Technical Report

MEASURES OF FISH RECRUITMENT RELATIONSHIPS IN THE JACQUES COUSTEAU NATIONAL ESTUARINE RESEARCH RESERVE AT MULLICA RIVER - GREAT BAY: A PRELIMINARY ANALYSIS

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ABSTRACT

In recent years the emphasis on fish recruitment has focused more on survival of postsettlement young-of-the-year (YOY). In an effort to evaluate the effectiveness of this approach we have attempted to determine the relationship between larval abundance for resident and transient fishes (18 species in plankton nets) and subsequent abundance in sampling gear (traps, trawls) designed to capture young-of-the-year fishes. This analysis is based on relatively long (4-12 years) sampling programs within the Jacques Cousteau National Estuarine Research Reserve at Mullica River - Great Bay in southern New Jersey. Several significant relationships between larval and YOY abundance were found and these varied among species, sampling gear, and the manner in which abundance was estimated. As a result of this preliminary analysis we recommend that continued sampling and analyses focus on the relationship between larval abundance, as measured by plankton nets, young-of-the-year abundance as measured by wire mesh traps (wire mesh traps) and otter trawls. These provide the most effective manner in which to monitor these relationships in the most cost-effective manner. This approach would also allow continued use of ongoing, long-term sampling programs.

INTRODUCTION

Factors influencing the recruitment of fishes has been the emphasis of many studies since the pioneering work of Hjort (1914) and has continued in the work of subsequent authors (May 1984, Blaxter 1988, Miller 1994, Neill et al. 1994, Chambers and Trippel 1997, Myers 1997, 2002). Much of this prior effort has focused on sources of variability during the egg and larval stages that might explain the extreme population fluctuations so frequently observed. In recent years there is an increasing realization that processes occurring immediately before and after fish settle to the bottom may influence the contribution to the adult stock (Cushing 1996). In these instances, the search for the mortality that would explain this year-class variation is expected in postsettlement young of-the-year (Sissenwine 1984, Houde 1987, Doherty 1991, Beverton and Iles 1992). It is also becoming more certain that long-term continuous data collection is central to understanding annual variation in fish recruitment (Jeffries and Terceiro 1985, Hobday et al. 1999, Jackson and Jones 1999, Kendall 2000) and other estuarine variables (Livingston 1997, Livingston et al. 1997, Allen and Barker 1990, Hobbie 2000).

The overall purpose of this analysis is to determine if there are useful measures of recruitment for the early life history stages (i.e. the first year) for dominant transient and resident species (see Able and Fahay 1998) in a relatively unimpacted estuarine system. For our purposes, we define recruitment as the relationship between pelagic larval abundance and subsequent abundance of settled fishes during the first year. In most instances this index of young-of-the-year is based on fish abundance in the fall after arrival and settlement in the estuary in spring or summer.

MATERIALS AND METHODS

Study area

The Great Bay-Little Egg Harbor estuarine system (Fig. 1) is polyhaline and shallow (average depth 1.7 m). It comprises a drowned river valley (Mullica River), embayment (Great Bay), and adjacent barrier beach estuary (Little Egg Harbor). A natural inlet (Little Egg Inlet) is the primary source of ocean water entering this estuary (Chant 2001). Several thoroughfares or "creeks," including Little Sheepshead Creek (Fig. 1), run through the Sheepshead Meadows peninsula and serve to connect Great Bay and Little Egg Harbor. This estuary shares many characteristics with other estuaries in the Middle Atlantic Bight including a broad seasonal temperature range (-2 to 28°C) and a moderate tidal range (about 1 m) (Able et al. 1992, Chant 2001).

All samples of planktonic larvae were collected from a bridge that spans Little Sheepshead Creek (Fig. 1). The bridge is located approximately 3 km from the creek mouth and 2.5 km from Little Egg Inlet. Water depth at the sampling location is about 4 m. Atlantic Ocean water flows into the estuary through Little Egg Inlet during flood tides and some directly into the mouth of Little Sheepshead Creek (Charlesworth 1970, Chant et al. 2000). Recently settled fishes were collected from a variety of locations throughout the estuary (Fig. 1, Table 1) with a variety of sampling gears designed to collect postsettlement young-of-the-year fishes.

Sampling Protocol

We collected larval fishes weekly by suspending a 1-m diameter (1-mm mesh) plankton net from the Little Sheepshead Creek bridge during night flood tides. During 1992 through 1999, we made three deployments of one net halfway between surface and bottom (midwater). To estimate the volume of water sampled, we fixed a General Oceanics flowmeter in the mouth of the net. We sampled an average of 401 m^3 ($\pm$150 m^3 SD) of water in each tow, and a small fraction (5%) of deployments sampled less than 100 m^3. After each deployment we sorted all samples in the laboratory by placing small portions of the samples in shallow pans and removing all fish, which were then preserved in 95% ethanol. For additional details of ichthyoplankton sampling see Witting et al. (1999) and Neuman and Able (in review).

Recently settled juvenile fishes were sampled with a wide array of gears (Table 1) and in a variety of habitats (see Szedlmayer and Able 1996 for descriptions of habitats). In an attempt to focus on specific habitat types within the Mullica River - Great Bay estuary, we used otter trawl and beam trawls repeatedly at several stations representing different habitat types (Fig. 1). These habitat types were chosen based on their depths, substrate type, and amount of structured habitat. Collections in these various stations were expressed on a catch per unit of effort (CPUE) basis. Further attempts to capture juvenile fishes included intensive sampling at a single location, i.e. the boat basin at the Rutgers University Marine Field Station (RUMFS) (Fig. 2). The boat basin has an approximate area of 0.6 hectares, is about 2.5 m deep, and is fringed by salt marsh cordgrass, Spartina alterniflora. Fish traps were deployed along piers in the RUMFS boat basin. For the purposes of this study two types of traps (wire mesh, experimental) were used (Table 1). Traps were unbaited, set in subtidal areas, and emptied every 1-3 days. The numbers and locations of each trap type were generally constant within a single year but varied among years. See Able and Hales (1997) for additional details of sampling and gear.

Species selection for this analysis of recruitment patterns were based on our prior experience in this estuary (Able et al. 1996, Able and Fahay 1998); which included both resident and transient components of the fish fauna (Table 2). Focus was on species, which were dominant in larval and settled fish samples.

Statistical Analysis

Eighty-two species of fish were collected and identified from ichthyoplankton samples, but only 18 had sufficient data to conduct meaningful analyses (Table 2). One species, Urophycis regia, had bimodal spawning with two cohorts encountered as a result of winter and summer spawning. Consequently, abundance was assessed based on each cohort separately. Comparisons for all species were made between larval abundance (catch per unit effort, CPUE) in the ichthyoplankton, which was linearly regressed against abundance (CPUE) from one of four gears (wire mesh traps, experimental fish traps, otter trawls, beam trawls) used to assess postsettlement, young-of-the-year abundance for each species (SAS Institute 1996). Two sets of analyses were conducted, one comparing peak monthly (CPUE) during a given year for each gear type and the other comparing a three-month composite estimate of abundance around the peak monthly CPUE for a given year. As an example, if peak gear CPUE abundance was in June, then a three-month composite would include CPUE data from May, June and July to include, potentially, the onset, peak, decline of fish abundance per gear type.

More specifically, to determine whether the abundance of larval fish related to the abundance of newly settled juveniles, a series of regression analyses was conducted based on monthly catch per unit effort (CPUE) value for comparative purposes. Ichthyoplankton data were then considered to be the independent variable in the model with the four juvenile collecting gear types as dependant variables. Based on larval life history traits and planktonic duration (see Able and Fahay 1998), corresponding data from wire mesh traps, experimental traps, beam trawls and otter trawls were time lagged in the model. Regressions were then conducted between peak monthly ichthyoplankton CPUE and peak monthly CPUE for the other four gear types with regression pairs associated with individual years of collection.

Previous analysis of the temporal distribution of the early life history of fishes in the Mid-Atlantic Bight has shown that the peak period of abundance of various stages can occur over several months (Able and Fahay 1998, Witting et al. 1999). Additionally, since spawning events and larval development may be protracted under varying environmental conditions, a second series of regressions were conducted using a three-month composite estimate of abundance

(CPUE) data for a given year. Specifically, peak monthly mean CPUE data for each young-of-the-year sampling gear were bracketed by monthly means for the preceding and following months. In this manner, a given year yielded three paired data points as opposed to a single pair in the original analyses. These analyses were conducted to fully utilize the long-term data sets and to assess the spatial and temporal variability associated with larval and juvenile fish abundance. For collections in which data from a given month in the distribution (i.e., pre- or post-peak) was not collected, those points were entered as missing in the analysis. As such, the maximum total sample size for gears in these analyses were 24 for wire mesh traps, 20 for experimental fish traps, 12 for otter trawls and 15 for beam trawls during the period from 1992 to 1999.

RESULTS AND DISCUSSION

In most instances, the species composition of larval fishes that we collected by plankton net in Great Bay - Little Egg Harbor estuary at Little Sheepshead Creek bridge was generally characteristic of the juveniles and adults that are collected in the polyhaline portion of the system (Able and Fahay 1998, Witting et al. 1999). The sizes of larval fishes in ichthyoplankton samples overlaps with that for settled YOY fishes (see Figure 3.1 in Able and Fahay 1998) and implies that these early life history stages are well represented for this analysis. The size and stage information for the dominant species in the ichthyoplankton sampling indicates that two general categories of fishes were present (see Witting et al. 1999). The first is characterized by abundant smaller, earlier-stage larvae that were often caught over a larger size range as well. These are primarily local spawners (e.g., Pseudopleuronectes americanus, Anchoa mitchilli, and Scophthalmus aquosus). The second is characterized by typically larger, later-stage fishes that spawn in the ocean and are transported or swim into the estuary (e.g., Anguilla rostrata, Conger oceanicus, Clupea harengus, Brevoortia tyrannus and P. dentatus) or are spawned in the estuary and hatch or are born at an advanced stage of development (e.g., Fundulus heteroclitus, Syngnathus fuscus, Opsanus tau and Hippocampus erectus). Further, our prior analyses of the larval fish assemblages of this estuary suggest a high degree of temporal predictability at seasonal and annual scales (Witting et al. 1999). Almost all of the dominant species not only occurred during all years sampled, but their rank order of abundance was also consistent among years.

Recruitment

Regression analyses based on peak monthly larval abundance and peak postsettlement young-of-the-year abundance indicated significant positive relationships for nine species/cohorts among the suite of gears tested while 10 of the species/cohorts tested showed no significant relationship (Table 3). Estimates of young-of-the-year abundance from wire mesh trap and experimental fish traps gears showed the greatest number of significant relationships (5) of the gears tested, but also represents the greatest long-term effort (8 and 7 years, respectively). Micropogonias undulatus (Fig. 11), Urophycis regia (fall cohort; Fig. 17), Apeltes quadracus, Tautoga onitis (Fig. 15), and Leiostomus xanthurus (Fig. 8) all showed positive relationships between peak larval CPUEs and wire mesh trap CPUEs. Experimental trap data showed significant relationships for November 27, 2002 some of the same species (Apeltes quadracus (Fig. 4), Leiostomus xanthurus (Fig. 9), Tautoga onitis Fig 15) as well as Etropus microstomus (Fig. 7). Estimates of young-of-the-year abundance from beam trawls showed four significant relationships, which included Syngnathus fuscus, Cynoscion regalis, Micropogonias undulatus, and Etropus microstomus, while otter trawls showed only a single positive relationship for Apeltes quadracus (Table 3). There were no statistically significant relationships for any gear combinations for Anchoa mitchilli, U. regia (spring cohort), Menidia menidia, Centropristis striata, Bairdiella chrysoura, Gobiosoma bosc, Scophthalmus aquosus, Paralichthys dentatus, Pseudopleuronectes americanus, and Sphoeroides maculatus. While these analyses provide important insights into larval-recruit relationships in estuaries, the limited data sets for both otter and beam trawls may reflect the limited degrees of freedom in the analyses and not their relative importance as sampling gear.

