Habitat Preference and Spatial Interactions of the Northwest Atlantic Skate Complex

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Abstract of the Thesis

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Increasingly targeted by commercial fisheries, the seven resident species of Northwest (NW) Atlantic skates possess life history traits that make them vulnerable to overexploitation, including slow growth, late maturation and relatively low fecundity. The various species occupy overlapping habitats and often migrate long distances. While their ecological role as benthic marine generalists and basic geographic ranges are understood, little is known about how they occupy available habitat relative to environmental and biotic factors. I statistically analyzed skate habitat preference using data collected by the National Marine Fisheries Service (NMFS) bottom trawl survey for 1963-2010. Using the nonparametric cumulative distribution approach of Perry and Smith (1994), I compared available and occupied habitat for each species. Significant associations were found for the environmental variables latitude, temperature, depth and salinity. Species-specific habitat associations and interspecific spatial interactions were estimated, with an emphasis on temporal variations. I discuss the implications of habitat preference for range overlap and interspecific competition. This study provides valuable insights into the spatial and temporal habitat use of skates and improves scientific understanding of skate ecology.

Dedication Page

This work is dedicated to my grandmother, Ruth Ida Meyers, for wholeheartedly supporting me in my endeavors and always encouraging me to follow my dreams.

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Acknowledgments

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Introduction

Fisheries management has traditionally focused on species of high commercial value; however, overexploitation has reduced their abundance and their ecological importance within many ecosystems (Jackson et al. 2001, Ward and Myers 2005). As the scientific community shifts to an emphasis upon ecosystem-based management it is imperative we improve our knowledge and understanding of the changing species complex that inhabits the environment (Fogarty and Murawski 1998, Pikitch et al. 2004). This includes information on species' life history strategies, population dynamics, trophic relationships, migratory movements, habitat preferences, and interaction with a changing and dynamic environment.

In the Northwest (NW) Atlantic the collapse of commercially important groundfish stocks, such as cod and haddock, on the fertile fishing grounds of George's Bank was followed by an "outburst" in small and medium sized elasmobranchs in the 1980s (Fogarty and Murawski 1998, Frisk et al. 2008). While the trophic guilds remained stable over time, the species composition has drastically changed, altering the dynamics of the ecosystem (Garrison and Link 2000b). Biomass increases in less commercially valuable elasmobranch species, such as skates (Family Rajidae) and dogfish coincided with a temporal shift towards increased piscivory in those species, expanding their ecological role within the ecosystem (Garrison and Link 2000b).

Skates are benthic marine generalists that feed on mollusks, crustaceans, fish and polychaetes (Dulvy et al. 2000, Garrison and Link 2000a, Frisk 2010). Furthermore, larger skate species such as winter skate (*Leucoraja oscellata*) and barndoor skate (*Dipturus laevis*) undergo ontogenetic diet shifts from shrimp/benthic invertebrate diets, similar to small and medium sized cod, to a diet dominated by fish and benthic prey (Garrison and Link 2000a, b, Link and Sosebee 2008). The ontogenetic shifts mean that a strong change to the size structure of the population due to year class strength or harvest will alter the trophic role the species plays in the ecosystem (Garrison and Link 2000a). The dynamics of ontogenetic shifts and changing size structure add complexity to understanding and managing ecosystems.

There are 232 species of skates (Class Chodrichthyes) worldwide with 7 species occurring in the Northwest (NW) Atlantic (Sosebee 2005, Frisk 2010). These are the barndoor (*Dipturus laevis*), clearnose (*Raja eglanteria*), little (*Leucoraja erinacea*), rosette (*L. garmani*), smooth (*Malacoraja senta*), thorny (*Amblyraja radiata*) and winter (*L. ocellata*) skates (Sosebee 2005). These 7 species have been estimated to comprise 10-15% of the finfish biomass in the NW Atlantic (Link 2007, Link and Sosebee 2008). Within this group are 2 sympatric species pairs, little-winter and smooth-thorny respectively (McEachran et al. 1976).

While these seven species occupy similar ecological roles and have broadly similar diets, they do show variation in their life history characteristics (Table 1) (McPhie and Campana 2009). Hogan et al (2013) graphed growth models based upon published von Bertalanffy growth parameters for five of the seven species, as clearnose and rosette skates lacked the required parameters (Fig. 1). Skates are vulnerable to overexploitation even when fishing pressure is low due to several of their life history traits including slow growth, late maturation and relatively low fecundity (Casey and Myers 1998, Dulvy et al. 2000, Frisk 2010). Skates are susceptible to population decline and local extinction at low exploitation rates, with species of larger body size being more prone to collapse (Dulvy et al. 2000).

Skates are traditionally caught and discarded as bycatch in U.S. commercial fisheries and reported as aggregate skate catches instead of individual species (Dulvy et al. 2000, Dulvy and Reynolds 2002). Skates are now increasingly targeted by U.S. commercial fisheries due in part to the decline of more lucrative species (Frisk et al. 2010, Hogan et al. 2013). Winter skates support an export frozen wing fishery, while little and juvenile winter skates are exploited as bait for the American lobster (*Homarus americanus*) fishery (Hogan et al. 2013). Several species can be hard to distinguish from sympatric species at smaller sizes, further encouraging the aggregated reporting of landings (McEachran and Musick 1973, Alvarado Bremer et al. 2005, Sosebee 2005). The practice of reporting skate aggregate catches hinders the ability to effectively monitor trends in specific species abundance and creates uncertainty regarding the "aggregate skate" population levels.

Monitoring aggregate catch in Europe, for example, has masked declining trends in larger bodied skate species, while it appears the aggregate stock remains stable (Dulvy et al. 2000, Dulvy and Reynolds 2002). Larger bodied skates were found to be disproportionately removed by commercial fisheries and resulted in a release of competitive pressure on small bodied species, allowing them to increase in abundance (Dulvy et al. 2000, Dulvy and Reynolds 2002). Contrary to this notion, individual species of skates may be increasing or declining creating a more dynamic assemblage structure than an aggregate stock would imply (Dulvy et al. 2000, Dulvy and Reynolds 2002). Proper ecosystem management requires comprehensive knowledge of the life history traits and ecological niche of every species in order to efficiently model and predict the results of increased fishing pressure (King and McFarlane 2003). Hogan et al (2013) reported that all seven species of skate in the NW Atlantic occupy distinct thermal habitat ranges throughout the year and concluded that the management of these species would be more efficient if they were managed on an individual species basis and not as a skate complex.

Compounding the problem of fully understanding these species is climate change. Ecosystems are fluid by nature; however the rate at which they are currently changing is much faster than during a stable climate regime (Brooker et al. 2007). This makes studying any mobile species more difficult, but it does provide a unique opportunity for a large-scale environmental preference experiment in the field. Marine species have been shown to migrate and alter their traditional geographic distributions as waters warm (Murawski 1993, Perry et al. 2005, Rose 2005). Skates have been shown to be opportunistic migrators (Frisk et al. 2013), and with their increasing commercial importance understanding their movements over time will improve our ability to predict their movements. In 2000, the Northeast Fisheries Science Center (NEFSC) identified several research needs for skates (NEFSC 2000). Investigating the influence of environmental factors on shifts in the range and distribution of the species within the skate complex, as well as the trophic interactions between skate species, were among the research gaps identified.

In order to investigate these research needs I undertook an analysis of the NEFSC's bottom trawl survey database with a specific focus on the seven skate species. We sought to elicit environmental habitat preferences for each species and whether or not they vary by region, season, or temporally. In addition I investigated how changing distributions may alter trophic interactions between skate species. This work will further our understanding of skate ecology within the NW Atlantic and provide insight into a changing climate's influence on altering the regional influence of skate species on the ecosystems they occupy.

Methods

CPUE

The NEFSC bottom trawl survey uses a stratified random design and has been conducted annually in the fall (since 1963) and spring (since 1968) from the Gulf of Maine to Cape Hatteras (Sosebee and Cadrin 2006). Stations are allocated to each stratum in proportion to the area of the stratum, resulting in 300-600 stations per survey (Sosebee and Cadrin 2006). Standard tows were 30 minutes at ~3.8 knots using a "#36 Yankee" trawl, except during spring 1973-81 when a "#41 Yankee" trawl was used. Additionally, over the course of the time series four vessels have been used to conduct the survey, and the trawl doors were changed in 1985. Conversion factors for the gear changes were utilized to standardize the skate catches over the time series (Sosebee and Cadrin 2006, Miller et al. 2010).

Abundance was estimated as the catch per unit effort (CPUE). CPUE is a measure of relative abundance and was calculated as catch per standardized tow. The total CPUE for each of the seven species (spring/fall) was calculated for every year of the survey, as well as in each of four regional ecosystems: Gulf of Maine (GOM), George's Bank (GB), Southern New England (SNE) and the Mid-Atlantic Bight (MAB) (Fig. 2).

Habitat Preference

In order to estimate habitat preferences for all seven species I used a catch-weighted non-parametric method (Perry and Smith 1994). This method uses the null hypothesis of random associations between habitat conditions and fish distributions to determine if significantly different habitat is occupied compared to available habitat for any environmental variable.

Cumulative distribution functions (CDF) were used to compare bottom temperature, depth, bottom salinity and latitude profiles of each species to available habitat as sampled during the fall (Sept-Dec, 1963-2010) and spring (Mar-June, 1968-2010) NEFSC bottom trawl surveys. Species were divided into immature and mature groups based on the size (cm) at first maturity, and averaged between sexes due to a lack of sex identification in the database published by Sosebee (2005) (Table 1). These CDFs were further broken down into the four regional ecosystems GOM, GB, SNE and MAB. To identify any temporal shifts in habitat preference the analysis was conducted on seven (six for spring) time periods (1963-67, 1968-74, 1975-81, 1982-88, 1989-95, 1996-02 and 2003-10). The time periods were chosen to provide good resolution of the catch data without reducing the statistical power of the analysis. Salinity was not recorded regularly until the mid-1990s and was therefore not analyzed for temporal shifts. The analysis first characterizes the general frequency distribution of the habitat variable by constructing its CDF. The stratified random survey design results in a probability of $1/n_h$ within each stratum, delineated by depth, instead of the more commonly used $1/n$ (all symbols are defined in Table 2). The CDF for any habitat variable (x_{hi}) is

$$f(t) = \sum_h \sum_i \frac{W_h}{n_h} I(x_{hi}) \qquad \textbf{(1)}$$

with the indicator function, $I(x_{hi}) = \begin{cases} 1, if\ x_{hi} \le t; \\ 0, otherwise \end{cases}$, where t represents a level, ranging from the lowest to the highest value of the habitat variable. This CDF identifies the range of the habitat variable for the area surveyed, quantifying available habitat covered by the survey.

Next the catch of a particular species is associated with the occupied habitat variable using,

$$g(t) = \sum_h \sum_i \frac{W_h}{n_h} \frac{y_{hi}}{\bar{y}_{st}} I(x_{hi}) \tag{2}$$

Scaling the number of fish caught (y_{hi}) by the stratified mean number of fish caught ($\bar{y}_{st}$) results in g(*t*) summing to 1 over all values of *t*. A strong association between a skate species and a habitat condition is suggested by large values of $y_{hi}/\bar{y}_{st}$being consistently associated with particular habitat conditions. Essentially the cumulative distribution function from equation 2 illustrates the range of conditions a species of skate occupies; this can be compared to the available habitat conditions as calculated by equation 1. The third step is assessing the strength of the association between the catch of a skate species and the habitat variable by evaluating the degree of difference between the two curves (Fig. 3). I calculated the test statistic as the maximum vertical distance between g(*t*) and f(*t*),

$$D = \max_{\forall t} |g(t) - f(t)| \tag{3}$$

The distribution of the test statistic under the null hypothesis of random association between the fish catch and the habitat variable is also modelled through Monte-Carlo sampling. This is produced by randomizing the pairings of $(W_h/n_h)[(y_{hi} - \bar{y}_{st})/\bar{y}_{st}]$ and x_{hi} over all *h* and *i* for the data within the survey and then calculating the test statistic in equation 3 for the new pairs. The x_{hi} for the pairings are obtained by sampling with replacement the observed x_{hi} with probability $W_h n_h$. This procedure is repeated 1,000 times to give a pseudo-population under the null hypothesis. This randomization test is a two-sided test, since it is the magnitudes of the absolute differences between $g(t)$ and $f(t)$ that are of interest.

The test statistic (equation 3) was also calculated between species' CDFs, as well between mature-immature groups, in order to test for significance of the habitat ranges amongst the species of interest. For the Monte-Carlo sampling, the catches of two species or immature and mature groups were combined and randomized with half allocated to each species or maturation groups and the test statistic recalculated with the new CDFs. This procedure was repeated 10,000 times for each species or immature and mature group comparison. The range in which 90% of the population occupied was defined as the species habitat range. This was calculated by taking the 5% and 95% values within the CDF. The 50% value was also determined.

Measure of Aggregation

The significance of the test statistic in the randomization tests can be affected by the degree of aggregation of the fish population (Swain et al. 1998). A highly aggregated population creates large jumps in the catch-weighted CDF due to the abundance being concentrated in a few large catches. These jumps are retained in the randomized pairings of catch and environmental variables, and can cause a given test statistic to be less significant than if the population is more evenly distributed (Swain et al. 1998). To test for the level of aggregation in a skate population a method by Swain et al. (1998) was used. This method uses Lorenz curves to compare the degree of aggregation between two catches. To build the Lorenz curves I calculated the estimated percentage of the population associated with each tow i $(N_i = 100(W_h/n_h)y_{hi}/\bar{y}_{st})$ as well as the area associated with each tow $\left(A_i = 100(W_h/n_h)\right)$ were calculated. The tows were sorted by N_i and plotted with cumulative percent area on the x-axis and cumulative percent abundance on the y-axis. The plotted curve becomes more concave as the population becomes more aggregated.

