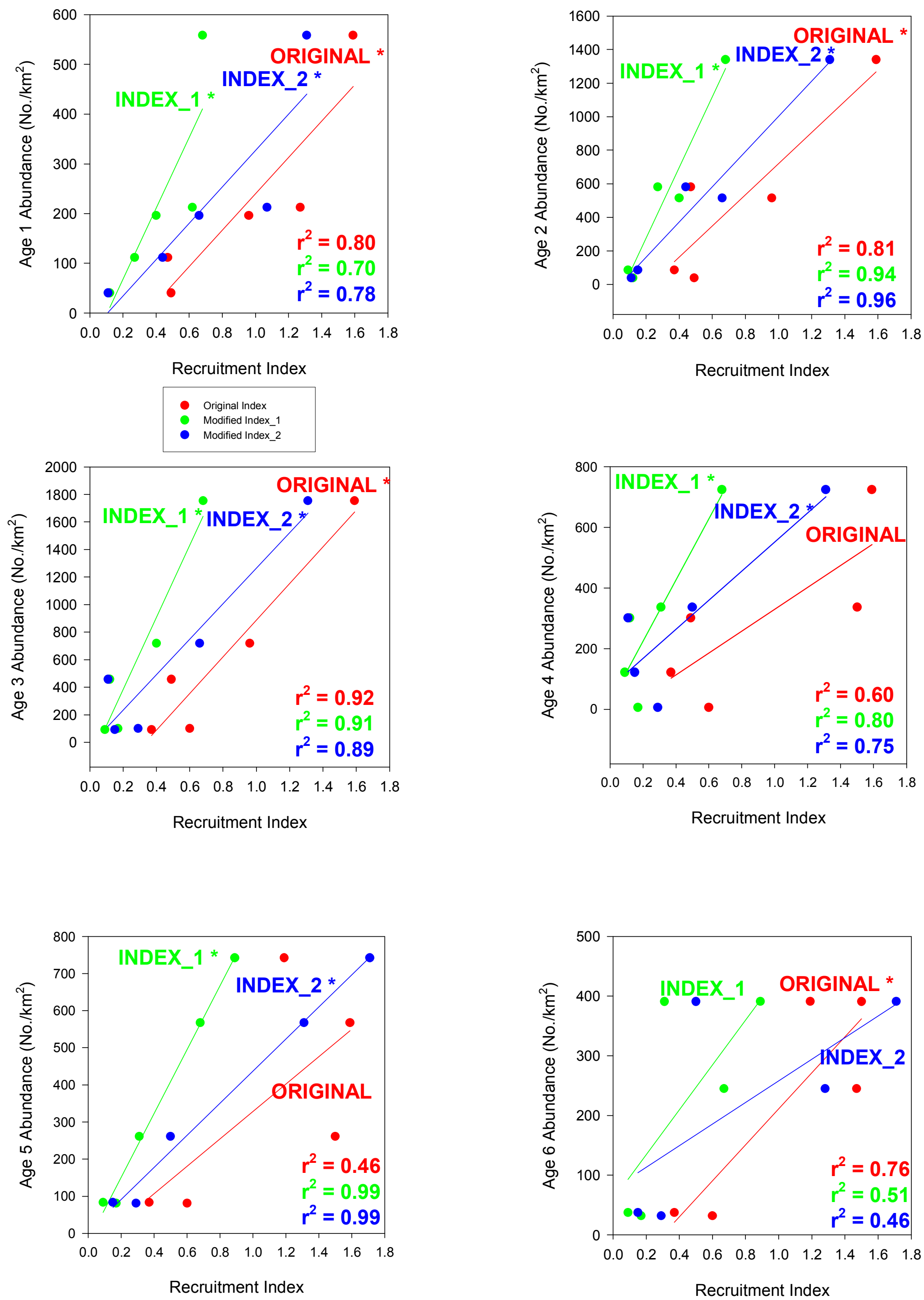


**Figure 7**. Age specific estimates of abundance for Atlantic croaker regressed against the recruitment index (expressed as a geometric mean) from the VIMS trawl survey. Regressions using the original recruitment index are shown in red. The first modified index (Index_1), represented in green, utilizes the months of April, May, and June in the index calculation. The second modified index (Index_2), represented in blue, includes the same three months and also incorporates data collected from stations shallower than 30 ft.

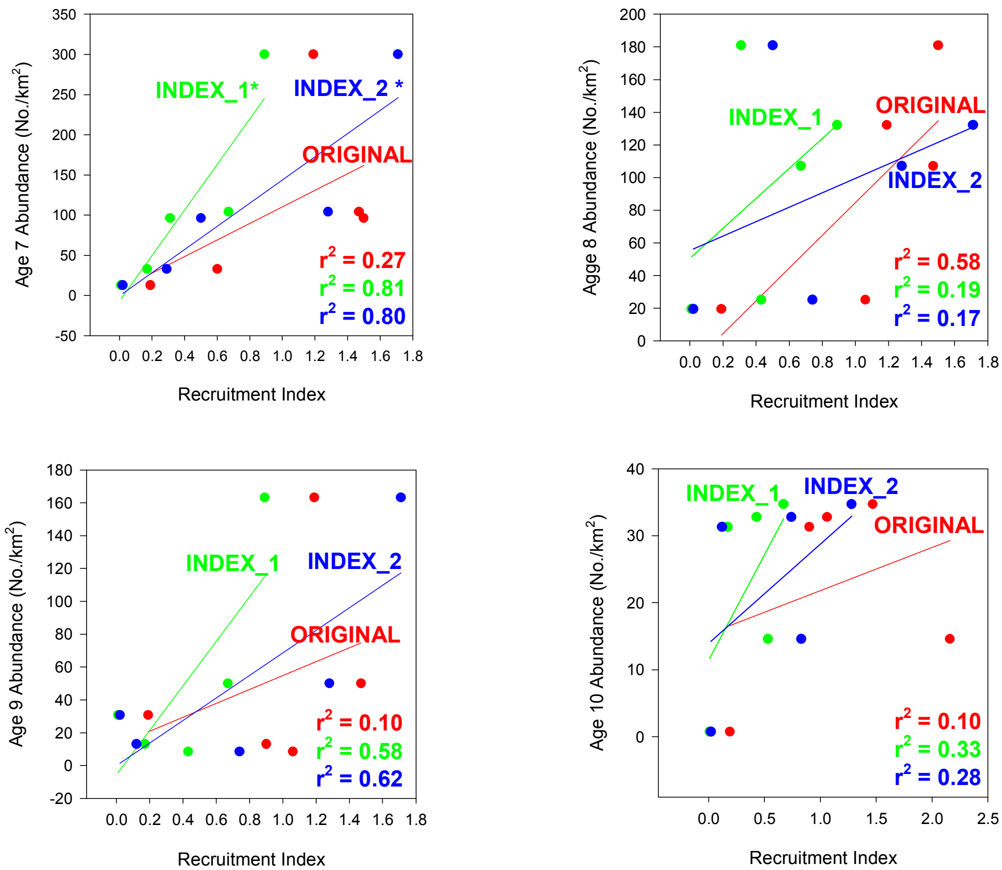


**Figure 7 (cont.)**. Age specific estimates of abundance for Atlantic croaker regressed against the recruitment index (expressed as a geometric mean) from the VIMS trawl survey. Regressions using the original recruitment index are shown in red. The first modified index (Index_1), represented in green, utilizes the months of April, May, and June in the index calculation. The second modified index (Index_2), represented in blue, includes the same three months and also incorporates data collected from stations shallower than 30 ft.