Regression analysis utilizing a three-month period of peak larval and juvenile abundance indicated similarities among the gears in detecting significant relationships between larval and juvenile abundance but identified more (13 vs. 9) significant relationships than the single peak (Table 4). Abundance estimates from wire mesh traps yielded significant relationships for eight species (Urophycis regia both cohorts Fig 16, 17, Opsanus tau (Fig. 12), Apeltes quadracus (Fig. 4), Centropristis striata (Fig. 5), Leiostomus xanthurus (Fig. 9), Micropogonias undulatus (Fig. 11), Tautoga onitis (Fig. 15), and Etropus microstomus, Fig 7). Although many of these were the same for the experimental traps, the gear differed in that there were no significant relationships for several (U. regia spring cohort, M. undulatus, and Etropus microstomus). Otter trawls yielded seven significant relationships (Anchoa mitchilli, Menidia menidia, Apeltes quadracus, Cynoscion regalis, Gobiosoma bosc , Etropus microstomus, Pseudopleuronectes americanus) while beam trawls yielded eight significant relationships (Menidia menidia, Syngnathus fuscus, Centropristis striata, Cynoscion regalis, Leiostomus xanthurus, Micropogonias undulatus, Tautoga onitis, Etropus microstomus). In addition, 14 of the 18 species analyzed using this data set showed significant relationships with only Bairdiella chrysoura, Scophthalmus aquosus, Paralichthys dentatus, and Sphoeroides maculatus showing no relationship between larval CPUE and juvenile CPUE among gears. Surprisingly, otter trawl and beam trawl data showed numerous significant relationships, despite their limited effort across the entire study period (four and five years, respectively).

Factors influencing recruitment relationships

The success of any long-term sampling program is influenced by the logistical demands of collecting fishes. Gears used to collect juvenile fish in this study were either at a fixed location (i.e., wire mesh traps and experimental traps) or represented boat towed sampling devices (i.e., otter and beam trawls). As such, the species collected which showed significant relationships varied between fixed and towed gears. By comparing the relationships among the most productive data sets (i.e. three-month averages, Table 4), it was possible to determine which gears were most effective at identifying relationships between larval and young-of-the-year fish. Fixed gears produced significant relationships for eight species, all of which were identified using wire mesh traps (Table 4), while towed gears showed significant relationships for 13 species; despite the reduced effort associated with these gears (Table 4). Fixed gears produced two unique species relationships (U. regia, both cohorts), while towed gear identified six unique relationships (Anchoa mitchilli, Menidia menidia, Syngnathus fuscus, Cynoscion regalis, Gobiosoma bosc, Pseudopleuronectes americanus). Since experimental fish traps produced no unique species and were fully represented by wire mesh traps (the other fixed gear) they are not likely to add significantly to further sampling and analysis. By assessing combined fixed and towed gears, wire mesh traps and otter trawls combined for 13 significant relationships while wire mesh traps and beam trawls accounted for only 11 significant relationships (Table 4). Consequently, the assessment of combined gear suggests that inclusion of otter trawl and wire mesh trap data provided the greatest detail into larval-juvenile recruitment dynamics in the estuary, and they may be best suited to continue long-term monitoring of early life history stages of estuarine fish in the Great Bay - Little Egg Harbor estuary and in other estuaries.

Four of the 18 species in this analysis, even though they were reasonably abundant in ichthyoplankton sampling as larvae, did not show any relationship with the samples designed to catch juveniles (Table 3, 4). This is perhaps not surprising for P. dentatus because this species enters the estuary over a long time period, with no pronounced peaks in abundance (Witting et al.1999) and the small juveniles are typically difficult to sample in this (Szedlmayer and Able 1996) and other northeastern U.S. estuaries (Able and Kaiser 1994). Scophthalmus aquosus is seldom captured in traps (Table 2) and may be under-represented in the trawl samples because it seems to prefer the coarse sand sediments (Neuman and Able 1998) that may not be well-represented in our samples. In addition, much of the population may be found in shallow areas in the estuary or outside the estuary in the nearshore ocean (Grosslein and Azarovitz 1982, Neuman and Able 2002). Two other species (B. chrysoura and S. maculatus) are more southern in distribution and their occurrence in New Jersey estuaries may be sporadic (Able and Fahay 1998).

It might be expected that the resident species (Table 2) would show the closest relationship to larval abundance because the vagaries of transport/movement from the ocean into the estuary are eliminated from consideration. In fact, only four resident species were consistently abundant enough in our samples to analyze and, of these, there was a varying number of significant relationships (1-3) to larval abundance (Table 4). Many of the other resident species in this, and other estuaries (Able and Fahay 1998), are closely tied to salt marshes and have "demersal" larvae (e.g. Fundulus spp, Cyprinodon variegatus) or are primarily found in the lower salinity portions of the estuary (e.g. Morone americana, Trinectes maculatus) and are not well-represented in our sampling program which is currently focused in the polyhaline and mesohaline portions. The preponderance of transient species (Table 2) in this analysis may simply reflect that they are a dominant component in this and other estuaries throughout the Middle Atlantic Bight (Able and Fahay 1998).

Disadvantages of This Approach

The most difficult aspect of this approach is the need for consistent, long-term sampling in order to determine recruitment relationships for fishes, which are known to be notoriously variable (May 1984, Blaxter 1988, Miller 1994, Neill et al. 1994, Chambers and Trippel 1997). This long-term sampling is especially difficult to maintain given the vagaries of funding. In addition, the sampling approach used in this study does not help to resolve the relationship between larval abundance and adult population size because adults are not sampled in this program. Perhaps in the future the relationship between the indices from this sampling program for larval and juvenile abundance and adult abundance can be examined with broader studies such as the large otter trawl sampling program for the coastal ocean of New Jersey (Byrne 1989). This effort could be difficult if the coastal ocean samples metapopulations that may be unrelated to recruitment related events in Great Bay - Little Egg Harbor. This may be especially true here and elsewhere in the Middle Atlantic Bight where most fish populations are highly migratory (Parr 1933, Grosslein and Azarovitz 1982, Able and Fahay 1998).

Sampling gear limitations are an issue with any attempt to determine abundance patterns of YOY fish and this study is no exception even though four types of gear for sampling juvenile fishes were included in this analysis. The first assumption of this sampling program is that the ichthyoplankton sampling for larval fish is representative of the estuary, even though it is limited to a single location. Fortunately, a prior extensive analysis (Witting et al. 1999) provides a thorough examination of this sampling program and generally indicates that there are few components of the ichthyoplankton that are not well sampled with the exception of some late larval stages of a few species (Able et al. 1997) and some of the resident species as mentioned above. However, subsequent ichthyoplankton sampling at the same location suggests that there is a lot of daily variability in catches (Neuman et al. in review) which could influence estimates of abundance for this once-a-week sampling program.

The spatial limitations of the ichthyoplankton sampling can also be applied to both types of trap sampling which were largely limited to the RUMFS boat basin (Fig. 1, 2). While this limitation can be important, it is encouraging that so many significant relationships were found for these gears (Table 4). The species for which trap data were significant are probably those species that have behavior that causes them to orient to structure naturally and thus may actually be attracted to traps (Kneib and Craig 2001). Good examples of this are <u>Centropristis</u> <u>striata</u> (Able and Hales 1997), <u>Tautoga</u> <u>onitis</u> and <u>Tautogolabrus</u> <u>adspersus</u> (Able, Hales, and Hagan unpub. data) which have had high recapture rates and long periods of residency based on prior sampling in this boat basin. Other species, especially those that are pelagic as juveniles (e.g. <u>Anchoa</u> <u>mitchilli</u>, <u>Menidia</u> <u>menidia</u>) show no such attraction to traps and thus no relationship to larval abundance (Table 3, 4).

The effectiveness of the two types of trawl gear may be habitat related. In eelgrass (<u>Zostera</u> <u>marina</u>) habitats, which were consistently sampled with both types of trawls, some species (e.g. <u>Apeltes</u> <u>quadracus</u>) were consistently collected (Able and Fahay 1998) and this may have made it easier for a positive relationship with ichthyoplankton collections to occur (Table 4). More importantly, if there is a habitat that is not represented in our trawl collections, then it might explain the lack of a relationship with larval abundance for species that occur in selected habitats.

Advantages of the Approach

This sampling approach has defined some significant relationships between larval and postsettlement juvenile abundance for a number of species. While it may not be able to define the relationship of larval abundance to the adult population, many believe that much of the mortality that occurs in the life of a fish population occurs within the first year of life and particularly within the first four months after hatching (Cushing 1996, Able and Fahay 1998, Veer and Bergman 1987) and thus the relationships established here may provide important insights into recruitment to the adult stock.

Another advantage to this sampling program is that it is relatively simple. Estuarine otter trawl programs exist for many states along the U.S. east coast and have already been used to assess juvenile abundance. It would be relative easy to initiate a trap sampling program in many estuaries because the traps are easy to acquire and inexpensive. Unfortunately few programs have consistent, annual ichthyoplankton sampling programs with the exception of North Carolina and this one is generally limited to winter (November - April) (Warlen et al. 2002).

Yet another advantage of the sampling program in the Jacques Cousteau National Estuarine Research Reserve is that it enables us to identify good year classes for some species and take advantage of the research possibilities. For example, in 1992, when large numbers of T. onitis, T. adspersus and C. striata appeared in wire mesh traps we initiated a tag/recapture program that provided detailed information on movements and residency for the YOY of these species (Able and Hales 1997, Able and Fahay 1998). Additionally, the larval sampling program provides an index of abundance to population status that has been used, for example, to help assess the status of Anguilla rostrata along the east coast of North America (Haro et al. 2000) and has provided spawning for genetics (Anguilla rostrata, Conger oceanicus), taxonomic (Mycteroperca spp., Etropus microstomus, and growth (Scophthalmus aquosus, Tautoga onitis).

Recommendations

As a result of this preliminary analysis, the emphasis of this sampling effort could be reduced yet still provide an assessment of recruitment factors for several ecologically and economically important species. It appears that a continued emphasis on assessing larval abundance is feasible with the current ichthyoplankton sampling program at Little Sheepshead Creek. However, there should be continued attention to assessing the impact of daily variation on estimates of larval abundance. Assessment of juvenile abundance can be reduced to a single trap type (wire mesh trap) and a single trawl type (otter) because these provide the best and most consistent relationship to larval abundance. It is suggested that the wire mesh traps be deployed over a broader area in more habitat types in order to extend the usefulness of this sampling program. In response to the above observations we have continued the otter trawl sampling program and extended it to reach from the coastal ocean in the vicinity of the Long-term Ecosystem Observatory in 15 m (Glenn et al. 1996, von Alt et al. 1997,,Grassle et al. 1998) into tidal freshwaters of the Mullica River (Martino and Able in press). Future analysis of recruitment relationships should take advantage of the array of National Estuarine Research Reserve dataloggers in this estuarine system to examine the impact of physical factors on annual patterns of larval and juvenile abundance and recruitment relationships as has been attempted to resolve upwelling effects (Neuman et al. in review).

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Table 1. Sampling location and effort for larval and settled young-of-the-year fishes in the Great Bay-Little Egg Harbor estuary. See Fig. 1 and 2 for sampling locations. RUMFS=Rutgers University Marine Field Station.

Gear	Location	No. of Stations	Duration/ Frequency	Focus of sampling (life history stage)	No. of samples	Source
Plankton net (1-m, 1 mm mesh)	Little Sheepshead Creek	1	1992-1999 weekly	Larvae	612	Witting et al. (1999), RUMFS sampling
Beam trawl (1-m, 3 m mesh)	Great Bay-Little Egg Harbor	20-43	1992-1996 monthly/bimonthly	Juveniles	2007	RUMFS sampling
Otter trawl (4.9 m, 6 mm mesh)	Great Bay-Little Egg Harbor	7-32	1996-1999 monthly - biyearly	Juveniles	1313	RUMFS sampling
Wire mesh trap (6 mm mesh)	RUMFS boat basin	37322	1992-1999 daily-biweekly	Juveniles	4810	RUMFS sampling
Experimental traps (3 mm mesh)	RUMFS boat basin	37335	1992-1998 daily-biweekly	Juveniles	4363	RUMFS sampling

Table 2. Characterization of fish species selected for recruitment analysis as modified from Able and Fahay (1998). Season in estuary indicated as either spring, summer, fall or winter (Sp = March-May, Su = June-August, Fa = September-November, Wi = December-February) MAB = Middle Atlantic Bight

Scientific name	Common name	General pattern of utilization	Spawning location	Season in estuary
Engraulidae				
Anchoa mitchilli	bay anchovy	transient	estuary/MAB	Sp-Fa
Phycidae				
Urophycis regia	spotted hake	transient	MAB	Sp & Fa
Batrachoididae				
Opsanus tau	oyster toadfish	resident	estuary	All
Atherinidae				
Menidia menidia	Atlantic	transient	estuary	Sp-Fa
Gasterosteidae				
Apeltes quadracus	fourspine	resident	estuary	Wi-Sp
Syngnathidae				
Syngnathus fuscus	northern pipefish	transient	estuary	Sp-Fa
Serranidae				
Centropristis striata	black sea bass	transient	MAB	Sp-Fa
Sciaenidae				
Bairdiella chrysoura	silver perch	transient	?	Su-Fa
Cynoscion regalis	weakfish	transient	estuary/MAB	Sp-Fa
Leiostomus xanthurus	spot	transient	MAB	Sp-Fa
Micropogonias undulatus	Atlantic croaker	transient	MAB	All
Labridae				
Tautoga onitis	tautog	transient	estuary/MAB	All
Gobiidae				

Scientific name	Common name	General pattern of utilization	Spawning location	Season in estuary
Gobiosoma bosc	naked goby	resident	estuary	All
Scophthalmidae				
Scophthalmus aquosus	windowpane	transient	estuary/MAB	Sp & Fa
Paralichthyidae				
Etropus microstomus	smallmouth	transient	MAB	Sp-Fa
Paralichthys dentatus	summer flounder	transient	MAB	All
Pleuronectidae				
Pseudopleuronectes	winter flounder	resident	estuary/MAB	All
Soleidae				
Trinectes maculatus	hogchoker	resident	estuary	All
Tetraodontidae				
Sphoeroides maculatus	northern puffer	transient	estuary	Su-Fa

Table 3. Regression comparisons between annual ichthyoplankton abundance (CPUE) with CPUE for wire mesh trap, experimental fish trap, otter trawl, and beam trawl data between 1992 and 1999. Values in the table represent the r^2 values for each regression with significant regressions denoted by * < 0.05, **< 0.01, ***< 0.001. "na" denotes a gear type that yielded no individuals for a given species during the analysis.