Critics of this method point to a lack of a defined domain within the analysis over time as well as questions as to how to handle zeroes in the catch data (Woillez et al. 2007). In order to address these concerns when looking at the survey as a whole in fall, population domains were defined for each species as any strata that were occupied by the species in the time series. This reduced the number of zeroes in the analysis and allowed for any temporal geographic range expansion. When used in the analysis, the domains for the four geographic ecosystem regions were simply the strata that defined each region. The species aggregation data was considered at two levels, the first of which was the species' aggregation within the domain and secondly within the species' population. To elicit the aggregation within a population, zeroes were removed from the analysis that produced the results within the domain.

In order to effectively quantify the differences in aggregation between any two Lorenz curves, I calculated the Gini coefficient (Gini 1921), or index for each curve. The Gini index is defined as twice the area between the Lorenz curve and a 1:1 line that represents complete equality in density. The index ranges from 0, total equality in density, to 1, where the entire abundance exists in one location. Lorenz curves and their corresponding Gini index values were calculated yearly for each species, both within the domain and the population for both seasons. These values were then graphed sequentially with time as well as with their corresponding CPUE values calculated within the defined domain. Linear and logarithmic trends ($>0.3\ R^2$) were identified and fitted to the data where applicable.

Index of Collocation

The local index of collocation was utilized to investigate changes in the spatial interactions between skate species I utilized the local index of collocation. The local index of collocation (LIC) indicates the spatial overlapping of species; in this case, how often two species are caught in the same trawl and therefore occupying the same benthic habitat (Bez and

Rivoirard 2000). The LIC was proposed by Bez & Rivoirard (2000) and assumes a value of 1 if the densities of the two species in question are proportional to each other in all tows and zero if they never occur together. The index for 2 skate species is defined as:

$$LIC(t) = \frac{\sum_{i=1}^{n} \hat{D}_i^{skateA}(t)\hat{D}_i^{skateB}(t)}{\sqrt{\sum_{i=1}^{n}\left(\hat{D}_i^{skateA}(t)\right)^2 \sum_{i=1}^{n}\left(\hat{D}_i^{skateB}(t)\right)^2}} \qquad \textbf{(4)}$$

where $\hat{D}_i^{skateA}(t)$ and $\hat{D}_i^{skateB}(t)$ are the survey density estimate for a given skate species in tow i in year t. The index values were calculated for each year, season (spring and fall), region (GOM, GB, SNE and MAB) and skate species pair.

Results

CPUE

Yearly CPUE values encompassing the entire expanse of the survey for each of the 7 skate species in spring and fall show considerable variability (Fig. 4). Little and winter skate's CPUE were an order of magnitude higher than the other species and substantially higher in spring over during the 1980s and early 1990s (Fig. 4). GOM (Fig. 5) had 5 of the 7 skate species: barndoor, little, smooth, thorny and winter skates. GB (Fig. 6) was comprised of the same 5 species; however, rosette skates were also caught in small numbers during the last decade. SNE (Fig. 7) consisted of 5 species (barndoor, little, rosette, thorny and winter) in spring, with smooth skate an infrequent low abundant visitor mainly in the early years of the survey. All 7 species occupied SNE in fall. MAB (Fig. 8) consisted of a 4 species complex (clearnose, little, rosette and winter) with small numbers of barndoor caught in the spring in the last 6 years of the survey.

Habitat Preference

All species' latitude ranges were significantly ($p<0.05$) different from the available habitat (Table 3) and the other skate species (Table 4). Smooth and thorny occupied the northern most latitudinal ranges of the survey in both fall and spring (Fig. 9A). Barndoor, little and winter were most abundant in the mid-latitudes. Clearnose and rosette occupied the more southerly available latitudes sampled by the survey (Fig. 9A). Clearnose skates' occupied significantly more northern latitudes in the fall than in the spring (Fig. 9A).

Most of the species occupied temperature ranges were significantly ($p<0.05$) different from the available, except for little in fall and barndoor in spring (Table 3). All species occupied significantly different ($p<0.05$) temperature ranges than the other skate species in both seasons, except for little and winter ($p<0.1$) (Table 5). Clearnose, little and winter skates occupied clearly different temperature ranges in fall compared to spring (Fig. 9B).

Rosette (spring/fall), thorny (spring/fall), smooth (spring) and barndoor (fall) were not significantly ($p<0.05$) different from the available depth ranges (Table 3). Smooth skate in fall was nearly significant ($p=0.055$) and occupied the deepest depth range in fall with a 5% value, i.e., the minimum habitat range, around 107 meters (Fig. 9C). Clearnose, little and winter occupied the shallowest mean depths in both seasons, and their ranges were all significantly ($p<0.05$) different from the available depth habitat (Table 3). Clearnose in spring occupied waters 164 meters deeper than in fall (Fig. 9C). Winter skates also occupied deeper water in spring; their maximum habitat was 80 meters deeper than in fall (Table 3). All species occupied significantly ($p<0.05$) different depth ranges from the other skate species, except for little and winter skate in fall (Table 6).

All species' occupied salinity ranges were significantly ($p<0.05$) different from available (Table 3). Clearnose (fall), little (spring/fall) and winter (spring/fall) occupied the lowest mean salinities of the seven species (Fig. 9D). Clearnose and winter occupied significantly expanded salinity ranges in spring when compared to fall (Fig. 9D). Rosette skates occupied the highest mean salinities in both seasons (Fig. 9D). In spring, all species occupied different ($p<0.05$) salinity ranges from one another, except for barndoor with clearnose and rosette skates, as well as, clearnose and smooth skates (Table 7). In fall, all species occupied unique salinity ranges from the other skate species (Table 7).

Immature/Mature Habitat Analysis

Only little, thorny and winter skates occupied significantly different ($p<0.05$) latitude ranges between immature and mature groups in spring (Table 8, Fig. 10A). Barndoor and winter skates occupied significantly depth different ranges between immature and mature groups (Table 8, Fig. 10B). Winter skate was the only species that occupied significantly different salinity ranges between immature and mature groups (Table 8, Fig. 10C). Only clearnose and winter skates occupied significantly different temperature ranges between immature and mature groups (Table 8, Fig. 10D). Winter skate was the only species to occupy significantly different habitat between immature and mature groups for all four environmental variables (Table 8).

The occupied latitude ranges for the seven species' immature and mature groups in fall (Fig. 11A) showed every species, except smooth skate, occupied significantly different ($p<0.05$) latitude ranges between immature and mature groups (Table 9). The occupied depth ranges for all seven species' immature and mature groups in fall (Fig. 11B) were only significantly different between immature and mature groups for thorny and winter skates (Table 9). The occupied salinity ranges for all seven species' immature and mature groups in fall (Fig. 11C) were only significant between groups for thorny skate (Table 9). The occupied temperature ranges for all seven species' immature and mature groups in fall (Fig. 11D) were significantly different between groups for clearnose, smooth, thorny and winter skates (Table 9). Winter skate occupied significantly different habitat between immature and mature groups for three environmental variables, while thorny skate was significant for all four variables (Table 9).

Regional Habitat Analysis

The data for the regional breakdown included only those species whose stratified mean abundance ($\bar{y}_{st}$) was $\geq 10^{-3}$ CPUE and were caught in multiple years within the region. Clearnose and rosette skates were rarely caught in the Gulf of Maine and George's Bank, the farthest north regions, in either season over the course of the dataset. Barndoor (fall), smooth (spring/fall) and thorny (spring/fall) skates did not occupy the Mid-Atlantic Bight, the farthest south region (Table 10 & 11). In addition, clearnose skates were not present in the Southern New England region during spring (Table 10).

The Gulf of Maine consisted of a 5 skate species complex with barndoor, little, smooth, thorny and winter skates represented. In spring, barndoor ($p=0.122$) and thorny ($p=0.061$) were the only species that were not significantly ($p<0.05$) different from the available latitude habitat. All of the species occupied unique and significantly different ($p<0.05$) latitude ranges (Table 12). Smooth ($p=0.121$), thorny ($p=1.000$) and barndoor (0.054) in spring were not significantly different from available temperature. The species that were significant, little (4.2°C) and winter (4.35°C), occupied cooler mean population temperatures than the mean available temperature (6.17°C) for the survey (Table 10). All of the species occupied significantly ($p<0.05$) different temperature ranges from the other species, except for the comparison between little and winter skates (Table 12). Barndoor and little skates were the two species significantly ($p<0.05$) different from the available depth range of the survey. Barndoor occupied the deepest depth range of the five species, while little occupied the shallowest range (Table 10). All species occupied unique and significantly different ($p<0.05$) depth ranges, except for the comparison between little and winter skate, which did not occupy significantly different depth ranges from each other (Table 12). All species except winter skate ($p=0.563$) were significantly different from the available survey salinity range. Most species occupied significantly ($p<0.05$) different salinity ranges from the other species, with the exception of winter skate with little ($p=0.1334$) and thorny ($p=0.06$) skates (Table 12).

In the Gulf of Maine in fall, all species' latitude ranges were significant. Little (42.73°) and winter (42.77°) skates were caught at lower max latitudes compared to the other species (>44°) (Table 11). All species occupied unique latitude ranges (Table 13). Barndoor ($p=0.28$) and thorny ($p=0.168$) skates' temperature ranges were not significantly different from the available temperature range; the other three species were all significant ($p=0.000$). Smooth skate occupied the coolest temperature range (5 - 9.84°C), while little skate occupied the warmest temperature range (8.71 – 14.53°C) (Table 10). The comparison between little and winter skate ($p=0.692$) was the only species pair that did not occupy significantly ($p<0.05$) different temperature ranges (Table 13). Little (14-217 m) and winter (17-219 m) skate occupied the shallowest depth ranges and were the only two that were significant ($p=0.00$) from the available range (71-322 m). Smooth skate occupied the deepest depth range (130-340 m) of the five species (Table 11). The comparison between little and winter ($p=0.074$) was the only species pairing that did not occupy significantly ($p<0.05$) different depth ranges (Table 13). Barndoor (p=0.368) was the only species that did not have a salinity range significantly (p=0.00) different from the available range of the survey for the Gulf of Maine. The comparison between barndoor and smooth (p=0.42) as well as little and winter (p=0.496) were the only species pairings that did not occupy unique and statistically significant (p<0.05) salinity ranges (Table 13).

George's Bank was characterized by a 6 skate species complex in spring consisting of barndoor, little, rosette, smooth, thorny and winter; however, it is likely more functionally a 5 species complex as rosette skates were caught in very low numbers (Table 10). In spring, barndoor (p= 0.248) was the only species to not be significantly different from the latitudinal survey range for GB (Table 10). All species occupied unique latitudinal ranges from the other skate species (Table 14). Rosette skate (p=0.002) was the only species with a significantly different temperature range for GB, occupying the warmest range (11-13°C) (Table 10). Most of the species occupied unique (p<0.1) temperature ranges, with the exception of little & thorny, little & winter, and thorny & winter (Table 14). Rosette was the only species that was not significantly (p<0.05) different from the available depth range of the survey (42-212 m) (Table 10). All species occupied unique significantly (p<0.05) different depth ranges than the other species, except for barndoor & rosette, barndoor & smooth and little & winter (Table 14). Every species was significantly (p<0.1) different from the available survey salinity range in GB; rosette was omitted due to limited salinity data (Table 10). All species occupied unique (p<0.1) salinity ranges, except for barndoor & rosette and barndoor & smooth (Table 14).

In the fall, GB consisted of the same 5 species skate complex that occupied GOM. Similar to spring, barndoor (p=0.263) was the only species with a latitudinal range not significantly different from the available survey range (Table 11). Every species occupied unique and significantly (p<0.05) different latitudinal ranges, except for the comparison of thorny and smooth skates (Table 15). Barndoor ($p=0.00$), smooth ($p=0.00$) and thorny ($p=0.00$) were the only species significantly different from the available survey temperature range. All three species preferred to occupy colder ranges than the available temperature range (Table 11). All of the species, except the two sympatric species pairs (little & winter and smooth & thorny), occupied significantly ($p<0.05$) different temperature ranges compared to the other skate species (Table 15). Barndoor skate ($p=0.433$) was the only species that was not significantly different from the available survey depth range (Table 11). Every species occupied unique and significantly ($p<0.05$) different depth ranges compared to the other species, except for smooth & thorny (Table 15). Every species was significantly different ($p<0.05$) from the available GB salinity range in fall (Table 11). The sympatric species pairs and barndoor & smooth did not occupy significantly ($p<0.1$) different salinity ranges compared to the other species in the complex (Table 15).

Southern New England consisted of a 5 skate species complex in the spring including barndoor, little, rosette (again in very low numbers), thorny and winter skates (Table 10). Every species, except thorny ($p=0.354$), was significantly different ($p=0.00$) from the available latitudinal survey range for SNE in spring (Table 10). All species, except thorny and smooth, occupied significantly ($p<0.05$) different latitudinal ranges than the other species in the region (Table 16). Little was the only species not significantly ($p<0.05$) different from the available temperature range (Table 10). All species, with the exception of smooth and thorny, occupied significantly different temperature ranges from the other species present (Table 16). Barndoor and winter were significantly different from the available depth range (Table 10). The sympatric species pairs, little & winter and smooth & thorny, were the only pairings that did not occupy significantly ($p<0.05$) different depth ranges within the SNE ecosystem (Table 16). Barndoor and little were the only significant salinity ranges (Table 10). Smooth skates did not occupy significantly ($p<0.1$) different salinity ranges than either barndoor or thorny skates, neither did little occupy a statistically significant range from winter skates (Table 16).

In fall, SNE was occupied by all seven skate species and all species, except barndoor ($p=0.196$), occupied significantly different latitudinal ranges from the available survey (Table 11). All species occupied significantly different ($p<0.05$) latitudinal ranges, except for smooth which did not occupy significantly different ranges from either thorny or winter skates (Table 17). Barndoor, clearnose, rosette and thorny occupied significantly ($p<0.05$) different temperature ranges than the available survey range (Table 11). All species occupied significantly different ($p<0.05$) temperature ranges from the other skate species, except for smooth skate that did not occupy a statistically different range from barndoor, rosette or thorny skates. In addition, little and winter skates did not occupy significantly different temperature ranges from one another (Table 17). Clearnose, rosette and winter were the only species to occupy significantly different ($p=0.00$) depth ranges, with rosette skate occupying the deepest range (Table 11). All species occupied unique and significantly different ($p<0.1$) depth ranges, except for thorny skates that did not occupy a significantly different range from barndoor or smooth skates (Table 17). Clearnose, rosette and winter were also the only species to occupy significantly different salinity ranges (Table 11). Thorny skate did not occupy a salinity range that was significantly different from barndoor, clearnose, little, smooth or winter skates. In addition, barndoor did not occupy a significantly different range from either little or smooth skates and smooth skates' salinity range was not significantly different from winter skate (Table 17).

The Mid-Atlantic Bight was occupied by a 5 skate species complex in spring, comprised of clearnose, barndoor (in the last 6 years of the survey), little, rosette and winter skates. In spring, all of the species, except barndoor, occupied significantly different ($p<0.05$) latitudinal, temperature and salinity ranges (barndoor not included) than the available survey habitat (Table 10). All species occupied significantly ($p<0.1$) different latitudinal ranges compared to the ranges of the other species (Table 18). Clearnose and rosette skates did not occupy significantly ($p<0.05$) different temperature ranges, while the other species all occupied significantly different ranges. Most of the species occupied significantly different ($p<0.05$) salinity ranges from those occupied by the other species, except for barndoor & clearnose and little & winter (Table 18). Only rosette and winter skates occupied significantly different depth ranges than the available range (Table 10). All species occupied significantly ($p<0.05$) different depth ranges, except for little and winter skates that occupied ranges that were not significantly different from each other (Table 18).

In fall, MAB consisted of a 4 skate species complex with clearnose, little, rosette and winter. Little, rosette and winter skate were the only species to occupy significantly ($p=0.00$) different latitudinal ranges from the available (Table 11). Clearnose, little and rosette occupied significantly different temperature ranges from the available habitat (Table 11). Clearnose occupying the shallowest depth range (12-42 m) and rosette occupying the deepest depth range (70-166 m) were the only species occupying ranges that were significantly ($p=0.00$) different from the available range (16-201 m) (Table 11). Clearnose, little and rosette all occupied significantly ($p<0.05$) different salinity ranges from the available survey range (Table 11). All the species occupied unique and significantly different ranges for all environmental variables in fall for the MAB region (Table 19).

Temporal Trends in Habitat Preference

In spring, barndoor skate had two time periods where its' latitudinal distributions were significantly different ($p<0.05$) from the available and negative linear trends in their 5% and 50% latitudinal values (Table 20). Barndoor only had one time period that was significant for temperature range, but did show positive trends in the 5%, 50% and 95% temperatures occupied over time (Fig. 12). The last two time periods of occupied depth ranges were significantly different from the survey (Table 20) with slightly positive trends in the 50% and 95% depths occupied (Table 20).

Clearnose was significantly ($p=0.00$) different from the survey for every time period in both latitude and temperatures occupied (Table 20). Clearnose showed a positive trend in 50% latitude values while no strong trends were evident for temperatures occupied in spring (Table 20). Only two of the time periods indicated occupied depth ranges that were significantly ($p<0.05$) different from the available survey depth ranges with no significant trends (Table 20).

Little skate was significantly ($p<0.05$) different from the available latitude range of the survey for all of the time periods (Table 20) and showed slightly negative linear trends in each of the reference values. For temperature, little had two significant time periods (Table 20) and the 95% values showed a negative linear trend. Little had significant depth ranges in every time period (Table 20) and showed negative linear trends in the 5% and 95% values (Table 20).

Rosette skate in spring occupied significant ($p<0.05$) latitude and temperature ranges in each time period (Table 20) and showed positive linear trends in 50% and 95% latitude values (Fig. 13), as well as a slightly positive trend in 50% temperature. Rosette only occupied significantly different depth ranges in two time periods (Table 20) and showed no significant linear trends in the habitat variable ranges over time.

Smooth skate occupied significant latitude and depth ranges in each time period and showed a positive linear trend in 5% depth values (Table 20). Smooth skate occupied significant temperature ranges in only two of the time periods (Table 20) and showed a slightly positive linear trend in the 5% temperature values.

Thorny skate occupied significant latitudinal ranges in each time period, none in temperature ranges and four time periods were significant in the depth ranges (Table 20). Thorny skate did not show any linear trends in habitat variables over time (Table 20).

Winter skate occupied significantly ($p<0.05$) different latitudinal ranges for every time period in spring (Table 20) and showed negative linear trends in both the 5% and 50% values. Winter skate occupied significant ($p<0.05$) temperature ranges in three of the time periods (Table 20) and showed a positive linear trend in the 50% temperature values. Winter skate occupied significant depth ranges in two of the time periods (Table 20) and showed a slightly positive linear trend in 50% depth values. The survey itself showed negative linear trends in the latitude values over time (Fig. 14).

In fall, barndoor skates occupied significant ($p<0.05$) latitudinal ranges in two of the time periods (Table 21) and showed a negative linear trend in the 95% reference values. Barndoor occupied significantly ($p<0.05$) different temperature ranges from the survey in two time periods (Table 21) and occupied warmer temperatures over time (Fig. 15). Barndoor did not occupy a single significantly ($p<0.05$) different depth range from the available survey (Table 21) but did show a slightly negative linear trend in the 95% depth values.

Clearnose was significantly ($p=0.00$) different from the available survey for every time period and for each of the environmental variables (Table 20). Positive linear trends existed for all three latitudinal values, the 50% and 95% temperature values and the 5% depth values (Fig. 16).

Little skate occupied significant ($p<0.05$) latitudinal ranges in 5 of the fall time periods (Table 21) and showed negative linear trends in the 5% and 50% latitudinal values. Little skate occupied a significantly ($p<0.05$) temperature range in only one time period, but did show positive linear trends in all three reference values (Fig. 17). Little skate occupied significantly ($p<0.05$) different depth ranges in six of the time periods (Table 21) with slightly negative trends in depths occupied.

Rosette skates occupied significantly ($p<0.05$) different latitudinal ranges from the available habitat (Table 21) and showed a slightly negative trend in the 95% values (Table 21). Rosette skate occupied significant ($p<0.05$) temperature ranges in two of the time periods and showed a positive trend in 50% temperature values (Table 21). Rosette skate occupied a significant ($p<0.05$) depth range in one time period (Table 21), but did show negative trends in the 50% and 95% occupied values.

Smooth skate occupied significant ($p=0.00$) latitudinal and temperature ranges for every time period in fall (Table 21), while no significant latitudinal trends existed, there were positive trends in all three occupied temperature values. Smooth skate occupied significant ($p<0.05$) depth ranges in five time periods (Table 21) and showed a positive trend in the 5% depth values.

Thorny skate occupied significantly ($p=0.00$) different latitudinal and temperature ranges for every time period (Table 21). Thorny skate showed a positive trend in the 5% latitudinal values and the 5% and 50% temperature values while also having a negative trend in the 95% latitudinal value (Fig. 18). Thorny skate occupied significantly ($p<0.05$) different depth ranges in three of the time periods (Table 21) and showed a negative linear trend in the 50% values (Fig. 18).

Winter skate occupied significantly different latitudinal ranges in every time period (Table 21) and showed slightly positive trends in the 5% and 95% values. Winter skate occupied significantly ($p<0.05$) different temperature range in one of the time periods, but did show positive linear trends in each of the three reference values (Fig. 19). Winter skate occupied significant ($p<0.05$) depth ranges in three of the time periods (Table 21) and showed no significant trends in occupied depths. The survey showed negative trends in latitude and depths sampled, while representing a positive trend in temperatures sampled (Fig. 20).

Measures of Aggregation

Seasonal temporal barndoor skate Gini values show a less aggregated stock within the domain and a more aggregated stock within the population as the stock recovers (Fig. 21). The seasonal population Gini values show significant logarithmic trends with increasing CPUE values (Fig. 21). Clearnose skate showed reduced aggregation within the domain over the fall time series with increased aggregation within the population (Fig. 22). When graphed against CPUE the fall Gini index values showed a negative linear trend within the domain and a significant logarithmic trend within the population as abundance increases, similar to barndoor skate (Fig. 22). A similar logarithmic trend in population aggregation with increasing CPUE was found in spring as well (Fig. 22). Little skate’s population level aggregation in fall showed a logarithmic trend with increasing CPUE (Fig. 23). Little skate showed positive linear trends in population aggregation levels temporally and with increasing CPUE in spring (Fig. 23).

Rosette skate's population showed no trends with year or within the domain, however it did show logarithmic trends with increasing CPUE values that also appear to level out in both seasons (Fig. 24). Smooth skate showed no trends with year and had negative linear trends for Gini index values within the domain with increasing CPUE in both seasons (Fig. 25). Within the population, Gini index values showed a significant logarithmic trend with increasing CPUE in fall (Fig. 25). Thorny skate showed the strongest linear trends (R^2= 0.67-0.75) of any species for Gini index values within the domain (Fig. 26). They were positively associated with year, but negatively associated with increasing CPUE values (Fig. 26). Within the population, thorny skate showed slightly logarithmic trends in Gini index values with increasing CPUE (Fig. 26). Winter skate showed a significant logarithmic trend within the population with increasing CPUE values in both seasons (Fig. 27).

GOM Gini index values ranged from 0.71 to 0.99 with two species becoming more aggregated in spring (barndoor and thorny), two more aggregated in fall (little and winter) and one remaining fairly stable between seasons (smooth) (Table 22). The population level aggregation was higher in spring than fall for all occupying species, with little skate the most aggregated species in both seasons (Table 22). In GB, the Gini values ranged from 0.76 to 0.99 and all six occupying species were more aggregated in spring than fall (Table 23). For population, thorny skate was the only species that was less aggregated in the spring than the fall (Table 23). SNE had Gini index values ranging from 0.85 to 0.99 and showed the least amount of variation between seasons of any of the regions (Table 24). For population, clearnose, rosette and smooth skates were less aggregated in spring versus fall; the remaining four species were all more aggregated in spring (Table 24). In MAB, the Gini index values ranged from 0.85 to 0.99 and showed the three northern occupying species (barndoor, little and winter) were more aggregated in fall and the two southern occupying species (clearnose and rosette) were more aggregated in spring (Table 25). All occupying species exhibited more aggregated populations during spring than in fall (Table 25).

Index of Collocation

For the survey as a whole in fall, little and winter had the highest average (0.44 ±0.17) followed by the pairing of smooth and thorny (0.32 ±0.16) (Table 26). Barndoor showed higher average associations with little (0.136 ±0.118), thorny (0.119 ±0.141) and winter (0.142 ±0.128) (Table 26). In spring, the only strong average associations were with little/winter (0.503 ±0.226) and smooth/thorny (0.348 ±0.158) (Table 27).

In the Gulf of Maine in spring, barndoor skate had strong average associations with smooth (0.241 ±0.294), thorny (0.148 ±0.242) and winter (0.113 ±0.242) skates (Table 28). These associations are driven by LICs prior to 1970 and after 2000 (Table 28). Thorny skate showed strong average associations with little (0.120 ±0.109), smooth (0.392 ±0.192) and winter (0.135 ±0.134) skates (Table 28). The LIC values for the smooth and thorny skate pairing showed a slightly negative linear trend with year (Fig. 28). Winter skates were highly associated with little (0.265 ±0.297) and smooth (0.106 ±0.162) skates (Table 28). In fall, barndoor was associated with smooth (0.103 ±0.183) and thorny (0.138 ±0.161) skates, these associations were mostly prior to 1972 and after 2000 (Table 29). The strongest associations were between sympatric species pairs, little & winter skates (0.218 ±0.258) and smooth & thorny (0.319 ±0.148) (Table 29). Smooth and thorny showed a strong negative linear trend in their LIC values (Fig. 29).

On George's Bank in the spring, barndoor skate was associated with little (0.173 ±0.201), thorny (0.130±0.166) and winter (0.131 ±0.202) skates; these associations were generally pre-1976 and post-1992 (Table 30). The strongest associations were for sympatric species pairs, little & winter (0.582 ±0.240) and smooth & thorny (0.372 ±0.299) skates (Table 30). In fall, barndoor was associated with little (0.212 ±0.163), smooth (0.136 ±0.240), thorny (0.203 ±0.236) and winter (0.208 ±0.172) skates; these associations were mostly pre-1976 and post-1984 (Table 31). Strong positive linear trends were evident for barndoor & little and with barndoor & winter from 1984-2010 (Fig. 30). The strongest LIC associations were between sympatric species, little & winter (0.596 ±0.172) and smooth & thorny (0.411 ±0.278) (Table 31).

In Southern New England in the spring, the strongest LIC associations were between winter and little skates (0.597 ±0.248) (Table 32) and showed a slightly positive linear trend (Fig. 31). Thorny skate showed high average associations with smooth (0.311 ±0.406) and winter (0.131 ±0.236) skates (Table 32). Barndoor had an association (0.206 ±0.424) with rosette skates; however they were only both caught in the survey for 5 years of the time series (Table 32). In fall, barndoor skates were associated with little (0.171 ±0.147) and winter (0.134 ±0.137) skates; most of the LIC values are pre-1968 and post-1999 (Table 33). Winter skate was also strongly associated with little (0.355 ±0.214) and to a lesser degree thorny (0.109 ±0.213) (Table 33). Smooth and thorny had a higher average LIC value (0.106 ±0.28), buoyed by two strong years (Table 33). Clearnose skate shows a significant increase in LIC values after 1990 with little and winter skates (Fig. 32). The Mid-Atlantic Bight in spring showed a strong average association between winter and little (0.444 ±0.239) skates (Table 34) and the LIC values show a positive linear trend (Fig. 33). In fall, winter and little (0.182 ±0.166) were the only average LIC values >0.10 (Table 35).