		Gear Type			
Species		Wire mesh trap n=8 yr	Experimental Trap n=7 yrs	Otter Trawl n=4 yrs	Beam Trawl n=5 yrs
Anchoa mitchilli		0.03	0.004	0.23	0.009
Urophycis regia	fall	0.94***	0.25	na	na
Urophycis regia	spring	0.4	0.46	0.32	0.33
Opsanus tau		0.1	0.92***	0.76	0.13
Menidia menidia		0.03	0.15	0.13	0.02
Apeltes quadracus		0.7**	0.69*	0.98*	0.008
Syngnathus fuscus		0.07	0.0004	0.44	0.85*
Centropristis striata		0.27	0.32	0.008	0.69
Bairdiella chrysoura		0.01	0.007	0.07	0.01
Cynoscion regalis		0.0009	0.14	0.63	0.99***
Leiostomus xanthurus		0.6*	0.6*	0.003	0.65
Micropogonias undulatus		0.66*	0.05	0.04	0.89*
Tautoga onitis		0.53*	0.96***	0.05	0.5
Gobiosoma bosc		0.04	0.02	0.03	0.0006
Scophthalmus aquosus		na	na	0.37	0.003
Etropus microstomus		0.27	0.9**	0.57	0.77*
Paralichthys dentatus		0.009	0.21	0.23	0.004
Pseudopleuronectes		0.17	0.04	0.85	0.32
Sphoeroides maculatus		0.0003	na	0.003	0.1

Table 4. Regression comparisons between ichthyoplankton abundance (CPUE) with peak CPUE averaged over three months annual peak abundance from wire mesh traps, experimental traps, otter trawls, and beam trawl data between 1992and 1999 Values in the table represent the r^2 values for each regression with significant regressions denoted by * < 0.05, **< 0.01, ***< 0.001. "na" denotes a gear type that yielded no individuals for a given species during the analysis or no relevant data was collected for comparison.

Species		Gear Type			
		Wire mesh trap n=8yrs	Experimental Trap n=7 yrs	Otter Trawl n=4 yrs	Beam Trawl n=5 yrs
Anchoa mitchilli		0.009	0.0077	0.44*	0.07
Urophycis regia	fall	0.79***	0.29*	na	na
Urophycis regia	spring	0.49***	0.58	0.027	0.001
Opsanus tau		0.21*	0.79***	0.16	0.0008
Menidia menidia		0.056	0.004	0.45*	0.55**
Apeltes quadracus		0.66***	0.57***	0.75***	0.01
Syngnathus fuscus		0.0004	0.059	0.004	0.53**
Centropristis striata		0.26*	0.29*	0.07	0.73***
Bairdiella chrysoura		0.0005	0.028	0.001	0.001
Cynoscion regalis		0.003	0.0082	0.69**	0.74***
Leiostomus xanthurus		0.43***	0.44**	0.04	0.53**
Micropogonias undulatus		0.54***	0.0025	0.16	0.895***
Tautoga onitis		0.36**	0.48***	0.24	0.57**
Gobiosoma bosc		0.15	0.08	0.59**	0.14
Scophthalmus aquosus		na	na	0.03	0.06
Etropus microstomus		0.32**	0.13	0.42*	0.53**
Paralichthys dentatus		0.03	0.002	0.1	0.1
Pseudopleuronectes americanus		0.028	0.035	0.498*	0.18
Sphoeroides maculatus		0.012	0.019	0.15	0.24

Figure Captions.

Fig. 1. Sampling location for larval (plankton net) and settled young-of-the-year (otter and beam trawls) fishes in the Jacques Cousteau National Estuarine Research Reserve at Mullica River - Great Bay at Mullica River - Great Bay. See Fig. 2 for additional sampling locations for settled fish.

Fig. 2 Location of sampling for settled young-of-the-year fishes with killitrap and experimental trap in the Jacques Cousteau National Estuarine Research Reserve at Mullica River - Great Bay at Mulllica River - Great Bay. See Fig. 1 for additional sampling locations for settled fishes.

Fig. 3 Relationships for Anchoa mitchilli between larval (ichthyoplankton sampling) and young-of-the-year (YOY) based on comparisons between a single monthly peak in abundance vs. three month average estimates of abundance for four gears (wire mesh trap, experimental trap, otter trawl, beam trawl).

Fig. 4 Relationships for Apeltes quadracus between larval (ichthyoplankton sampling) and young-of-the-year (YOY) based on comparisons between a single monthly peak in abundance vs. three month average estimates of abundance for four gears (wire mesh trap, experimental trap, otter trawl, beam trawl).

Fig. 5 Relationships for Centropristis striata between larval (ichthyoplankton sampling) and young-of-the-year (YOY) based on comparisons between a single monthly peak in abundance vs. three month average estimates of abundance for four gears (wire mesh trap, experimental trap, otter trawl, beam trawl).

Fig. 6 Relationships for Cynoscion regalis between larval (ichthyoplankton sampling) and young-of-the-year (YOY) based on comparisons between a single monthly peak in abundance vs. three month average estimates of abundance for four gears (wire mesh trap, experimental trap, otter trawl, beam trawl).

Fig. 7 Relationships for Etropus microstomus between larval (ichthyoplankton sampling) and young-of-the-year (YOY) based on comparisons between a single monthly peak in abundance vs. three month average estimates of abundance for four gears (wire mesh trap, experimental trap, otter trawl, beam trawl)

Fig. 8 Relationships for Gobiosoma bosc between larval (ichthyoplankton sampling) and young-of-the-year (YOY) based on comparisons between a single monthly peak in abundance vs. three month average estimates of abundance for four gears (wire mesh trap, experimental trap, otter trawl, beam trawl)

Fig. 9 Relationships for Leiostomus xanthurus between larval (ichthyoplankton sampling) and young-of-the-year (YOY) based on comparisons between a single monthly peak in abundance vs. three month average estimates of abundance for four gears (wire mesh trap, experimental trap, otter trawl, beam trawl)

Fig. 10 Relationships for Menidia menidia between larval (ichthyoplankton sampling) and young-of-the-year (YOY) based on comparisons between a single monthly peak in abundance vs. three month average estimates of abundance for four gears (wire mesh trap, experimental trap, otter trawl, beam trawl)

Fig. 11 Relationships for Micropogonias undulatus between larval (ichthyoplankton sampling) and young-of-the-year (YOY) based on comparisons between a single monthly peak in abundance vs. three month average estimates of abundance for four gears (wire mesh trap, experimental trap, otter trawl, beam trawl)

Fig. 12 Relationships for Opsanus tau between larval (ichthyoplankton sampling) and young-of-the-year (YOY) based on comparisons between a single monthly peak in abundance vs. three month average estimates of abundance for four gears (wire mesh trap, experimental trap, otter trawl, beam trawl)

Fig. 13 Relationships for Pseudopleuronectes americanus between larval (ichthyoplankton sampling) and young-of-the-year (YOY) based on comparisons between a single monthly peak in abundance vs. three month average estimates of abundance for four gears (wire mesh trap, experimental trap, otter trawl, beam trawl)

Fig. 14 Relationships for Syngnathus fuscus between larval (ichthyoplankton sampling) and young-of-the-year (YOY) based on comparisons between a single monthly peak in abundance vs. three month average estimates of abundance for four gears (wire mesh trap, experimental trap, otter trawl, beam trawl)

Fig. 15 Relationships for Tautoga onitis between larval (ichthyoplankton sampling) and young-of-the-year (YOY) based on comparisons between a single monthly peak in abundance vs. three month average estimates of abundance for four gears (wire mesh trap, experimental trap, otter trawl, beam trawl)

Fig. 16 Relationships for Urophycis regia (spring cohort) between larval (ichthyoplankton sampling) and young-of-the-year (YOY) based on comparisons between a single monthly peak in abundance vs. three month average estimates of abundance for four gears (wire mesh trap, experimental trap, otter trawl, beam trawl)

Fig. 17 Relationships for Urophycis regia (fall cohort) between larval (ichthyoplankton sampling) and young-of-the-year (YOY) based on comparisons between a single monthly peak in abundance vs. three month average estimates of abundance for four gears (wire mesh trap, experimental trap, otter trawl, beam trawl)

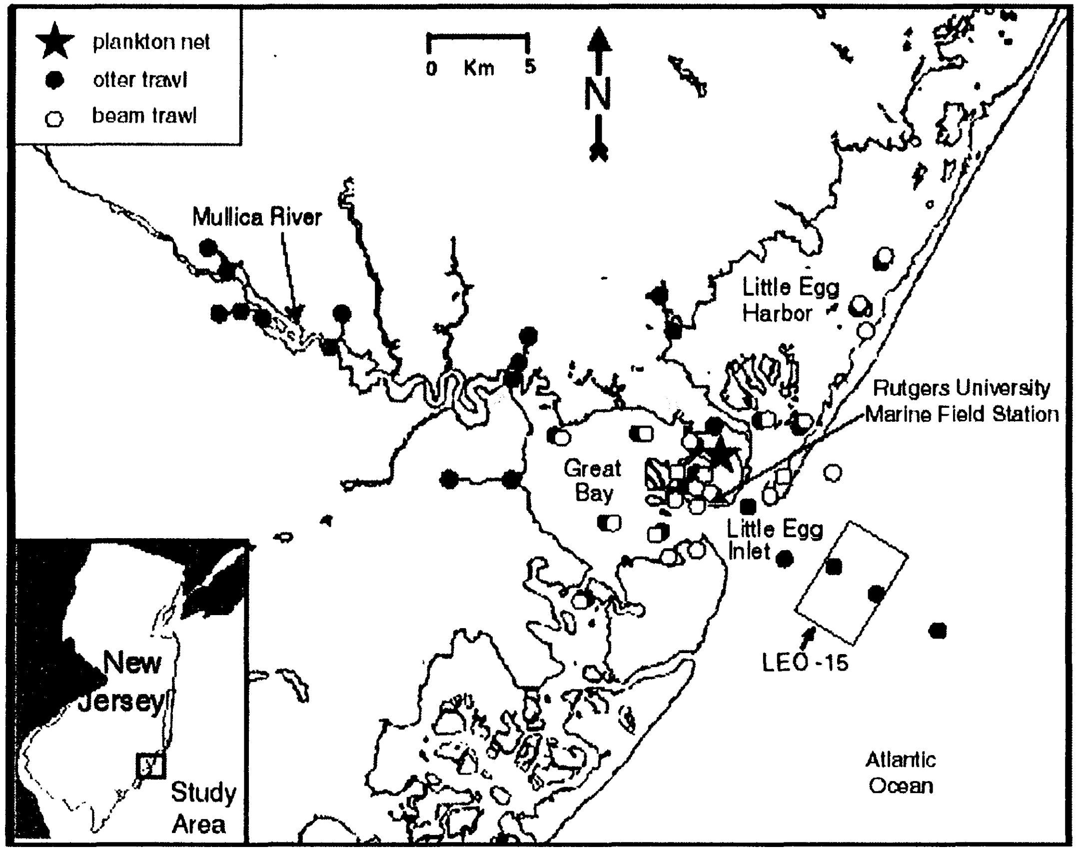

Fig. 1 Sampling location for larval (plankton net) and settled young-of-the-year (otter and beam trawls) fishes in the Jacques Cousteau National Estuarine Research Reserve at Mullica River - Great Bay. See Fig. 2 for additional sampling locations for settled fishes.