Discussion

While long term surveys are important tools for researchers, they do possess the inherent caveat of not being a species-specific survey. Optimized for improving knowledge of the ecosystem as a whole, there are always species that will not be sampled within the entirety of their range. This limitation does affect several of the skate species in the NW Atlantic skate complex, mainly those occupying deeper or more southern ranges. It is important to keep in mind that all of the results presented are within the context and limitations of the NEFSC bottom trawl survey.

CPUE/Stock Status

Little and winter skates are the two most abundant species of skate in the NW Atlantic, often an order of magnitude higher abundance than the other five species (Fig. 4). They tend to be caught more often in spring than in fall for most years of the survey, particularly in the 1980s to early 1990s in the case of winter skate (Fig. 4). However in the late 1990s spring interannual variation in winter skate abundance decreased, possibly due to lower emigration from areas outside of the survey's scope (Fig. 4) (Frisk et al. 2013). Little and winter skate are also the only two species that are present in all four regional ecosystems during both spring and fall (Figs. 5-8).

Seasonal little and winter skate CPUEs varied much more drastically in the Southern New England and Mid-Atlantic Bight ecosystems compared to Gulf of Maine and George's bank (Fig. 5-8). This seasonal difference is most striking in the MAB where abundances of little and winter skate appear to be increasing in spring while remaining fairly stable in fall over the course of the time series (Fig. 8). This increase could represent a range expansion southward by these two species into an ecosystem as their increased abundances in spring coincide with the reductions in the seasonal variation seen in the SNE (Fig. 7-8). Overall the little and winter skate stocks are the most abundant among the NW Atlantic skate complex, however they are also the two species that are currently targeted by the commercial skate fisheries. While the stocks are currently robust, it is important to note their differences in life history (Table 1) and growth rates (Fig. 1) as these two factors will influence their resilience to fishing pressure (Frisk and Miller 2006, Cicia et al. 2009). The differences between little and winter skate's life histories and growth rates are similar to the variances of the other sympatric species pair, thorny and smooth. For little and winter skate this may suggest that little skate with a faster life history will be more resilient to exploitation and could recover faster than winter skate from a depleted state.

In contrast to the abundances of little and winter, thorny and smooth skates have been declining through most of the time series (Fig. 4). While smooth skate CPUE appears to stabilize in the mid-1980s and slightly increase in recent years, thorny skate continues to decline (Fig. 4). This stabilization for smooth skate could be related to it maturing faster and therefore having a shorter generation time when compared to thorny skate (Table 1) (Sulikowski et al. 2005, Sulikowski et al. 2009).

Thorny and smooth skates were the most abundant skate species in the Gulf of Maine at the beginning of the time series, but are surpassed by little and winter skates in the 1980s (Fig. 5). Both smooth and thorny skates decline then stabilize in the 1980s on George's Bank and as in most of their range, there is not a consistently large seasonal variation in their abundances in any of the ecosystems (Fig. 5-8). Currently thorny skate stock is considered overfished with possession prohibited throughout the Northeast US continental shelf. While considered not to be overfished, possession of smooth skate is prohibited the GOM regulated mesh area. Even with restrictions on their catch, as with all skates, there will always be an element of bycatch mortality from other fisheries that may negatively impact the recovery of both species.

Similar to thorny skate, the possession of barndoor skate is prohibited throughout the NE US continental shelf. Barndoor skates were caught in all four regional ecosystems at various points throughout the survey; however abundance was lowest in the MAB (Fig. 5-8). CPUE in all regional ecosystems declines at the beginning of the time series, essentially reaching zero in the early to mid-1970s before suddenly increasing again in the early 1990s (Fig. 4-8). This pattern has been explained as stock collapse followed by recovery, possibly due to maximal growth and survival rates at low population levels from reduced intra-specific competition (Casey and Myers 1998, Gedamke et al. 2007, Gedamke et al. 2009). The level of aggregation within barndoor skate populations does decrease dramatically with reduced CPUE (Fig. 21). Alternatively, catch rates of barndoor skate have been found to increase below 450m, suggesting that the NEFSC bottom trawl survey does not capture the majority of the barndoor skate habitat with 95% of the tows at depths below 310 meters (Table 3) (Kulka et al. 2002). Frisk et al. (2013) suggested that contradictory life history parameters for barndoor skates, with some models proposing an inordinately quick life cycle for such a large bodied elasmobranch species may actually be due to adult-mediated population connectivity. While the migration from deeper waters could be a result of improved environmental conditions at shallower depth, the majority of barndoor skates caught in the NEFSC survey are immature (<100 cm) (Gedamke et al. 2009). This could be due to range expansion or reduced competition for resources at the shallower depths. A more concentrated effort to sample a larger proportion of the barndoor skate range should be undertaken to better understand the population dynamics of this species.

Clearnose and rosette skates are the species with the most southern distributions and show increases in CPUE in both seasons over the second half of the time series (Fig. 4). Due to the majority of their populations being located south of Cape Hatteras (Packer et al. 2003b, a), it is likely the NEFSC bottom trawl survey only samples a portion of their range. Rosette skates have been caught in small numbers over the past decade on George's Bank (Fig. 6). Clearnose skate's abundance has increased in Southern New England during fall since the mid-1990s (Fig. 7). Clearnose and rosette skates were most abundant in the Mid-Atlantic Bight, the southernmost ecosystem, in both seasons and have increased steadily in both seasons since the mid-1980s (Fig. 8).

Habitat Preference

The latitude ranges of the seven species show three general groups with similar distributions. A northern group was comprised of thorny and smooth, with their occupied means around 42.3° N and their 90% ranges north of 41° N as well as their 95% latitudinal values beyond that of the survey (Fig. 9A, Table 3). A mid-latitude group was comprised of barndoor, little and winter skates with mean occupied values distributed very close to the mean of the survey ~41° N (Fig. 9A, Table 3). A southern group was comprised of clearnose and rosette skates, with 90% latitudinal ranges that span from 40° to south of 36°, their occupied ranges extend the farthest south beyond the 5% value of the survey (Fig. 9A, Table 3).

The northern species are also characterized by their small seasonal variation in occupied habitat (Fig. 9). Smooth and thorny skates occupy colder waters than the other five species in fall; in fact they are the only two species which occupy entire ranges below the mean of the survey and whose range includes temperatures colder than the 5% value of the survey (Fig 9B,

Table 3). Thorny skates occupied a slightly warmer range than smooth skates, which also coincides with a slightly shallower depth distribution and a less saline environment (Fig. 9, Table 3). In spring, smooth and thorny skates occupy very similar habitats in all four environmental variables, with thorny skates occupying slightly shallower, cooler water (Fig. 9B).

The mid-latitude group of skates shows more seasonal variation than the northern group, as well as much more variation within the occupying species themselves. Winter skates occupied the narrowest latitudinal range of the three species in both seasons (Fig. 9A). Barndoor skate's range extends the farthest north in both seasons, whereas little skate occupies the range that extends the farthest south (Fig. 9A, Table 3). Interestingly, all three mid-latitude species occupy a 90% range and mean latitude that extends farther south than they do in the fall, this may be due to the cooler temperatures in that season (Fig. 9A, Table 3). Little and winter skates occupy very similar habitat in the fall, however in spring winter skates occupy a deeper depth distribution in warmer and more saline water (Fig. 9, Table 3). This suggests a distribution closer to the shelf break where the influence of Gulf Stream water would be more apparent contrasting the colder well mixed spring conditions near the coast. Barndoor skates occupy deeper water than little and winter skates, especially in spring when the mean depth occupied is 332 meters, 24 meters deeper than the 95% survey depth value (Table 3). This results in barndoor skate occupying colder water in fall and warmer water in the spring when compared to little and winter skates.

The two southern species occupy drastically different 90% depth ranges in the fall; they are the only group not to overlap their depth ranges in a season (Fig. 9C, Table 3). Clearnose skates occupy the warmest temperature range in both seasons; this is due to their shallow distribution in fall and their migration south to warmer water in the spring (Fig. 9B, Table 3). During spring, clearnose skates occupy significantly deeper, more saline water (Fig. 9, Table 3).

Rosette skates also move to deeper water in spring, this is a distributional shift that exists for four of the seven species in the complex (Fig. 9A). This may be due to a universal cue such as increased food availability in the shallower waters during the fall.

Immature/Mature Habitat Analysis

There was more disparity between immature and mature groups during fall, perhaps due to increased variability in the fall available habitat ranges (Table 8 & 9). The abundances between immature and mature groups likely had an effect on their significance especially with species with low catch rates. Thorny and winter skates were the only species to exhibit significant differences between immature and mature groups in all four environmental variables (Table 8 & 9). This suggests that in larger bodied species' immature and mature groups may be more prone to occupy different habitat. The larger skates exhibit ontogenetic shifts in diet (Garrison and Link 2000b), likely requiring the mature group to seek different prey grounds. Mature barndoor skates occupied deeper water than immature, whereas the immature rosette skates occupy deeper water than mature in both seasons (Fig. 10 & 11). In spring, mature clearnose and winter skate occupied larger and deeper depth ranges than their immature groups (Fig. 10 & 11). In fall, they occupy narrower depth ranges that are shallower than the immature groups.

Regional Habitat Analysis

The Gulf of Maine is the most northerly ecosystem and is the deepest and coldest water sampled in both seasons (Table 10 & 11). The northern species, smooth and thorny, have the lowest D test statistics in the Gulf of Maine; the D values increase the farther south the occupied ecosystem (Table 10 & 11). While smooth and thorny skates are nearly ubiquitous within the

GOM they tend to occupy the more northern available latitudes and the deeper, cooler water in the other occupied ecosystems (Table 10 & 11). In the GOM, barndoor skates occupy a much narrower habitat range in spring compared to fall (Table 10 & 11).

Southern New England and George's Bank share the largest overlap in latitude range amongst the ecosystems, but SNE is shallowest ecosystem and experiences warmer water temperatures in fall and colder temperatures in spring than GB (Table 10 & 11). The mid-latitude species exhibit the lowest D test statistic values on GB and in SNE and their ranges shifted towards the lower latitudes in GOM and the higher latitudes in MAB (Table 10 & 11). Little and winter skates occupy the shallowest ranges on GB in both seasons (Table 10 & 11). SNE was the only ecosystem in which all seven skate species occupied in a season (Table 11).

The Mid-Atlantic Bight is the southernmost ecosystem that has the warmest temperature range and the second largest depth range. Clearnose occupied the warmest temperature range in both seasons, despite occupying significantly deeper water in the spring (Table 10 & 11). Rosette skates occupied similar temperature ranges in both seasons despite differences in depth ranges, suggesting that they are maintaining an ideal range in the ecosystem (Table 10 & 11).

Temporal Trends in Habitat Preference

Fish distributions have been shown to shift over time with changing climate, with southern species moving pole ward or towards deeper water (Perry et al. 2005, Dulvy et al. 2008, Nye et al. 2009). Species with narrow thermal niches and fast life history strategies are the fastest in shifting their occupied ranges, either pole ward or toward deeper water when faced with warming water conditions (Murawski 1993, Perry et al. 2005). Over the course of the time series the survey has shifted farther south in spring (Fig. 14). This may affect the ability of the survey to properly sample the northern species and lead to increased catches of the southern species as a result. Barndoor skates entire 90% occupied temperature range has increased over the time series, most significantly for the 95% values (Fig. 12). Rosette skates have shifted northward in their 50% and 95% values (Fig. 13).

The fall survey produced more significant temporal trends when compared to the spring survey. The fall survey, like the spring survey, has shifted southward over the course of the time series (Fig. 20A). The temperature range of the survey has increased (Fig. 20B) while the survey has concentrated more tows at shallower depths (Fig. 20C). The increased temperature range is also reflected in many of the occupied species ranges as well, suggesting an overall increase in temperature within the system (Figs. 15, 16B, 17, 18B, 19). Clearnose skate have been occupying increasingly more northern latitudes as well as deeper 5% values over time (Fig. 16A & 16C). Thorny skate has experienced a narrowing in latitudinal range with a decreasing in 95% values, while the 5% values have increased (Fig. 18A), Nye et al. (2009) reported a reduction in occupied area at -517.5 km^2 yr^{-1}. The mean occupied depth values have decreased by nearly 50 meters over the course of the time series (Fig. 18C).

Consistent with Nye et al. (2009), the most southerly species of skates appear to be making the fastest distributional changes, as clearnose and rosette skates are moving farther north (Figs. 8, 16A, 13). This is consistent with distributional shifts in a warming period in the NW Atlantic and will likely continue given projected warming in the next century (Rose 2005). My results are also consistent with Nye et al. (2009), in that little and winter skate are moving farther south in the spring (Fig. 8).

Measures of Aggregation

As barndoor skate CPUE increases the population becomes more aggregated but its relation on a domain level becomes less aggregated (Fig. 21). Clearnose skate have become less aggregated over time during fall on a domain level, but the population has become more aggregated (Fig. 22). As clearnose skate populations increase, their populations become more aggregated, but appear to reach an ideal population density and maintain a constant distribution (Fig. 22). This relationship occurs in all seven species, but is most apparent in species which have experienced very low abundance numbers at some point throughout the time series (Figs. 21, 22, 24, and 25). Species currently at higher abundances (little, thorny and winter) would likely exhibit a similar relationship if their numbers became depleted enough. The Gini index values seem to level out at a population density where the population starts to expand, evident by a reduction in the aggregation within the domain (Figs. 21, 22, 24, 25). Modeling this relationship may be able to predict an abundance level, below which they decline, as a management reference point for the ideal population density. Declining below this abundance level could result in reduced reproductive success as finding mates would become increasingly difficult.

Thorny skate is a unique case in that trends existed in each of the domain aggregation levels, but not within the population aggregations (Fig. 26). The population becomes more disperse within the domain while maintaining a similar population level of aggregation. As the population declines, thorny skates are not dispersing and any mortality pressure is more likely to affect a larger proportion of the population (Fig. 26).

Local Index of Collocation

The local index of collocation shows that the strongest interactions are between sympatric species pairs (Tables 26 & 27, Figs. 28, 29, 31, and 33). The declines in the trends between smooth and thorny skate are likely due to declining abundances in both species (Figs. 28 & 29). Similarly, the increasing trends seen in little and winter skates may be due to their increasing abundances over the time series. Barndoor skates were often caught in the same tows as a variety of species when they were present in the system, but mainly with species with habitat overlap (Fig. 9). Since they have returned to the system, barndoor skates are increasingly caught in the same tows as little and winter skate (Fig. 30). Clearnose skates have been increasingly caught in the same tows as little and winter skates in the fall in Southern New England (Fig. 32).

The LIC values show spatial interaction, but likely are a measure of possible species interactions as well. Increased interspecific competition from increasing species spatial interactions and range expansion could have an effect on the fitness of skate species. Since skate species are all benthic marine generalists, increased LIC values between skate species likely represent some competition for resources. The varying habitat preferences of skate species may help to reduce this inter-specific competition. A good example of this may be the sympatric species pairs, both of which include a larger and smaller bodied skate species. The reason they may be able to coexist in such a high percentage of stations is due to resource partitioning (McEachran et al. 1976). The ontogenetic diet shift in the larger bodied species may help to reduce competition between sympatric species pairs, by further dividing up the available resources.

Conclusion

The NW Atlantic skate complex is a group of seven skate species that have distinct and varying life history strategies and environmental preferences that, along with variations in historic fishing pressure and bycatch mortality, elicit different population responses to fishing and climate change. Each of the seven species possesses unique habitat preferences that influence their interactions with the other skate species and any likely commercial fishing industries. These preferences can vary by season and life-stage and evolve over time with changes to the environment. Population densities within these habitats may provide insight into how these species regulate their own abundances with relationships indicating range expansion after a certain population aggregation level. Unfortunately, it is unlikely that every species is being sampled efficiently enough to fully understand and manage these species properly. While the habitat they occupy will be a crucial tool for management, understanding how likely they are to shift their distributions to maintain these preferences will be an important key for predicting the future of these species.

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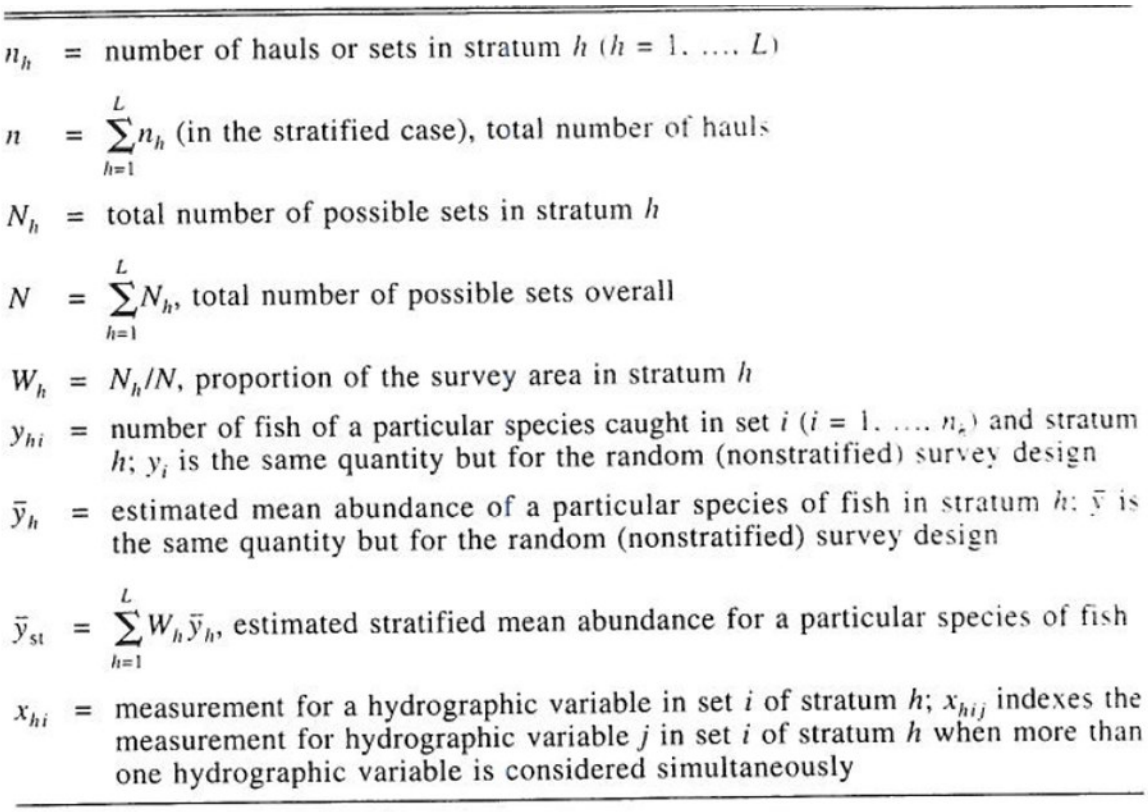
Species	Size at First Maturity (cm)	Age at 50% Maturity (years)	Maximum Est. Size (cm)	Maximum Est. Age (years)	References
Rosette skate	33	*N/A*	57	*N/A*	Sosebee (2005); Packer et al. (2003)
Little skate	40	8.6	62	12.5	Sosebee (2005); Frisk and Miller (2006); Cicia et al. (2009)
Smooth skate	45	9.5	71	14.5	Sosebee (2005); Natanson et al. (2007); Sulikowski et al. (2009)
Clearnose skate	59	*N/A*	94.5	6	Sosebee (2005); Gelsleichter (1998); Packer et al. (2003)
Thorny skate	47	10.95	104	19 (28)	Sosebee (2005); Sulikowski et al. (2005); McPhie and Campana (2009)
Winter skate	62	12.5	129.6	20.5	Sosebee (2005); Frisk and Miller (2006); Frisk and Miller (2009)
Barndoor skate	100	6.15	166.3	11 (15-25)	Sosebee (2005); Gedamke et al. (2005); Gedamke et al. (2009)

Table 1. Summary of life history characteristics of the seven skate species in the NW Atlantic from published data. N/A values lack published data and values in parentheses are extrapolated from archived specimens.



n_h = number of hauls or sets in stratum h ($h = 1, \ldots, L$)

n = $\sum_{h=1}^{L} n_h$ (in the stratified case), total number of hauls

N_h = total number of possible sets in stratum h

N = $\sum_{h=1}^{L} N_h$, total number of possible sets overall

W_h = N_h/N, proportion of the survey area in stratum h

y_{hi} = number of fish of a particular species caught in set i ($i = 1, \ldots, n_h$) and stratum h; y_i is the same quantity but for the random (nonstratified) survey design

$\bar{y}_h$ = estimated mean abundance of a particular species of fish in stratum h; $\bar{y}$ is the same quantity but for the random (nonstratified) survey design

$\bar{y}_{\mathrm{st}}$ = $\sum_{h=1}^{L} W_h \bar{y}_h$, estimated stratified mean abundance for a particular species of fish

x_{hi} = measurement for a hydrographic variable in set i of stratum h; x_{hij} indexes the measurement for hydrographic variable j in set i of stratum h when more than one hydrographic variable is considered simultaneously

Table 2. Definitions of quantities associated with trawl survey calculations (Perry and Smith 1994).

All Years	**Latitude**				**Temperature**				**Depth**				**Salinity**			
Spring	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*
BS	**0.3153**	40.08	40.48	42.45	0.2963	4.93	6.93	12.67	**0.5816**	84.98	332.74	349.24	**0.4745**	32.75	34.84	35.55
CS	**0.8145**	35.26	36.03	37.75	**0.4621**	6.57	12.22	17.02	**0.4244**	12.77	48.44	218.50	**0.2647**	29.38	34.00	35.54
LS	**0.2682**	38.54	40.67	41.59	**0.4083**	3.18	5.23	8.26	**0.6196**	15.22	49.41	103.73	**0.4155**	30.53	32.44	33.45
RS	**0.6418**	35.77	37.46	40.30	**0.6086**	8.71	11.32	13.74	0.2504	85.18	148.19	290.68	**0.6818**	33.85	35.24	35.62
SS	**0.6269**	41.40	42.48	44.23	**0.315**	4.29	6.62	8.64	0.3572	108.79	197.15	340.26	**0.3569**	32.54	33.69	35.01
TS	**0.5885**	41.23	42.44	44.08	**0.3029**	3.69	6.00	8.74	0.2073	74.18	179.94	334.28	**0.1516**	32.19	33.26	35.02
WS	**0.3507**	40.20	40.98	41.96	**0.4384**	3.18	5.02	9.99	**0.4895**	19.47	58.80	199.20	**0.2284**	31.25	32.77	35.19
Survey		36.09	40.67	43.56		3.94	7.09	14.47		29.99	141.97	308.71		31.29	33.07	35.42
Fall	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*
BS	**0.3335**	40.32	41.21	42.65	**0.343**	6.78	10.59	15.51	0.2996	50.71	90.88	232.65	**0.2079**	32.22	33.02	34.94
CS	**0.6353**	35.76	38.02	40.07	**0.5894**	15.33	20.43	23.87	**0.856**	11.63	20.52	54.29	**0.5865**	30.45	31.50	33.16
LS	**0.2489**	39.33	40.95	41.92	0.1727	8.87	13.93	19.55	**0.6006**	25.26	56.35	118.23	**0.3181**	31.28	32.54	33.83
RS	**0.6755**	35.86	37.24	39.72	**0.334**	8.27	12.75	16.84	0.2927	75.57	118.20	245.69	**0.4901**	32.93	35.25	35.83
SS	**0.5731**	41.33	42.37	44.16	**0.6852**	5.10	7.53	10.29	0.3632	107.22	198.94	338.87	**0.4808**	33.03	34.09	35.13
TS	**0.562**	41.27	42.34	44.12	**0.6178**	5.30	7.93	11.41	0.1989	77.81	170.32	314.37	**0.2682**	32.11	33.50	35.12
WS	**0.442**	40.74	41.36	42.10	**0.2538**	8.31	13.74	17.36	**0.5829**	27.38	59.58	119.52	**0.3734**	31.73	32.44	33.37
Survey		36.24	40.81	43.61		6.98	13.3	24		31.77	145.54	310.19		31.05	32.99	35.55

Table 3. The maximum difference D for each species' CDF compared to the available survey habitat for both seasons and all four environmental variables ($p \leq 0.05$ is bolded, ≤ 0.1 is underlined). The 5%, 50% and 95% values of the CDFs are given for each species and the survey for each variable and season. Barndoor (BS), clearnose (CS), little (LS), rosette (RS), smooth (SS), thorny (TS) and winter (WS).

Lat/Spring	BS	CS	LS	RS	SS	TS
CS	**0.9932**					
LS	**0.2433**	**0.9489**				
RS	**0.9137**	**0.5553**	**0.7885**			
SS	**0.7579**	**0.9951**	**0.89**	**0.9972**		
TS	**0.7407**	**0.9951**	**0.8521**	**0.9968**	**0.1041**	
WS	**0.4615**	**0.9788**	**0.3398**	**0.9151**	**0.7729**	**0.758**
Lat/Fall	BS	CS	LS	RS	SS	TS
CS	**0.946**					
LS	**0.255**	**0.8534**				
RS	**0.9672**	**0.2416**	**0.8889**			
SS	**0.5823**	**0.9833**	**0.7545**	**0.9872**		
TS	**0.5337**	**0.9853**	**0.7317**	**0.9905**	**0.0819**	
WS	**0.2516**	**0.9749**	**0.3694**	**0.9838**	**0.6485**	**0.6001**

Table 4. The maximum difference D for species comparisons of CDFs for latitude in both seasons for the entire geographic scope of the survey (p≤0.05 are bolded). Barndoor (BS), clearnose (CS), little (LS), rosette (RS), smooth (SS), thorny (TS) and winter (WS).

Temp/Spring	BS	CS	LS	RS	SS	TS
CS	**0.5584**					
LS	**0.6753**	**0.8028**				
RS	**0.7323**	**0.2345**	**0.9146**			
SS	**0.3767**	**0.6803**	**0.4004**	**0.9071**		
TS	**0.49**	**0.696**	**0.2038**	**0.9009**	**0.2177**	
WS	**0.698**	**0.8358**	0.0924	**0.9155**	**0.478**	**0.2703**
Temp/Fall	BS	CS	LS	RS	SS	TS
CS	**0.9086**					
LS	**0.4322**	**0.7471**				
RS	**0.4636**	**0.9134**	**0.2792**			
SS	**0.5138**	**0.9806**	**0.804**	**0.8091**		
TS	**0.4063**	**0.9767**	**0.7296**	**0.7616**	**0.1154**	
WS	**0.455**	**0.8182**	0.0752	**0.2627**	**0.7829**	**0.725**

Table 5. The maximum difference D for species comparisons of CDFs for temperature in both seasons for the entire geographic scope of the survey (p≤0.05 are bolded, p≤0.1 are underlined). Barndoor (BS), clearnose (CS), little (LS), rosette (RS), smooth (SS), thorny (TS) and winter (WS).

Depth/Spring	BS	CS	LS	RS	SS	TS
CS	**0.8479**					
LS	**0.8633**	**0.1631**				
RS	**0.3712**	**0.862**	**0.8993**			
SS	**0.3184**	**0.8943**	**0.9347**	**0.3859**		
TS	**0.3534**	**0.8186**	**0.8504**	**0.182**	**0.259**	
WS	**0.7784**	**0.3488**	**0.1933**	**0.8461**	**0.8892**	**0.7627**
Depth/Fall	BS	CS	LS	RS	SS	TS
CS	**0.9659**					
LS	**0.564**	**0.7354**				
RS	**0.4094**	**0.9707**	**0.8176**			
SS	**0.7035**	**0.9851**	**0.8981**	**0.6506**		
TS	**0.483**	**0.9787**	**0.8149**	**0.3624**	**0.2977**	
WS	**0.5025**	**0.7914**	0.0668	**0.7718**	**0.8886**	**0.7654**

Table 6. The maximum difference D for species comparisons of CDFs for depth in both seasons for the entire geographic scope of the survey ($p \leq 0.05$ are bolded). Barndoor (BS), clearnose (CS), little (LS), rosette (RS), smooth (SS), thorny (TS) and winter (WS).