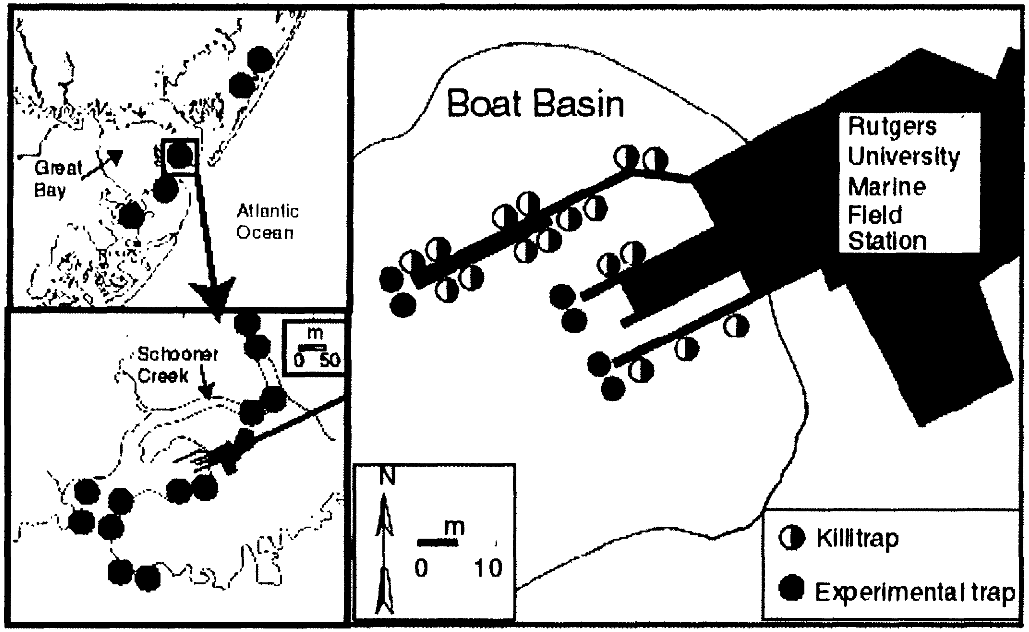

Fig. 2 Location of sampling for settled young-of-the-year fishes with killitrap and experimental trap in the Jacques Cousteau National Estuarine Research Reserve at Mullica River - Great Bay. See Fig. 1 for additional sampling locations for settled fishes.

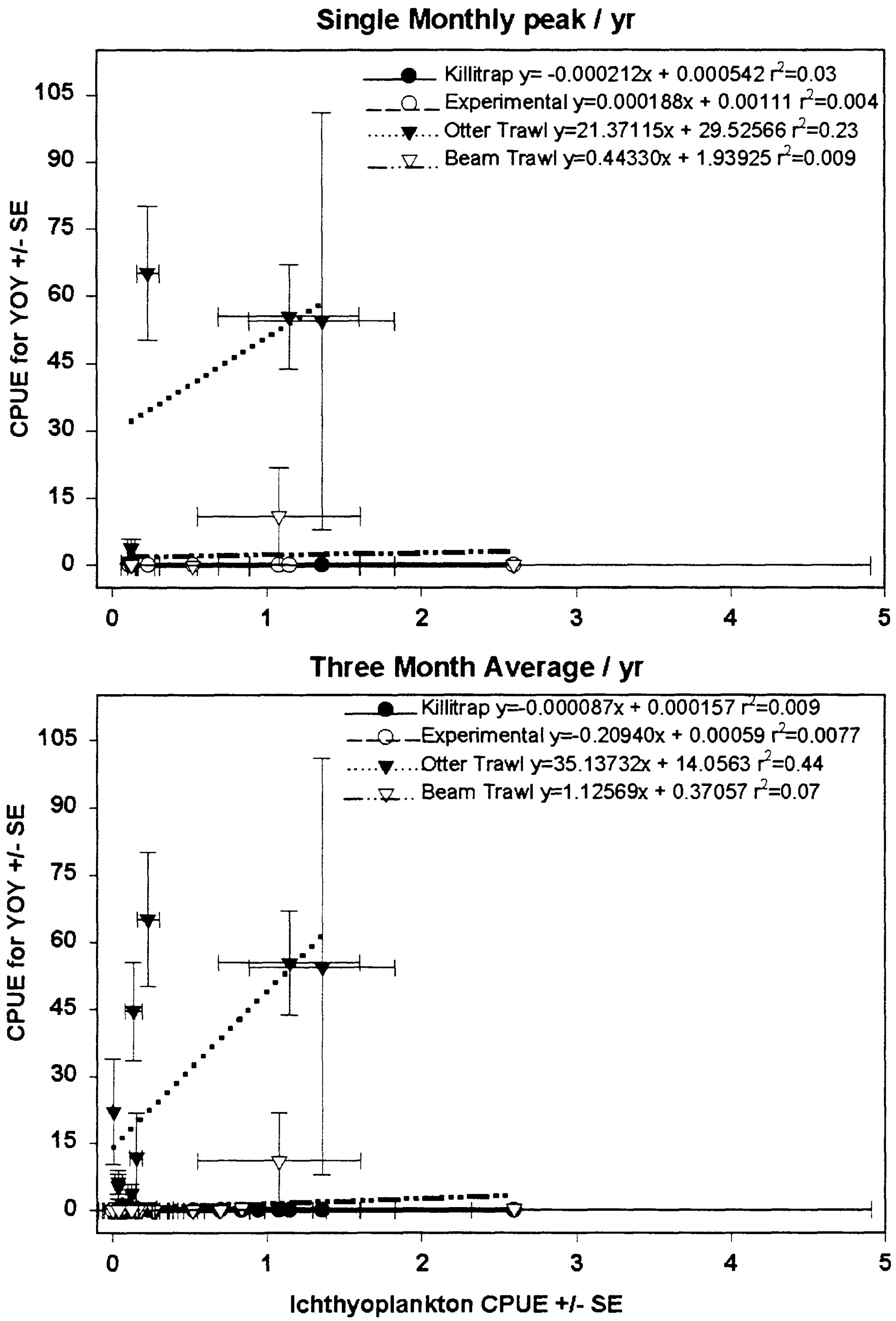

Fig. 3. Relationships for Anchoa mitchilli between larval (ichthyoplankton sampling) and young-of-the-year (YOY) based on comparisons between single monthly peak in abundance vs. three month average estimates of abundance for four gears (killitrap, experimental trap, otter trawl, beam trawl).

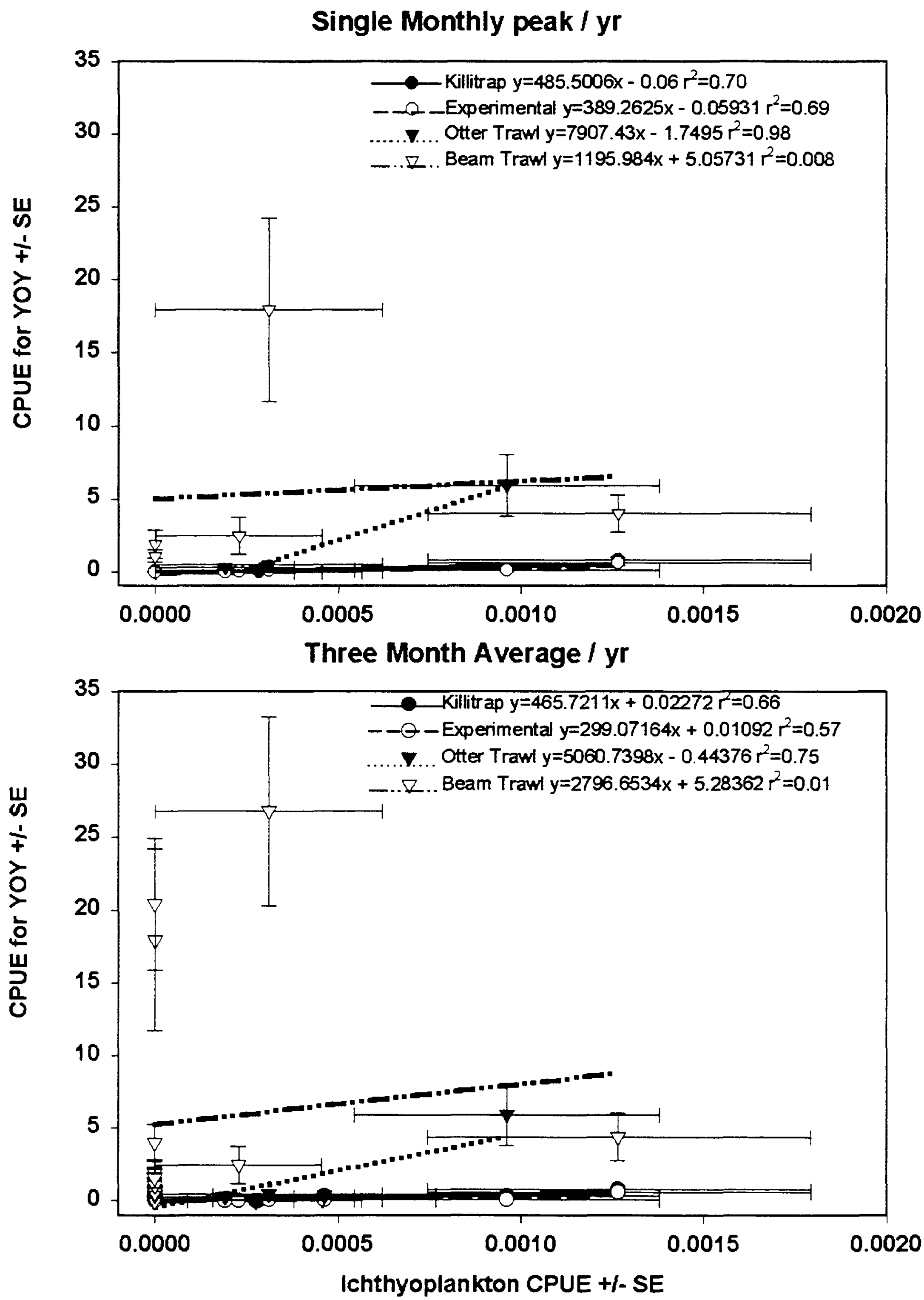

Fig. 4. Relationships for <u>Apeltes quadracus</u> between larval (ichthyoplankton sampling) and young-of-the-year (YOY) based on comparisons between single monthly peak in abundance vs. three month average estimates of abundance for four gears (killitrap, experimental trap, otter trawl, beam trawl).