Sal/Spring	BS	CS	LS	RS	SS	TS
CS	0.3206					
LS	**0.7948**	**0.5792**				
RS	0.4753	**0.5178**	**0.9432**			
SS	**0.4376**	0.2136	**0.7088**	**0.6704**		
TS	**0.5057**	**0.3239**	**0.5099**	**0.7635**	**0.314**	
WS	**0.6802**	**0.4675**	**0.2575**	**0.8471**	**0.5383**	**0.325**
Sal/Fall	BS	CS	LS	RS	SS	TS
CS	**0.7708**					
LS	**0.3448**	**0.5548**				
RS	**0.6088**	**0.912**	**0.7851**			
SS	**0.5287**	**0.9079**	**0.7779**	**0.5834**		
TS	**0.2456**	**0.7789**	**0.5133**	**0.5751**	**0.3182**	
WS	**0.4703**	**0.6302**	**0.1386**	**0.8442**	**0.8353**	**0.5903**

Table 7. The maximum difference D for species comparisons of CDFs for salinity in both seasons for the entire geographic scope of the survey (p≤0.05 are bolded). Barndoor (BS), clearnose (CS), little (LS), rosette (RS), smooth (SS), thorny (TS) and winter (WS).

Spring	Lat	Depth	Sal	Temp
Barndoor	0.1975	**0.4445**	0.3020	0.2629
Clearnose	0.0592	0.1572	0.1668	**0.2340**
Little	**0.0890**	0.0640	0.0336	0.0641
Rosette	0.1032	0.1700	0.2117	0.1911
Smooth	0.1116	0.1015	0.1828	0.1018
Thorny	**0.1145**	0.0397	0.1288	0.0780
Winter	**0.2289**	**0.2736**	**0.3809**	**0.2866**

Table 8. Spring maximum difference D for immature and mature group Analysis for all four environmental variables ($p \leq 0.05$ are bolded, $p \leq 0.1$ are underlined).

Fall	Lat	Depth	Sal	Temp
Barndoor	**0.2380**	0.0977	0.2279	0.1349
Clearnose	**0.3002**	0.0433	0.0844	**0.1233**
Little	**0.1555**	0.0664	0.1376	0.0729
Rosette	**0.2009**	0.0632	0.1295	0.1806
Smooth	0.0988	0.0833	0.1678	**0.1763**
Thorny	**0.1395**	**0.0773**	**0.1604**	**0.1418**
Winter	**0.2393**	**0.1050**	0.0987	0.0799

Table 9. Fall maximum difference D for immature and mature groups for all four environmental variables ($p \leq 0.05$ are bolded, $p \leq 0.1$ are underlined).

Spring	**Latitude**				**Temperature**				**Depth**				**Salinity**			
GOM	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*
Barndoor	0.4479	42.33	42.45	42.59	0.5696	6.6	6.92	8.35	**0.8222**	267.71	348.65	359.65	**0.8717**	34.64	34.89	35.14
Little	**0.6555**	41.76	41.97	43.59	**0.5224**	2.67	4.2	6.5	**0.7209**	21.64	45.32	182.77	**0.5774**	31.17	32.08	32.78
Smooth	**0.112**	41.52	42.46	44.19	0.1757	4.22	6.67	8.59	0.2173	122.06	211.13	348.67	**0.3442**	32.54	33.75	35.05
Thorny	0.0502	41.68	42.57	44.15	0.0391	3.62	6.13	8.63	0.0493	77.53	187.89	342.76	**0.0876**	31.85	32.95	34.99
Winter	**0.4946**	41.65	42.11	43.68	**0.3895**	2.93	4.35	7.26	0.3768	27.53	108.91	312.74	0.1711	31.68	32.78	34.9
Survey		41.77	42.56	44.09		3.47	6.17	8.59		67.05	188.28	334		31.51	33.1	34.95
GB	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*
Barndoor	0.3675	40.36	40.84	41.72	0.4928	4.57	6.71	13.28	**0.6058**	85.1	329.22	332.65	**0.6646**	32.77	34.25	35.36
Little	**0.1495**	40.61	41.3	41.91	0.1513	4.02	5.24	7.31	0.2371	37.46	65.2	107.43	**0.1747**	32.28	32.78	33.4
Rosette	**0.9732**	40.12	40.35	40.49	**0.9222**	10.91	11.05	13.19	0.738	102.24	147.31	210.16				
Smooth	**0.3364**	41.1	41.5	42.18	0.2288	4.31	5.39	8.69	**0.5456**	84.73	109.38	280.76	**0.4958**	32.57	33.66	34.92
Thorny	**0.3357**	41.03	41.79	42.14	0.1637	3.74	5.24	8.01	**0.3442**	72.67	98.59	251.76	**0.5437**	32.48	33.24	34.96
Winter	**0.1013**	40.62	41.42	42	0.1379	4.05	5.21	13.24	**0.264**	38.43	64.14	130.94	0.1261	32.26	32.96	35.35
Survey		40.53	41.38	42.07		4.03	5.53	11.28		42.19	82.45	212.11		32.23	32.88	34.71
SNE	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*
Barndoor	**0.4074**	40.02	40.44	40.87	**0.3542**	4.33	7.34	12.59	**0.5185**	54.9	78.04	146.21	**0.5269**	32.61	33.16	35.49
Little	**0.2012**	40.33	40.76	41.19	0.1645	2.96	5.02	7.57	0.2814	12.98	33.84	69.23	**0.2108**	30.68	32.33	33.22
Smooth	**0.6653**	40.01	41.07	41.91	0.2675	2.28	6.51	10.36	0.5025	51.93	55.9	310.26				
Thorny	0.288	40.47	40.83	41.71	**0.5446**	2.86	4.08	5.75	0.3926	41.2	59.71	78.11	0.413	32.17	32.83	32.99
Winter	**0.3381**	40.5	40.88	41.28	**0.2521**	2.88	4.54	6.48	**0.3416**	14.9	34.51	77.48	0.1384	30.92	32.55	33.32
Survey		39.92	40.7	41.28		3.24	5.21	11.32		18.58	51.69	116.15		31.16	32.55	34.07
MAB	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*
Barndoor	0.4218	38.37	39.07	39.24	0.398	5.56	8.36	10.53	**0.6619**	64.77	77.57	281.81				
Clearnose	**0.6401**	35.46	36.19	38.43	**0.5481**	6.56	12.45	16.44	0.0866	9.54	37.77	152.39	**0.3162**	28.5	33.78	35.37
Little	**0.2417**	37.97	39.06	39.95	**0.28**	3.63	5.78	8.37	0.3177	11.32	23.54	60.25	**0.271**	29.73	31.65	33.76
Rosette	**0.4489**	35.77	37.18	38.99	**0.6673**	7.34	11.13	13.67	**0.7084**	74.51	134.68	280.18	**0.7344**	33.56	34.84	35.6
Winter	**0.2918**	37.55	39.23	40.07	**0.3227**	3.35	5.33	7.87	**0.444**	11.54	20.04	51.04	**0.3387**	29.78	31.75	33.32
Survey		36.1	38.69	39.86		4.05	6.63	12.65		14.18	43.63	257.25		30.2	32.58	34.83

Table 10. The maximum difference D for each species' CDF compared to the available survey habitat for each of the four regional ecosystems in spring for all four environmental variables (p ≤ 0.05 is bolded, p≤0.1 is underlined). The 5%, 50% and 95% values of the CDFs are given for each species and the survey for each variable. Values highlighted in yellow are calculated from very low abundances and with too few data points to properly test the salinity preferences.

Fall	Latitude				Temperature				Depth				Salinity			
GOM	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*
Barndoor	**0.231**	41.28	42.41	44.02	0.216	5.9	7.4	10.78	0.171	89.52	178.12	348.75	0.231	32.43	33.98	35.14
Little	**0.669**	41.71	41.82	42.73	**0.555**	8.71	11.07	14.53	**0.723**	13.69	33.71	216.96	**0.717**	30.9	31.77	32.67
Smooth	**0.149**	41.43	42.38	44.2	**0.240**	5	7.23	9.84	0.148	129.73	200.15	340.12	**0.325**	33.13	33.99	35.09
Thorny	**0.057**	41.43	42.62	44.31	0.121	5.11	7.69	11.05	0.080	78.98	177.28	322.25	**0.177**	31.84	33.11	34.87
Winter	**0.523**	41.7	42.09	42.77	**0.469**	7.19	10.32	12.6	**0.635**	17.1	50.1	218.49	**0.670**	31.52	32.17	33.26
Survey		41.73	42.6	44.1		5.58	8.27	12.32		70.54	185.03	321.62		31.65	33.45	35.01
GB	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*
Barndoor	0.087	40.59	41.39	42.08	**0.290**	6.84	10.71	15.76	0.204	51.61	86.39	147.71	**0.254**	32.22	32.9	34.39
Little	**0.127**	40.71	41.3	42	0.134	8.94	13.88	16.42	**0.316**	38.1	62.01	101.72	**0.169**	31.85	32.49	33.75
Smooth	**0.274**	41.12	41.51	42.18	**0.699**	5.78	8.14	11.63	**0.412**	65.9	104.67	273.74	**0.490**	32.5	33.08	35.09
Thorny	**0.259**	41.12	41.67	42.14	**0.627**	5.79	8.12	12.22	**0.396**	71.68	98.89	229.25	**0.482**	32.53	33.29	35.05
Winter	**0.114**	40.88	41.54	42.07	0.141	8.13	13.99	16.54	**0.290**	34.71	61.64	100.25	**0.160**	31.9	32.48	33.4
Survey		40.63	41.44	42.08		7.28	13.19	16.39		41.02	79.66	201.72		31.97	32.6	34.74
SNE	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*
Barndoor	0.156	40.17	40.74	41.51	**0.429**	8.57	11.07	14.31	0.282	40.56	54.43	88.77	0.280	31.77	32.64	33.93
Clearnose	**0.310**	39.96	40.56	40.99	**0.696**	15.6	18.69	21.14	**0.594**	11.53	24.72	72.77	**0.560**	30.59	31.54	32.41
Little	**0.224**	40.28	40.94	41.28	0.148	10	14.5	19.4	0.257	21.86	44.58	68.73	0.088	31.29	32.51	33.44
Rosette	**0.868**	39.22	39.67	40.16	**0.581**	7.35	12.28	13.09	**0.784**	69.47	99.59	152.4	**0.910**	33.66	34.45	35.7
Smooth	**0.403**	40.6	41.01	41.94	0.424	7.83	11.75	15.79	0.170	33.88	52.07	75.39	0.320	31.91	32.06	33.94
Thorny	**0.575**	40.74	41.47	41.97	**0.425**	6.93	10.41	16.55	0.276	35.81	52.98	68.67	0.229	31.12	32.39	32.96
Winter	**0.385**	40.69	41.05	41.56	0.103	10.3	14.29	18.35	**0.351**	22.03	37.97	62.39	**0.257**	31.61	32.22	32.81
Survey		39.87	40.81	41.42		9.15	13.85	18.99		23.25	51	98.99		31.35	32.41	34.28
MAB	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*
Clearnose	0.076	36.19	38.45	39.94	**0.327**	15.45	20.36	23.57	**0.664**	11.87	20.38	42.19	**0.380**	30.51	31.48	32.82
Little	**0.374**	38.1	39.13	39.98	**0.310**	8.04	12.79	20.95	0.318	20.87	52.95	76.83	**0.216**	30.82	32.6	33.93
Rosette	**0.359**	35.93	37.44	39	**0.630**	7.81	12.75	14.86	**0.558**	69.58	103.15	166.25	**0.701**	32.97	35.23	35.83
Winter	**0.624**	38.89	39.38	39.92	0.325	8.28	13.18	20.68	0.431	19.25	38.3	73.68	0.286	30.25	32.45	33.03
Survey		36.08	38.62	39.81		8.82	18.63	23.75		16.33	60.42	200.89		30.47	32.28	35.42

Table 11. The maximum difference D for each species' CDF compared to the available survey habitat for each of the four regional ecosystems in fall for all four environmental variables ($p \leq 0.05$ is bolded, $p \leq 0.1$ is underlined). The 5%, 50% and 95% values of the CDFs are given for each species and the survey for each variable.

Lat	BS	LS	SS	TS
LS	**0.8925**			
SS	**0.3877**	**0.6621**		
TS	**0.4438**	**0.6975**	**0.1161**	
WS	**0.8163**	**0.4352**	**0.5168**	**0.5464**
Temp	BS	LS	SS	TS
LS	**0.9536**			
SS	**0.537**	**0.6755**		
TS	**0.6776**	**0.5033**	**0.2163**	
WS	**0.9113**	0.1322	**0.5675**	**0.4117**
Depth	BS	LS	SS	TS
LS	**0.9778**			
SS	**0.7086**	**0.9062**		
TS	**0.8344**	**0.8417**	**0.2072**	
WS	**0.9162**	0.27	**0.7412**	**0.6498**
Salinity	BS	LS	SS	TS
LS	**0.9913**			
SS	**0.6784**	**0.8579**		
TS	**0.8637**	**0.5596**	**0.4097**	
WS	**0.8895**	0.4515	**0.4351**	0.1857

Table 12. Spring GOM maximum difference D for comparisons between species' CDFs for all four environmental variables (p≤0.05 are bolded, p≤0.1 are underlined). Barndoor (BS), little (LS), smooth (SS), thorny (TS) and winter (WS).