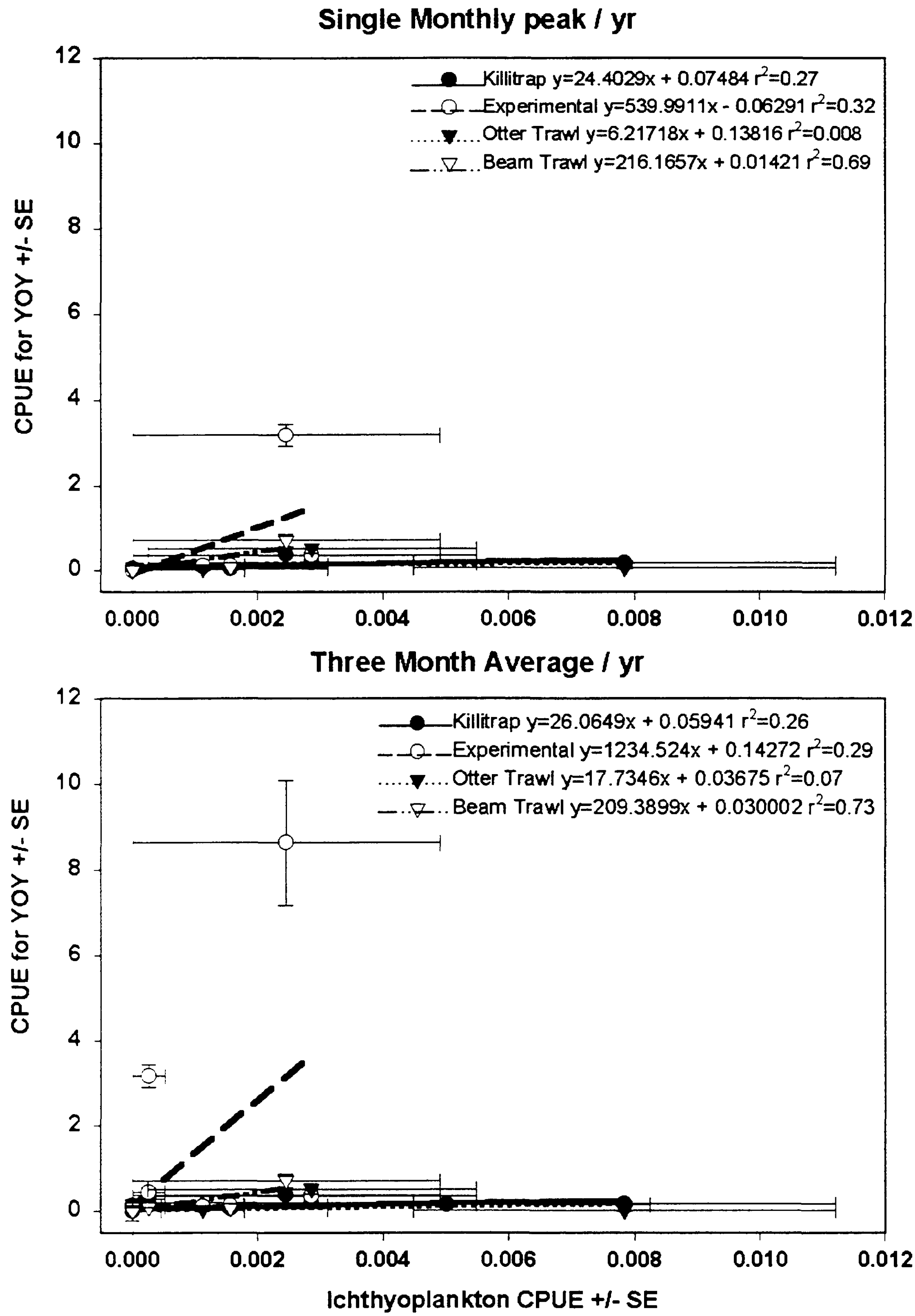

Fig. 5. Relationships for Centropristis striata between larval (ichthyoplankton sampling) and young-of-the-year (YOY) based on comparisons between single monthly peak in abundance vs. three month average estimates of abundance for four gears (killitrap, experimental trap, otter trawl, beam trawl).

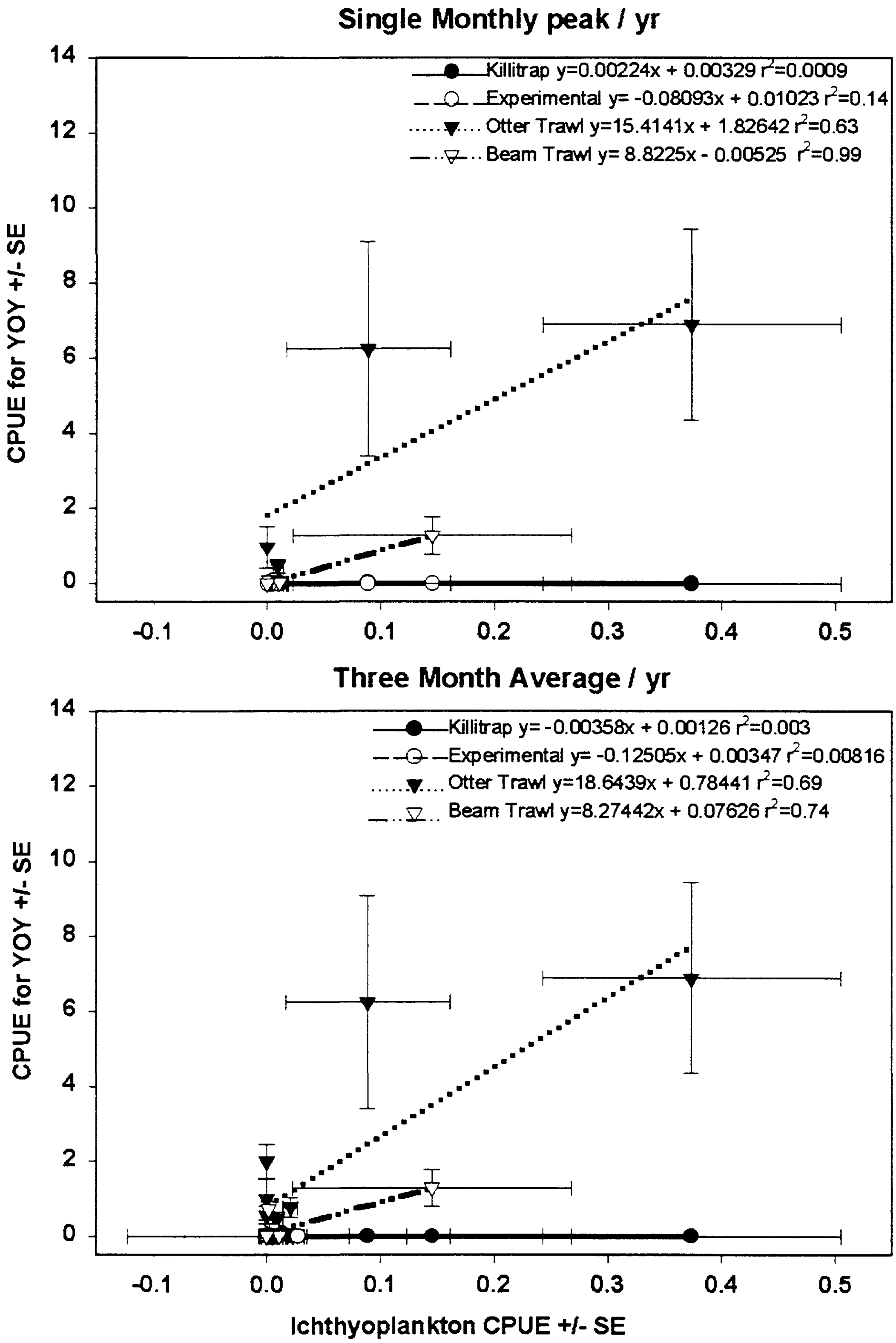

Fig. 6. Relationships for Cynoscion regalis between larval (ichthyoplankton sampling) and young-of-the-year (YOY) based on comparisons between single monthly peak in abundance vs. three month average estimates of abundance for four gears (killitrap, experimental trap, otter trawl, beam trawl).

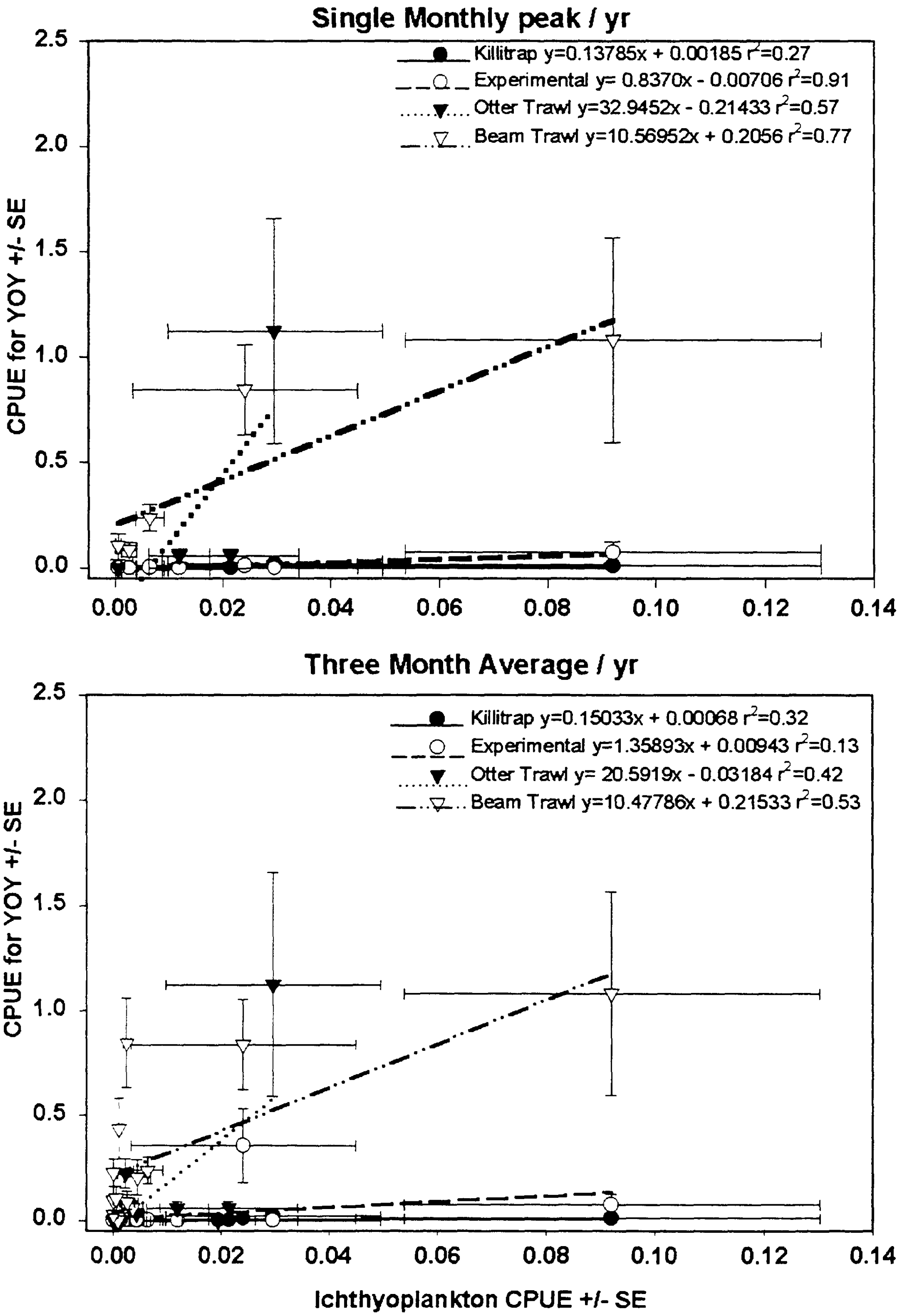

Fig. 7. Relationships for Etropus microstomus between larval (ichthyoplankton sampling) and young-of-the-year (YOY) based on comparisons between single monthly peak in abundance vs. three month average estimates of abundance for four gears (killitrap, experimental trap, otter trawl, beam trawl).

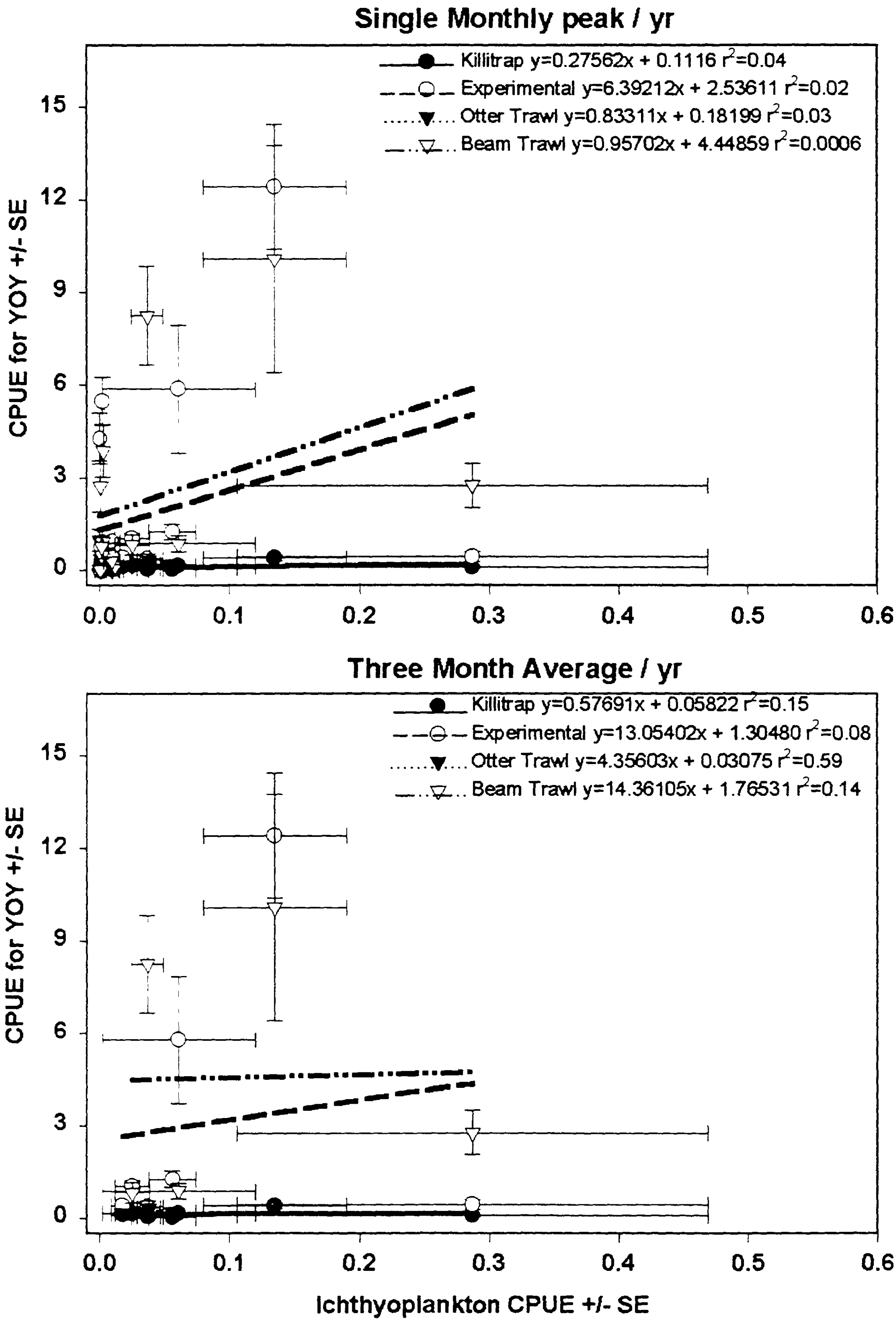

Fig. 8. Relationships for Gobiosoma bosc between larval (ichthyoplankton sampling) and young-of-the-year (YOY) based on comparisons between single monthly peak in abundance vs. three month average estimates of abundance for four gears (killitrap, experimental trap, otter trawl, beam trawl).