Lat	BS	LS	SS	TS
LS	**0.5726**			
SS	**0.1977**	**0.5893**		
TS	**0.1979**	**0.6812**	**0.1802**	
WS	**0.4173**	**0.4827**	**0.4019**	**0.5563**
Temp	BS	LS	SS	TS
LS	**0.7942**			
SS	**0.2101**	**0.8222**		
TS	**0.1585**	**0.7025**	**0.1316**	
WS	**0.6702**	0.1987	**0.7038**	**0.5823**
Depth	BS	LS	SS	TS
LS	**0.9223**			
SS	**0.2932**	**0.9432**		
TS	**0.1303**	**0.8969**	**0.2663**	
WS	**0.8792**	0.3627	**0.8988**	**0.8282**
Salinity	BS	LS	SS	TS
LS	**0.768**			
SS	0.1549	**0.8671**		
TS	**0.2171**	**0.6811**	**0.3006**	
WS	**0.7194**	0.3185	**0.8078**	**0.6326**

Table 13. Fall GOM maximum difference D for comparisons between species' CDFs for all four environmental variables (p≤0.05 are bolded, p≤0.1 are underlined). Barndoor (BS), little (LS), smooth (SS), thorny (TS) and winter (WS).

Lat	BS	LS	RS	SS	TS
LS	**0.3989**				
RS	**0.9205**	**0.9826**			
SS	**0.5973**	**0.3945**	**0.9968**		
TS	**0.5825**	**0.4806**	**0.9965**	**0.255**	
WS	**0.4406**	**0.1426**	**0.9728**	**0.2882**	**0.4158**
Temp	BS	LS	RS	SS	TS
LS	**0.5824**				
RS	**0.8839**	**0.9532**			
SS	0.5274	**0.3878**	**0.9538**		
TS	**0.5773**	0.1082	**0.957**	**0.3838**	
WS	**0.5921**	0.0514	**0.9352**	**0.3877**	0.1228
Depth	BS	LS	RS	SS	TS
LS	**0.744**				
RS	0.4537	**0.9455**			
SS	0.348	**0.7758**	**0.6191**		
TS	**0.51**	**0.6765**	**0.7795**	**0.4296**	
WS	**0.7716**	0.0431	**0.9385**	**0.7875**	**0.7122**
Salinity	BS	LS	RS	SS	TS
LS	**0.7781**				
RS	0.7607	**0.978**			
SS	0.4449	**0.5959**	**0.8891**		
TS	**0.5846**	**0.638**	**0.908**	0.3782	
WS	**0.5616**	**0.2656**	**0.8404**	**0.3855**	**0.4098**

Table 14. Spring GB maximum difference D for comparisons between species' CDFs for all environmental variables ($p \leq 0.05$ are bolded, $p \leq 0.1$ are underlined). Barndoor (BS), little (LS), rosette (RS), smooth (SS), thorny (TS) and winter (WS).

Lat	BS	LS	SS	TS
LS	**0.122**			
SS	**0.339**	**0.3641**		
TS	**0.327**	**0.3553**	0.1522	
WS	**0.1951**	**0.2125**	**0.1919**	**0.234**
Temp	BS	LS	SS	TS
LS	**0.4325**			
SS	**0.5065**	**0.7817**		
TS	**0.416**	**0.7403**	0.1124	
WS	**0.4242**	0.0425	**0.7554**	**0.7089**
Depth	BS	LS	SS	TS
LS	**0.5164**			
SS	**0.4128**	**0.6999**		
TS	**0.3997**	**0.7387**	0.0913	
WS	**0.5113**	**0.0866**	**0.6787**	**0.7236**
Salinity	BS	LS	SS	TS
LS	**0.363**			
SS	0.2611	**0.5899**		
TS	0.2923	**0.5653**	0.1608	
WS	**0.3826**	0.0561	**0.6083**	**0.5807**

Table 15. Fall GB maximum difference D for comparisons between species' CDFs for all four environmental variables ($p \leq 0.05$ are bolded, $p \leq 0.1$ are underlined). Barndoor (BS), little (LS), smooth (SS), thorny (TS) and winter (WS).

Lat	BS	LS	SS	TS
LS	**0.5744**			
SS	**0.8267**	**0.7411**		
TS	**0.6555**	**0.2957**	0.4605	
WS	**0.7232**	**0.2448**	**0.6266**	**0.3737**
Temp	BS	LS	SS	TS
LS	**0.361**			
SS	**0.5912**	**0.3232**		
TS	**0.7384**	**0.4839**	0.4827	
WS	**0.4915**	**0.2224**	**0.3034**	**0.275**
Depth	BS	LS	SS	TS
LS	**0.8485**			
SS	**0.6874**	**0.8947**		
TS	**0.5839**	**0.7343**	0.4749	
WS	**0.866**	0.1087	**0.9204**	**0.7597**
Salinity	BS	LS	SS	TS
LS	**0.657**			
SS	0.3799	**0.7512**		
TS	0.5597	**0.5864**	0.5443	
WS	**0.5246**	0.1792	**0.619**	**0.465**

Table 16. Spring SNE maximum difference D for comparisons between species' CDFs for all four environmental variables ($p \leq 0.05$ are bolded, $p \leq 0.1$ are underlined). Barndoor (BS), little (LS), smooth (SS), thorny (TS) and winter (WS).

Lat	BS	CS	LS	RS	SS	TS
CS	**0.3268**					
LS	**0.3497**	**0.4461**				
RS	**0.9408**	**0.8791**	**0.9536**			
SS	**0.5526**	**0.5605**	**0.3372**	**0.995**		
TS	**0.6529**	**0.8479**	**0.6329**	**0.9999**	0.366	
WS	**0.5337**	**0.6168**	**0.263**	**0.9951**	0.2402	**0.486**
Temp	BS	CS	LS	RS	SS	TS
CS	**0.9093**					
LS	**0.4962**	**0.7008**				
RS	**0.5004**	**0.9344**	**0.636**			
SS	0.2783	**0.886**	**0.5382**	0.2954		
TS	**0.3651**	**0.865**	**0.5705**	**0.6111**	0.4014	
WS	**0.4854**	**0.7585**	0.0791	**0.5954**	**0.4803**	**0.5977**
Depth	BS	CS	LS	RS	SS	TS
CS	**0.8866**					
LS	**0.5017**	**0.5751**				
RS	**0.8468**	**0.94**	**0.939**			
SS	0.3293	**0.895**	**0.3478**	**0.9085**		
TS	0.2521	**0.835**	**0.5176**	**0.9133**	0.3536	
WS	**0.6628**	**0.5761**	**0.2068**	**0.9698**	**0.4618**	**0.6302**
Salinity	BS	CS	LS	RS	SS	TS
CS	**0.6896**					
LS	0.1806	**0.5581**				
RS	**0.9131**	**0.9976**	**0.9718**			
SS	0.4207	**0.7349**	**0.3427**	**0.8843**		
TS	0.3138	0.5183	0.1633	**1**	0.3503	
WS	**0.4456**	**0.5131**	**0.3229**	**0.9929**	0.3436	0.3201

Table 17. Fall SNE maximum difference D for comparisons between species' CDFs for all four environmental variables (p≤0.05 are bolded, p≤0.1 are underlined). Barndoor (BS), clearnose (CS), little (LS), rosette (RS), smooth (SS), thorny (TS) and winter (WS).

Lat	BS	CS	LS	RS
CS	**0.9266**			
LS	**0.3877**	**0.8303**		
RS	**0.7707**	**0.402**	**0.6702**	
WS	**0.4986**	**0.8015**	0.1504	**0.6387**
Temp	BS	CS	LS	RS
CS	**0.5077**			
LS	**0.6529**	**0.73**		
RS	**0.5647**	0.227	**0.8594**	
WS	**0.7055**	**0.7788**	**0.1706**	**0.8742**
Depth	BS	CS	LS	RS
CS	**0.9208**			
LS	**0.9873**	**0.196**		
RS	**0.7335**	**0.8704**	**0.9419**	
WS	**0.9932**	**0.2236**	0.1002	**0.966**
Salinity	BS	CS	LS	RS
CS	0.3762			
LS	**0.8378**	**0.4804**		
RS	**0.6573**	**0.4984**	**0.8868**	
WS	**0.9021**	**0.5395**	0.0754	**0.9429**

Table 18. Spring MAB maximum difference D for comparisons between species' CDFs for all four environmental variables ($p \leq 0.05$ are bolded, $p \leq 0.1$ are underlined). Barndoor (BS), clearnose (CS), little (LS), rosette (RS) and winter (WS).

Lat	CS	LS	RS
LS	**0.4496**		
RS	**0.2936**	**0.7276**	
WS	**0.6735**	**0.378**	**0.8845**
Temp	CS	LS	RS
LS	**0.7145**		
RS	**0.9292**	**0.2583**	
WS	**0.7033**	**0.2976**	**0.2633**
Depth	CS	LS	RS
LS	**0.7048**		
RS	**0.9762**	**0.8608**	
WS	**0.7107**	**0.386**	**0.9259**
Salinity	CS	LS	RS
LS	**0.5753**		
RS	**0.9348**	**0.7344**	
WS	**0.488**	**0.4349**	**0.8934**

Table 19. Fall MAB maximum difference D for comparisons between species' CDFs for all four environmental variables (p≤0.05 are bolded). Clearnose (CS), little (LS), rosette (RS) and winter (WS).

Spring	Latitude				Temperature				Depth			
BS	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*
68-74	0.2847	40.44	40.86	42.66	0.3256	3.31	5.14	7.35	0.2574	51.19	81.86	322.32
75-81	**0.7418**	41.26	41.49	42.86	0.1887	4.08	5.28	8.15	0.5666	90.2	133.83	195.4
82-88	0.2641	40.47	41	41.52	0.5334	5.03	6.92	8.17	0.5538	69.3	105.2	136.98
89-95	0.2219	40.21	40.92	41.49	0.2895	4.35	5.61	11.66	0.5045	48.56	98.76	258.83
96-02	**0.3405**	40.26	40.68	41.84	0.301	5.01	7.06	11.67	**0.4868**	63.71	98.33	321.93
03-10	0.225	40.1	40.47	42.44	**0.5044**	4.87	6.79	12.97	**0.6405**	87.93	333.5	350.68
CS	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*
68-74	**0.9285**	35.42	35.95	38.45	**0.8447**	10.69	14.63	17.47	**0.8168**	8.18	17.59	197.32
75-81	**0.9388**	35.13	35.75	37.18	**0.638**	5.67	8.89	13.38	0.3541	21.04	50.32	329.51
82-88	**0.9318**	34.53	36.11	38.24	**0.6676**	5.69	11.36	16.05	0.1902	17.71	83.9	201.98
89-95	**0.9226**	35.44	35.84	38.28	**0.7313**	6.25	13.71	14.48	**0.6178**	14.32	19.03	116.85
96-02	**0.8466**	35.36	36.7	38.36	**0.5794**	6.07	8.85	19.22	0.3769	11.75	33.8	163.91
03-10	**0.9119**	35.55	36.22	37.53	**0.556**	5.98	10.51	13.53	0.328	24.4	50.98	190.89
LS	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*
68-74	**0.3191**	39.11	40.84	41.75	0.1499	2.82	5.82	11.07	**0.5323**	22.95	51.8	107.76
75-81	**0.2167**	39.17	40.8	41.37	**0.2988**	3.56	4.94	8.03	**0.3938**	15.18	45.41	98.64
82-88	**0.2157**	39.31	40.78	41.6	0.2777	3.53	4.62	6.44	**0.4265**	15.3	30.23	92.93
89-95	**0.2053**	39.06	40.87	41.47	0.2337	2.16	4.7	6.54	**0.3802**	14.77	39.94	88.33
96-02	**0.2193**	38.66	40.67	41.21	0.2436	3.99	5.32	6.95	**0.4418**	11.22	26.59	75.96
03-10	**0.2081**	38.98	40.66	41.39	**0.3252**	3.18	4.83	7.12	**0.5196**	16.24	50.21	90.54
RS	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*
68-74	**0.9246**	35.77	37.17	38.9	**0.7488**	7.97	9.99	12.27	0.2846	76.83	123.51	281.66
75-81	**0.9222**	35.75	36.87	37.9	**0.8797**	8.93	10.71	12.22	0.5385	89.92	220.15	331.08
82-88	**0.8722**	33.03	36.53	39.34	**0.8705**	9.01	11.38	16.71	0.5181	62.75	143.09	323.27
89-95	**0.8794**	36.41	37.15	38.65	**0.9016**	10.25	13.41	13.75	**0.7228**	87.07	161.25	186.77
96-02	**0.604**	35.92	38.89	40.47	**0.8534**	9.02	11.73	13.88	**0.6602**	76.68	223.14	258.34
03-10	**0.708**	36.02	38.33	40.27	**0.6947**	7.03	11.08	13.26	0.4625	85.96	128.1	277.34
SS	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*
68-74	**0.55**	41.4	42.31	44.22	0.2119	4.19	6.45	8.71	**0.4503**	99.95	198.66	337.49
75-81	**0.7256**	41.42	42.47	44.12	**0.2373**	3.9	6.52	8.7	**0.5435**	82.85	196.77	341.87
82-88	**0.7741**	41.44	42.51	44.31	0.3354	4.28	6.61	8.24	**0.6694**	100.17	198.16	336.5
89-95	**0.7395**	41.31	41.46	43.84	**0.4832**	5.17	5.34	7.69	**0.7998**	109.79	109.79	293.14
96-02	**0.7935**	41.35	43.9	44.4	0.1966	4.6	5.98	7.98	**0.7411**	100.84	159.11	318.65
03-10	**0.7414**	41.33	42.44	44.34	0.2964	4.53	6.68	8.48	**0.6414**	128.61	300.33	357.01
TS	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*
68-74	**0.4939**	41.1	42.17	44.28	0.1838	3.47	6.14	8.67	0.2984	75.49	186.98	328.67
75-81	**0.6772**	41.2	42.22	43.96	0.0933	3.76	5.33	8.29	0.3795	71.5	155.05	337.73
82-88	**0.7032**	41.32	42.44	44.19	0.1109	3.8	5.55	8.51	**0.485**	63.31	167.54	340.01
89-95	**0.5795**	40.56	41.67	43.99	0.2257	3.54	5	7.71	**0.4794**	58.64	108.88	220.36
96-02	**0.7903**	41.41	41.94	44.2	0.2866	3.59	5.26	8.1	**0.593**	76.85	101.41	247.44
03-10	**0.604**	40.42	42.03	44.12	0.1584	3.6	6.13	8.73	**0.4433**	70.43	191.8	367.68
WS	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*
68-74	**0.2456**	40.5	41.01	42.02	**0.3779**	2.57	4.58	8.2	**0.5551**	31.05	54.84	97.18
75-81	**0.3803**	40.68	40.87	41.75	0.3884	4.09	5.07	6.26	0.4789	15.63	37.53	82.12
82-88	**0.256**	40.54	40.95	41.65	**0.3328**	3.28	4.27	6.1	**0.4695**	16.26	30.45	72.34
89-95	**0.3233**	40.54	41.07	41.84	**0.2774**	2.54	4.51	6.25	0.2805	17.71	49.23	94.15
96-02	**0.3404**	39.65	40.85	41.73	0.2565	3.45	5.2	7.46	0.278	12.99	49.54	93.64
03-10	**0.2479**	40.15	40.76	41.93	0.1112	3.43	5.44	13.42	0.1227	31.55	79.12	332.81
Survey	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*
68-74		38.27	41.09	43.49		3.38	6.27	12.26		36.49	109.06	295.25
75-81		38.19	40.85	42.84		3.79	5.47	10.71		21.2	82.47	266.76
82-88		38.24	40.9	42.63		3.58	5.3	10.54		19.7	65.08	249.59
89-95		38.13	40.91	42.25		3.02	5.23	10.75		18.34	64.09	204.12
96-02		37.33	40.62	42.14		4.03	5.92	11.44		17.27	64.99	216.58
03-10		37.46	40.69	42.5		3.53	5.71	12.52		25.41	88.49	322.24