Single Data Point/yr **3 data points/yr**

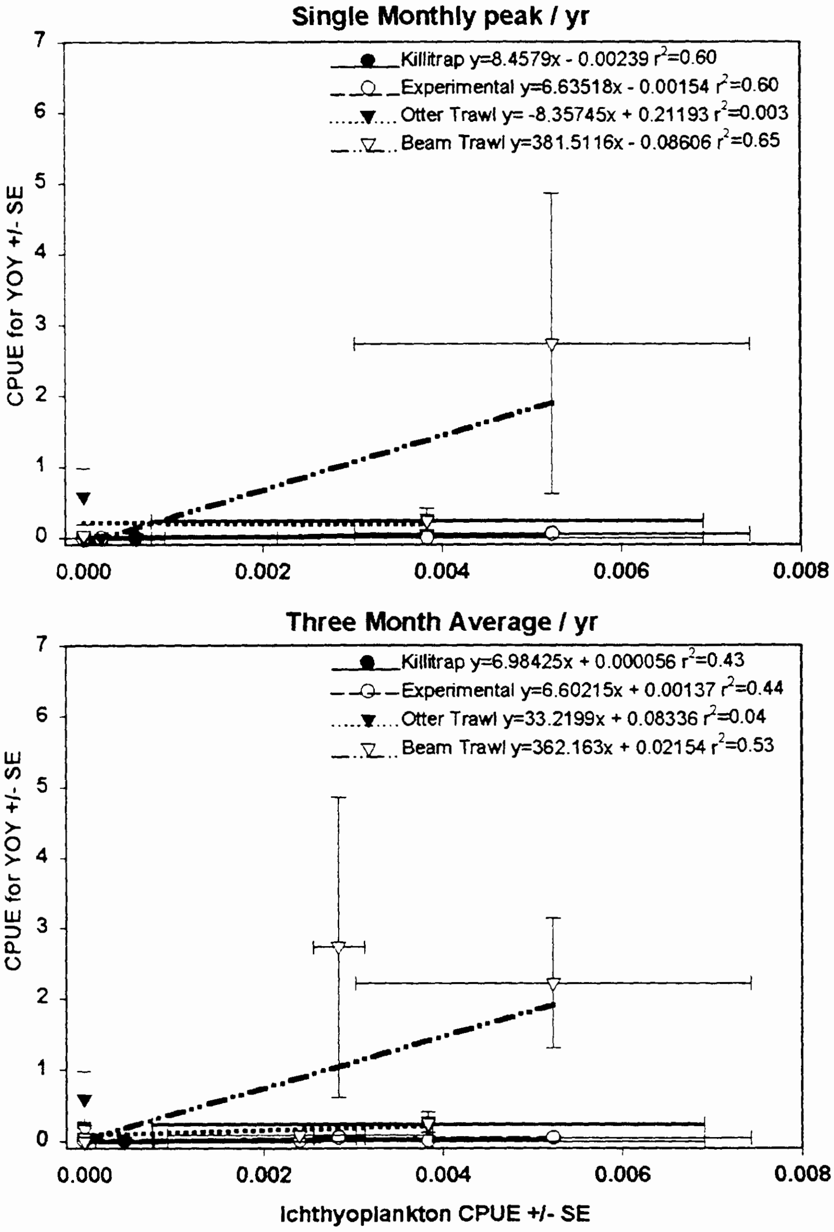

Fig. 9. Relationships for Leiostomus xanthurus between larval (ichthyoplankton sampling) and young-of-the-year (YOY) based on comparisons between single monthly peak in abundance vs. three month average estimates of abundance for four gears (killitrap, experimental trap, otter trawl, beam trawl).

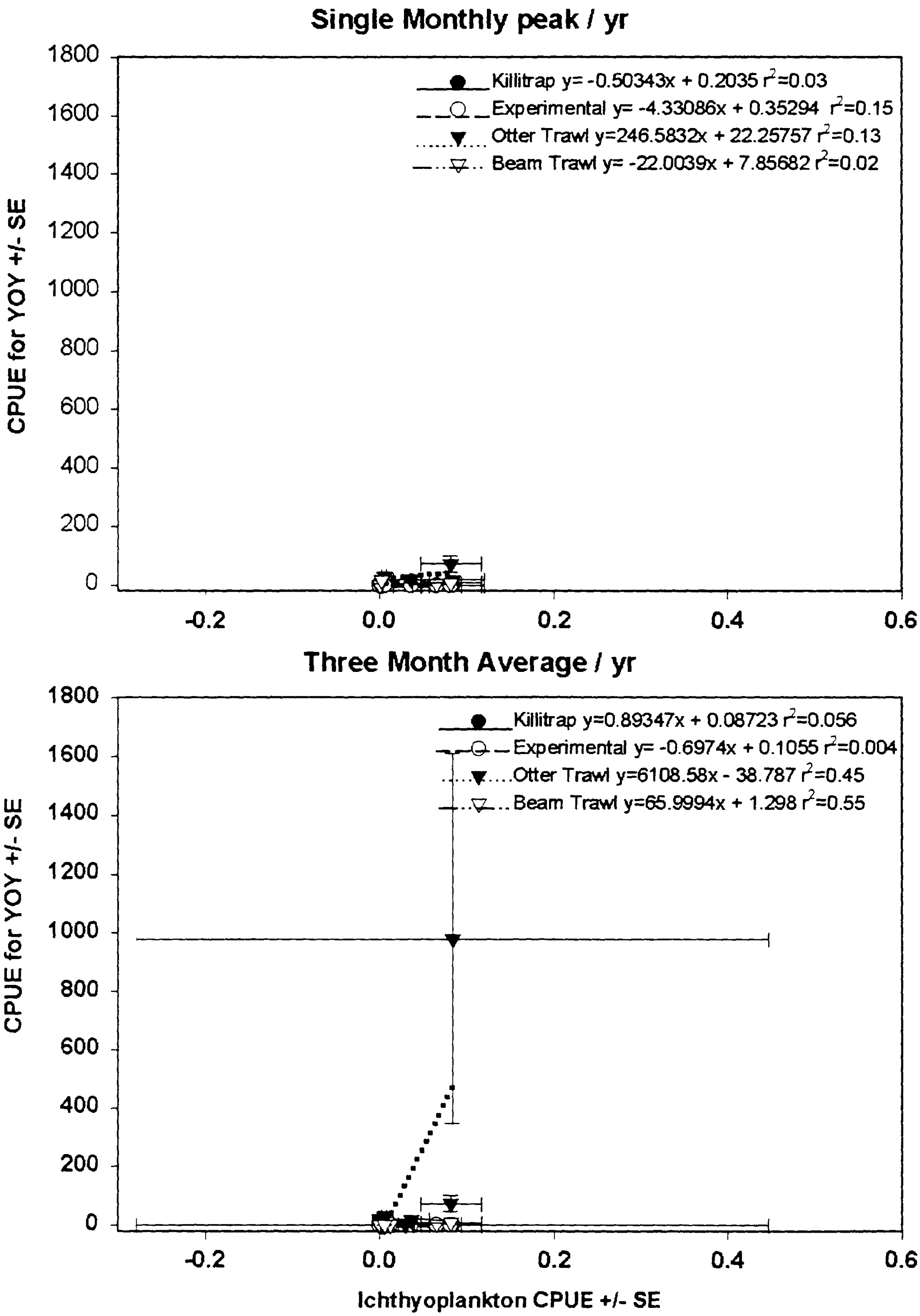

Fig. 10. Relationships for Menidia menidia between larval (ichthyoplankton sampling) and young-of-the-year (YOY) based on comparisons between single monthly peak in abundance vs. three month average estimates of abundance for four gears (killitrap, experimental trap, otter trawl, beam trawl).

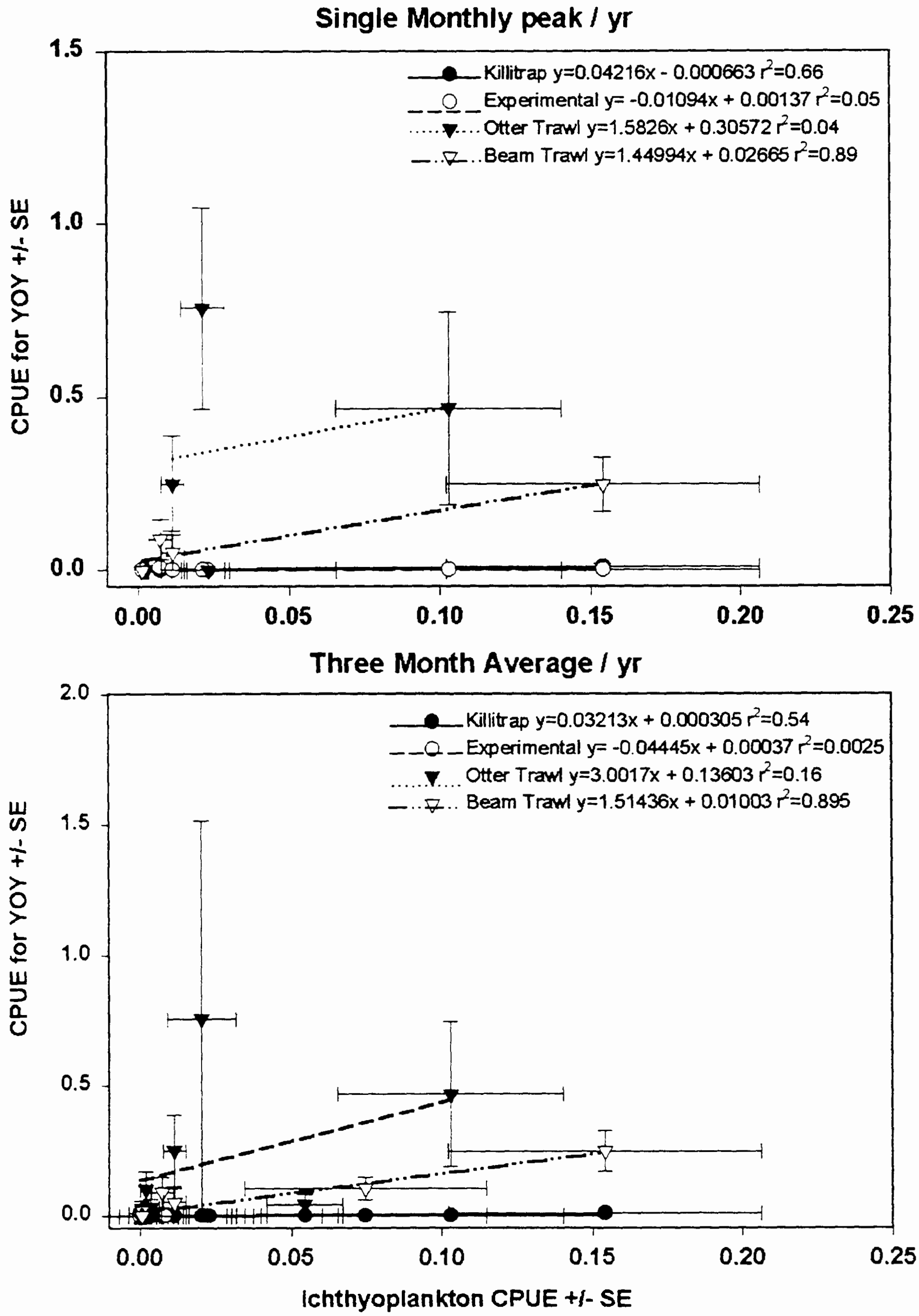

Fig. 11. Relationships for Micropogonias undulatus between larval (ichthyoplankton sampling) and young-of-the-year (YOY) based on comparisons between single monthly peak in abundance vs. three month average estimates of abundance for four gears (killitrap, experimental trap, otter trawl, beam trawl).

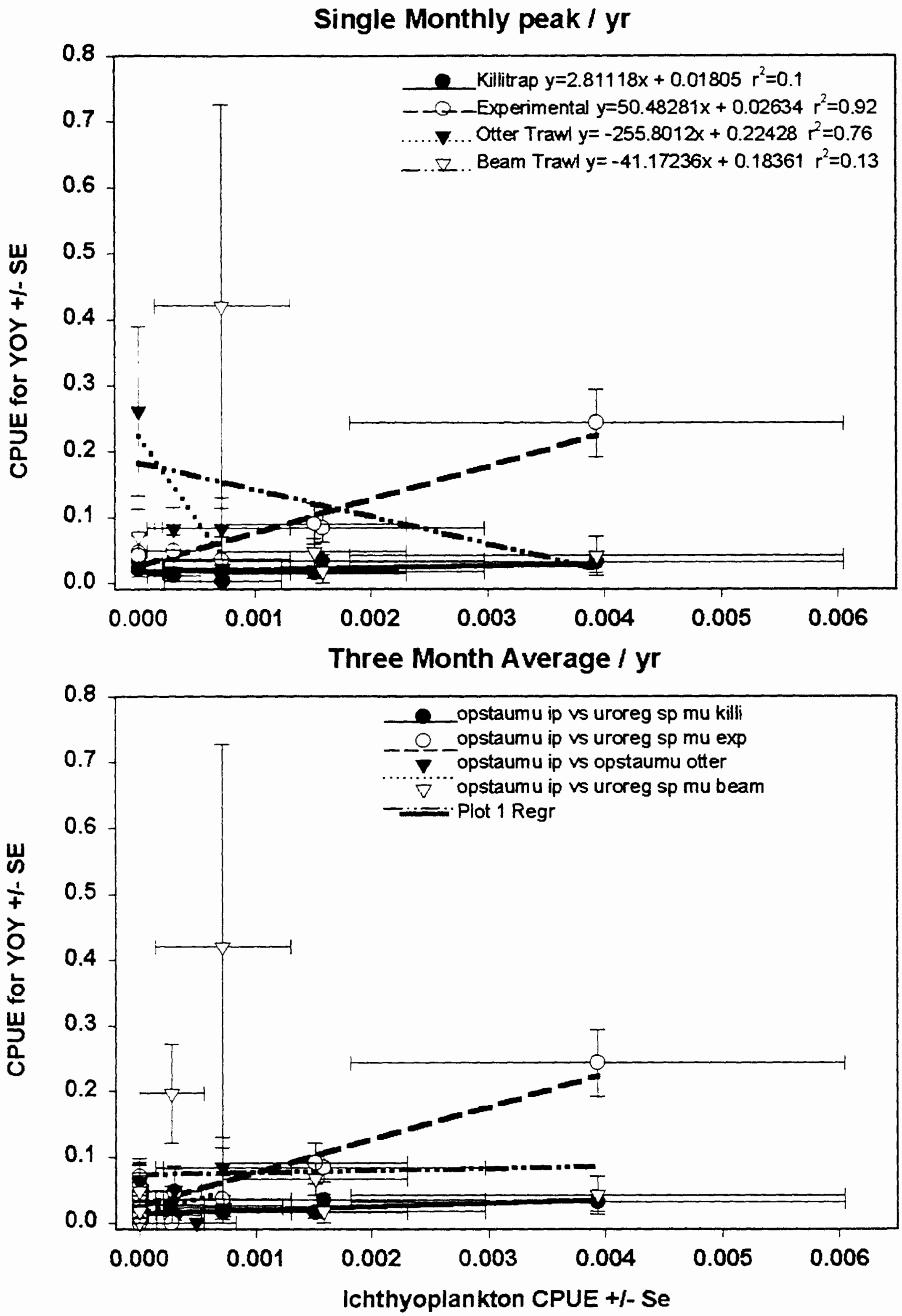

Fig. 12. Relationships for Opsanus tau between larval (ichthyoplankton sampling) and young-of-the-year (YOY) based on comparisons between single monthly peak in abundance vs. three month average estimates of abundance for four gears (killitrap, experimental trap, otter trawl, beam trawl).

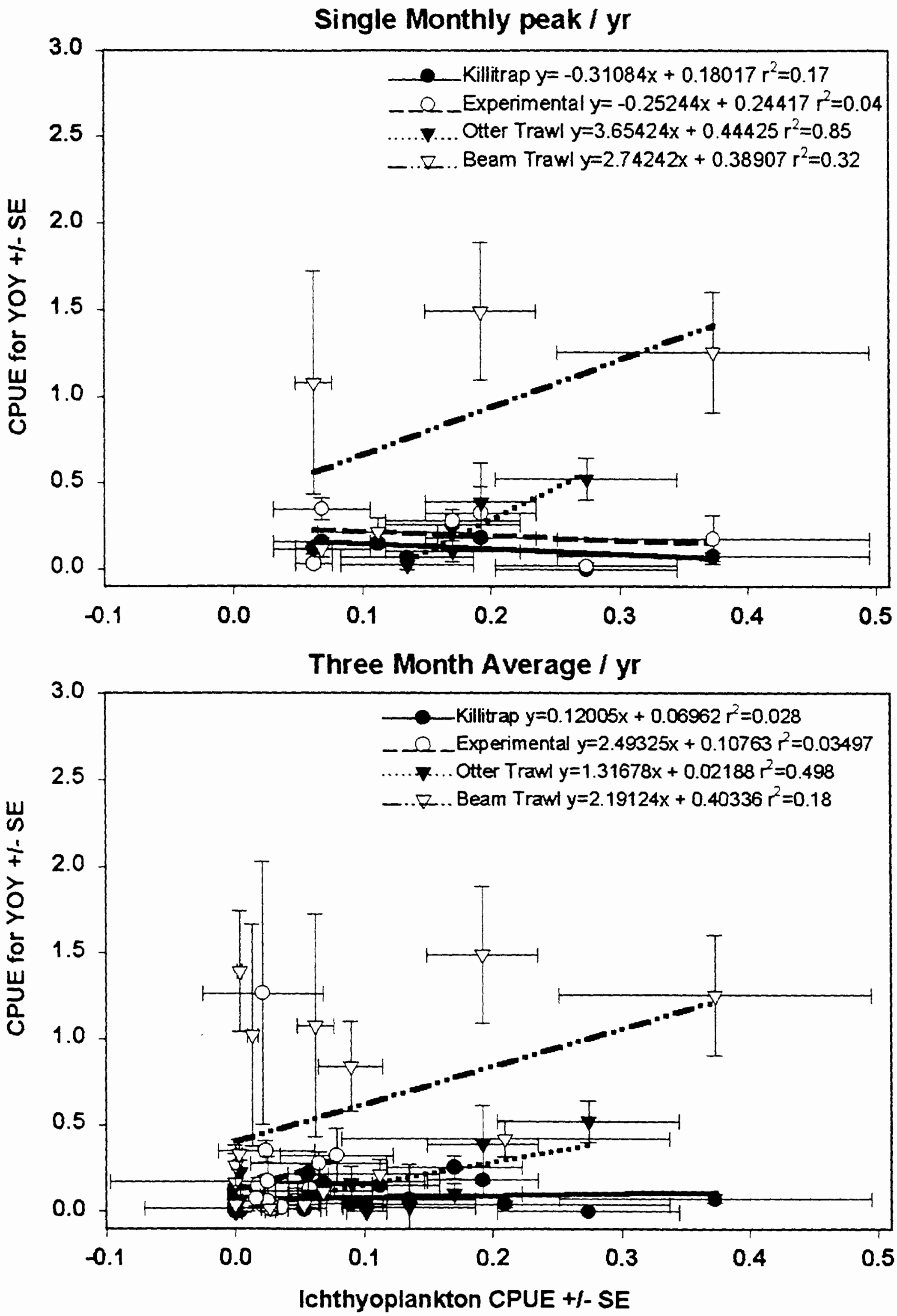

Fig. 13. Relationships for Pseudopleuronectes americanus between larval (ichthyoplankton sampling) and young-of-the-year (YOY) based on comparisons between single monthly peak in abundance vs. three month average estimates of abundance for four gears (killitrap, experimental trap, otter trawl, beam trawl).

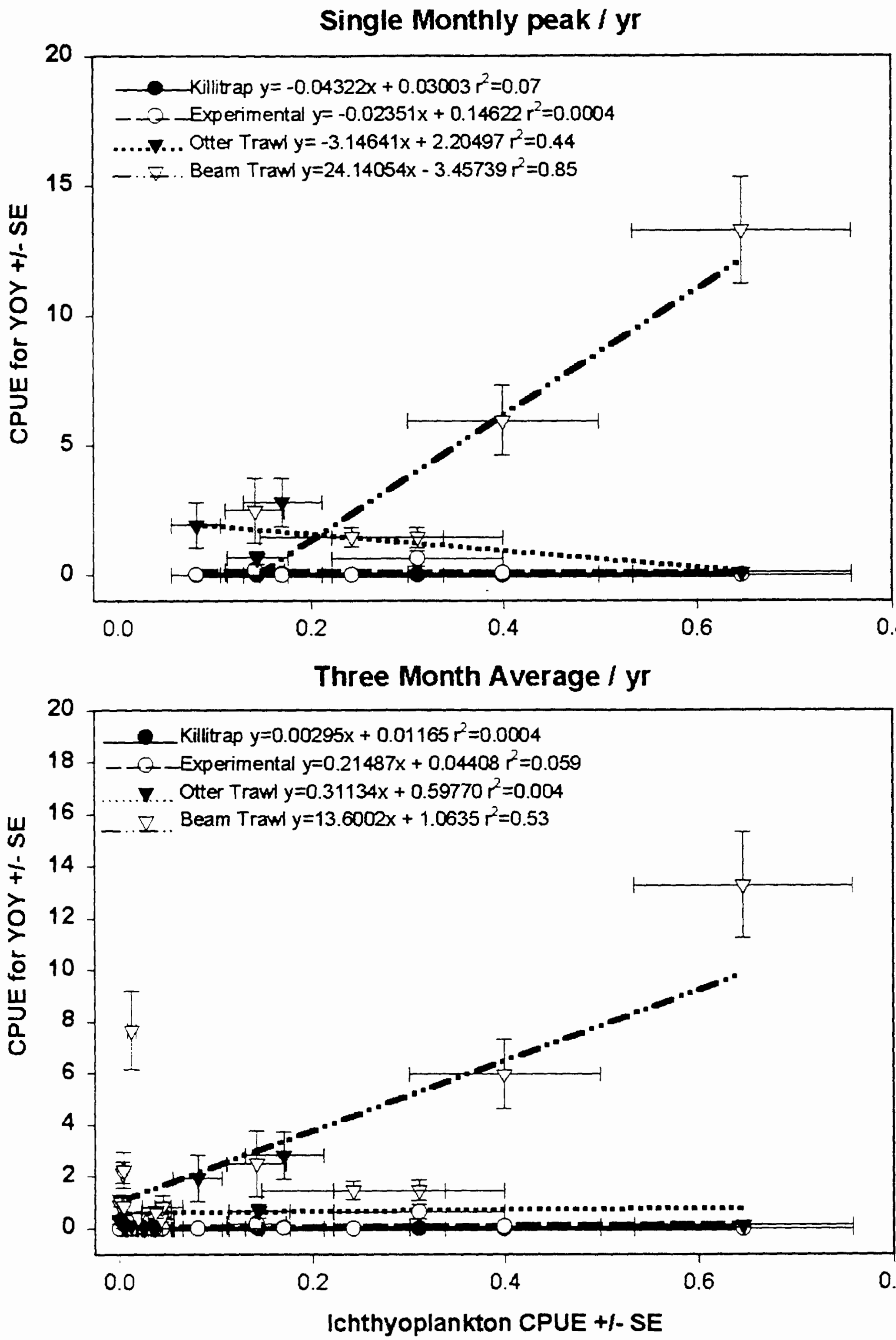

Fig. 14. Relationships for Syngnathus fuscus between larval (ichthyoplankton sampling) and young-of-the-year (YOY) based on comparisons between single monthly peak in abundance vs. three month average estimates of abundance for four gears (killitrap, experimental trap, otter trawl, beam trawl).

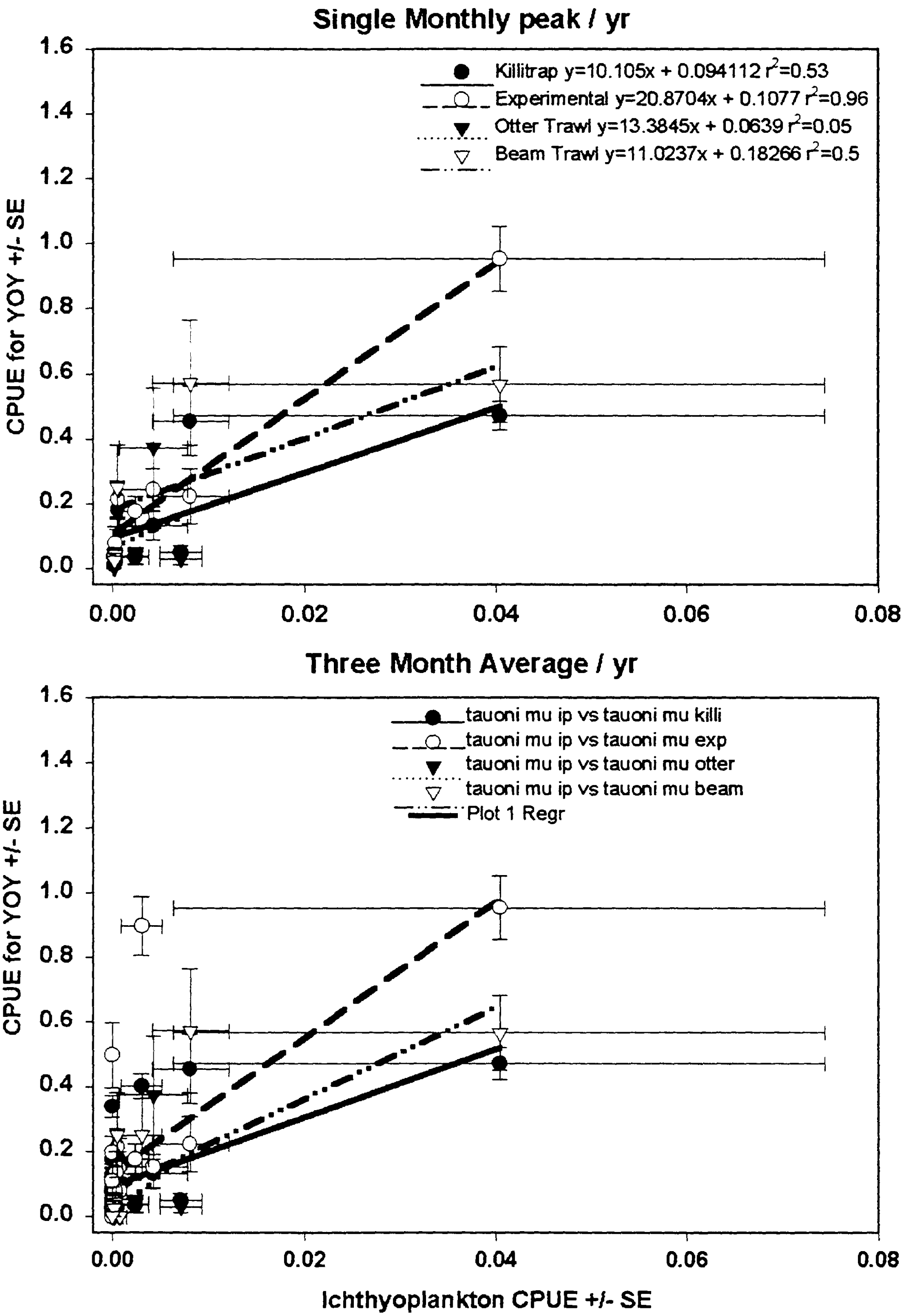

Fig. 15. Relationships for Tautoga onitis between larval (ichthyoplankton sampling) and young-of-the-year (YOY) based on comparisons between single monthly peak in abundance vs. three month average estimates of abundance for four gears (killitrap, experimental trap, otter trawl, beam trawl).

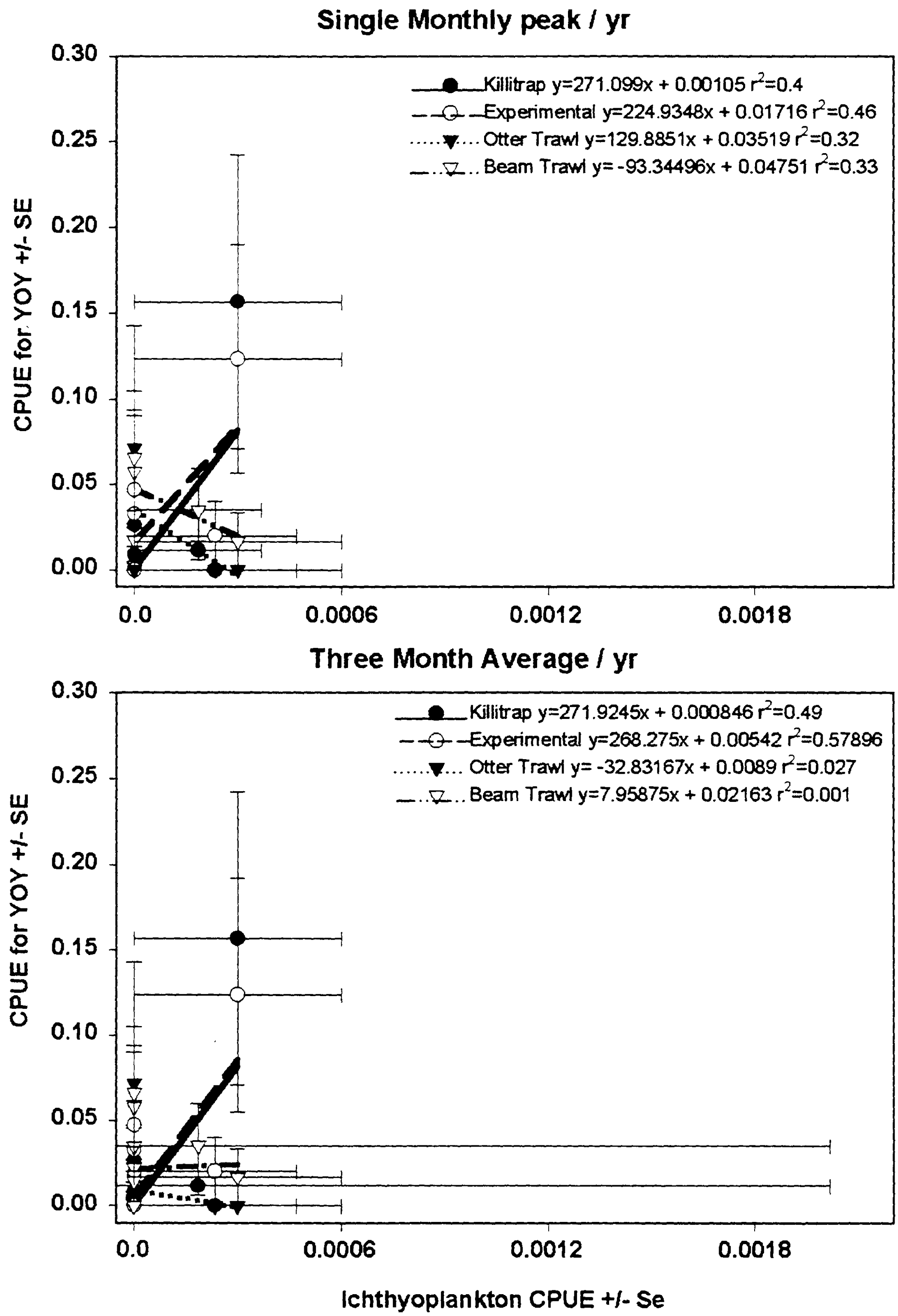

Fig. 16. Relationships for Urophycis regia (spring cohort) between larval (ichthyoplankton sampling) and young-of-the-year (YOY) based on comparisons between single monthly peak in abundance vs. three month average estimates of abundance for four gears (killitrap, experimental trap, otter trawl, beam trawl).

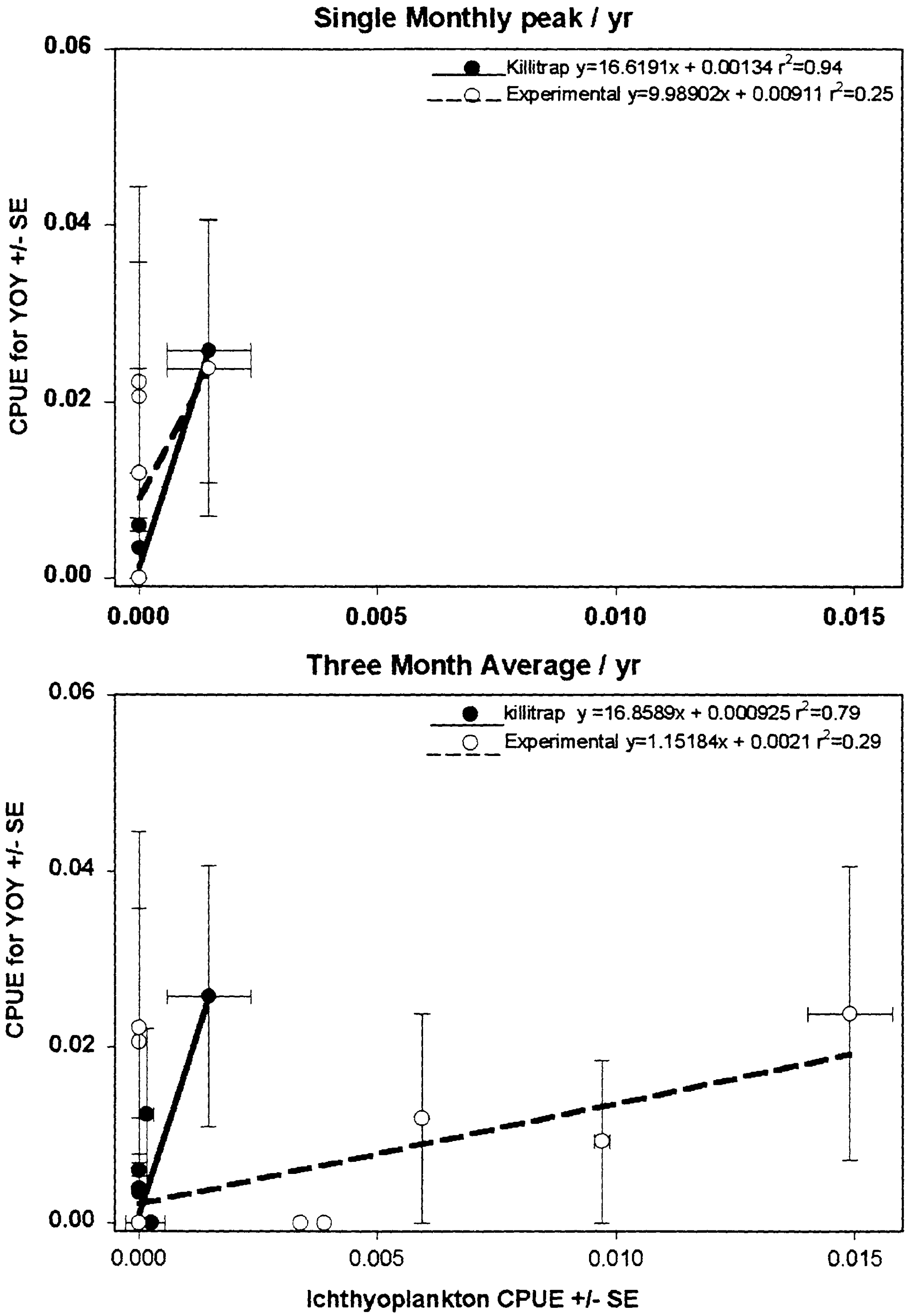

Fig. 17. Relationships for Urophycis regia (fall cohort) between larval (ichthyoplankton sampling) and young-of-the-year (YOY) based on comparisons between single monthly peak in abundance vs. three month average estimates of abundance for four gears (killitrap, experimental trap, otter trawl, beam trawl).