Table 20. Spring maximum difference D for each species' CDF compared to the available survey habitat for each time period for the three applicable environmental variables (salinity excluded) ($p \leq 0.05$ is bolded, $p \leq 0.1$ is underlined). The 5%, 50% and 95% values of the CDFs are given for each species and the survey for each variable. Barndoor (BS), clearnose (CS), little (LS), rosette (RS), smooth (SS), thorny (TS) and winter (WS).

Fall	**Latitude**				**Temperature**				**Depth**			
BS	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*
63-67	**0.3419**	40.31	40.78	42.31	0.1681	6.5	9.96	13.91	0.3436	44.66	81.73	182.93
68-74	0.2624	40.67	41.48	42.69	0.3271	6.27	10.41	14.42	0.2449	63.96	99.83	202.46
75-81	0.5405	41.32	41.67	42.22	**0.7332**	7.86	8.92	11.01	0.5025	91.67	107.58	182.66
82-88	0.2981	40.48	41.29	41.96	0.5844	7.33	10.55	12.59	0.363	62.84	92.08	129.94
89-95	0.3822	40.8	41.44	42.17	0.2927	7.91	13.55	16.08	0.2587	55.35	93	182.38
96-02	*0.2619*	40.71	41.52	42.15	0.2578	6.94	12.12	16.49	0.2937	49.53	85.28	122.87
03-10	**0.2237**	40.58	41.3	42.08	**0.369**	7.66	11.24	15.55	0.1991	48.56	85.03	169.66
CS	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*
63-67	**0.9995**	36.43	36.66	37.3	**0.9999**	17.03	17.62	17.78	**0.9937**	2.14	21.08	32.84
68-74	**0.8881**	34.42	36.89	39.48	**0.7557**	14.76	19.73	22.13	**0.9092**	8.92	18.67	40.3
75-81	**0.9224**	35.91	38.25	39.56	**0.8504**	16.39	19.33	22.39	**0.7117**	10.92	19.8	68.41
82-88	**0.9152**	36.2	38.23	39.75	**0.8435**	15.47	19.65	22.82	**0.8433**	11.81	19.88	61.82
89-95	**0.8065**	36.44	38.86	40.31	**0.6982**	15.3	19.9	23.66	**0.8909**	11.26	17.91	28.97
96-02	**0.7355**	36.14	38.97	40.43	**0.6889**	16.2	20.62	23.99	**0.8496**	12.26	21.33	34.19
03-10	**0.6951**	36.74	38.94	40.91	**0.7166**	16.07	20.31	23.53	**0.8376**	14.07	21.59	37.96
LS	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*
63-67	**0.3435**	40.57	41.1	41.78	**0.3354**	7.95	11.1	14.48	**0.5847**	32.76	50.93	104.63
68-74	**0.2669**	40.39	41.01	42.01	0.2306	9.28	13.99	16.47	**0.5207**	37.77	54.28	110.18
75-81	**0.2001**	40.62	41.15	41.91	0.1727	9.03	13.74	16.3	**0.4429**	18.98	57.7	96.26
82-88	0.1727	40.58	41.12	41.89	0.2296	9.62	14.27	16.21	**0.4253**	23.92	49.64	91.75
89-95	**0.2587**	40.3	41.04	41.89	0.2675	10.96	15.32	19.61	**0.4382**	22.83	49.87	94.19
96-02	0.1154	39.31	41.06	42.05	0.1234	8.71	14.63	18.18	0.3082	26.83	54.02	105.4
03-10	**0.2275**	39.9	40.95	41.77	0.1524	9.77	15.26	19.7	**0.4211**	21.83	48.74	89.46
RS	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*
63-67	**0.5856**	35.97	40.04	43.72	0.2463	5.58	11.22	13.06	0.4186	100.72	131.06	196.32
68-74	**0.9146**	32.59	35.99	39.45	0.2177	7.29	12.12	17.16	0.3633	63.94	170.1	273.73
75-81	**0.9379**	35.94	36.83	38.97	0.3219	10.05	12.76	14.67	0.3839	77.23	122.8	208.52
82-88	**0.9312**	36.31	38.12	39.73	0.2754	8.2	12.49	20.49	0.4105	69.3	116.2	251.87
89-95	**0.895**	36.58	38.45	39.08	**0.6066**	7.83	12.16	14.25	0.3421	55.34	115.78	158.75
96-02	**0.9117**	35.9	37.44	38.66	0.4018	7.49	14.11	14.91	0.4583	68.29	101.47	152.83
03-10	**0.8225**	35.89	37.74	39.98	**0.4579**	7.35	12.65	14.27	**0.4623**	78.36	103.35	167.6
SS	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*
63-67	**0.4447**	41.25	42.04	44.05	**0.6024**	4.62	6.3	9.11	0.3823	74.91	186.05	339.3
68-74	**0.4381**	41.22	42.35	44.33	**0.6364**	4.97	7.73	10.64	0.36	83.9	179.28	299.62
75-81	**0.4448**	40.94	42.13	44.26	**0.6916**	5.62	8.25	11.69	**0.4513**	83.63	190.59	381.02
82-88	**0.5516**	41.39	42.3	43.94	**0.77**	5.81	7.24	10.53	**0.6173**	93.5	197.75	340.45
89-95	**0.5509**	41.26	41.92	44.21	**0.7785**	5.42	6.5	10.58	**0.598**	97.74	186	294.03
96-02	**0.5857**	41.07	42.17	43.89	**0.751**	6.33	7.71	11.7	**0.6525**	76.05	176.78	313.59
03-10	**0.6211**	41.35	42.4	44.22	**0.7615**	5.15	8.05	10.95	**0.6634**	102.54	200.78	349.99
TS	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*
63-67	**0.3796**	41.14	41.92	43.81	**0.5606**	4.25	6.58	9.08	0.2846	77.57	154.88	271.01
68-74	**0.4092**	41.19	42.16	44.32	**0.5727**	5.75	8.34	11.25	0.2502	76.48	162.88	275.51
75-81	**0.4301**	41.14	41.92	44.19	**0.6143**	5.75	8.59	13.41	**0.3573**	77.74	139.12	330.12
82-88	**0.536**	41.34	42.07	44.13	**0.6732**	5.82	7.95	12.77	**0.4689**	72.51	116.65	323.88
89-95	**0.5375**	41.29	41.97	43.94	**0.6673**	5.69	7.35	14.48	0.3591	64.43	108	221.69
96-02	**0.5521**	41.21	42.06	43.29	**0.6952**	6.57	8.98	12.34	0.3908	49.26	96.19	224.24
03-10	**0.6189**	41.34	41.64	43.24	**0.7872**	5.41	9.33	10.24	**0.5369**	71.67	109.3	261.79
WS	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*
63-67	**0.3444**	40.63	41.08	41.84	**0.3274**	7.02	11.06	14.44	**0.5267**	27.46	52.17	99.07
68-74	**0.2279**	40.7	41.46	42.11	0.1982	8.22	13.68	15.47	**0.5451**	41.28	61.22	97.31
75-81	**0.2011**	40.81	41.39	41.99	0.2064	10.31	13.63	15.56	**0.5046**	25.85	53.51	91.41
82-88	**0.2311**	40.89	41.47	42.06	0.2748	8.54	14.19	16.18	0.375	25.57	49.34	92.65
89-95	**0.2667**	40.82	41.19	42.05	0.1418	9.37	14.78	18.08	0.3675	24.23	60.65	99.82
96-02	**0.3313**	40.84	41.43	42.07	0.1837	8.64	14.44	17.15	0.2716	25.74	50.33	106.25
03-10	**0.2966**	40.73	41.25	42.03	0.1701	9.49	14.51	18.36	0.3293	23.6	53.34	96.62
Survey	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*	*D*	*5%*	*50%*	*95%*
63-67		40.21	41.36	43.41		5.19	9.52	13.65		40.89	125.55	262.25
68-74		38.75	41.37	43.58		6.86	12.67	19.41		40.13	111.51	276.88
75-81		39.15	41.28	43.26		7.43	13	17.87		33.5	91.66	259.37
82-88		39.25	41.23	42.94		7.43	13.29	18.79		28.78	79.03	250.13
89-95		38.55	41.13	43.13		7.55	14.27	20.93		26.2	81.92	242.76
96-02		38.21	41.09	42.44		7.93	14.4	21.78		26.03	71.78	230.12
03-10		38.24	41.05	42.55		7.87	14.2	21.2		26.32	77.7	249.76

Table 21. Fall maximum difference D for each species' CDF compared to the available survey habitat for each time period for all applicable environmental variables (salinity excluded) (p≤ 0.05 is bolded, p≤0.1 is underlined). The 5%, 50% and 95% values of the CDFs are given for each species and the survey for each variable. Barndoor (BS), clearnose (CS), little (LS), rosette (RS), smooth (SS), thorny (TS) and winter (WS).

GOM	Spring	Fall
Barndoor	0.9958	0.984
Little	0.9693	0.9772
Smooth	0.8586	0.8587
Thorny	0.7414	0.713
Winter	0.9718	0.9795
Population	Spring	Fall
Barndoor	0.6936	0.4213
Little	0.7851	0.7563
Smooth	0.5177	0.4471
Thorny	0.4763	0.4622
Winter	0.6804	0.6636

Table 22. Seasonal Gini index values within the region and population for each occupying species in the Gulf of Maine.

GB	Spring	Fall
Barndoor	0.9818	0.9296
Little	0.8168	0.7626
Rosette	0.9992	0.9978
Smooth	0.9779	0.9621
Thorny	0.9325	0.9154
Winter	0.8243	0.7743

Population	Spring	Fall
Barndoor	0.7459	0.4694
Little	0.7109	0.6316
Rosette	0.6443	0.4146
Smooth	0.541	0.4369
Thorny	0.5704	0.5914
Winter	0.6783	0.6101

Table 23. Seasonal Gini index values within the region and population for each occupying species on George’s Bank.

SNE	Spring	Fall
Barndoor	0.9775	0.9794
Clearnose	0.9991	0.9854
Little	0.8595	0.8579
Rosette	0.9962	0.9909
Smooth	0.9975	0.9957
Thorny	0.9939	0.9937
Winter	0.9105	0.9282
Population	**Spring**	**Fall**
Barndoor	0.5073	0.4443
Clearnose	0.2025	0.3996
Little	0.7962	0.7472
Rosette	0.24	0.2609
Smooth	0.1374	0.2537
Thorny	0.6033	0.4246
Winter	0.7665	0.7067

Table 24. Seasonal Gini index values within the region and population for each occupying species in Southern New England.

MAB	Spring	Fall
Barndoor	0.9977	0.9998
Clearnose	0.94	0.8597
Little	0.8709	0.9404
Rosette	0.9747	0.9624
Winter	0.9311	0.994
Population	**Spring**	**Fall**
Barndoor	0.2918	0
Clearnose	0.6545	0.4947
Little	0.7363	0.681
Rosette	0.5343	0.4493
Winter	0.6064	0.3441

Table 25. Seasonal Gini index values within the region and population for each occupying species in the Mid-Atlantic Bight.

Species Comparison Fall LIC																					
Year	**BS & CS**	**BS & LS**	**BS & RS**	**BS & SS**	**BS & TS**	**BS & WS**	**CS & LS**	**CS & RS**	**CS & SS**	**CS & TS**	**CS & WS**	**LS & RS**	**LS & SS**	**LS & TS**	**LS & WS**	**RS & SS**	**RS & TS**	**RS & WS**	**SS & TS**	**SS & WS**	**TS & WS**
1963	N/A	0.298	0.027	0.165	0.232	0.140	N/A	N/A	N/A	N/A	N/A	0.000	0.016	0.074	0.615	0.000	0.000	0.000	0.408	0.012	0.038
1964	N/A	0.251	0.025	0.073	0.201	0.168	N/A	N/A	N/A	N/A	N/A	0.004	0.053	0.072	0.569	0.000	0.026	0.006	0.511	0.309	0.306
1965	N/A	0.269	0.090	0.025	0.065	0.172	N/A	N/A	N/A	N/A	N/A	0.002	0.016	0.043	0.648	0.000	0.000	0.000	0.166	0.024	0.101
1966	N/A	0.180	0.000	0.013	0.019	0.113	N/A	N/A	N/A	N/A	N/A	0.000	0.024	0.036	0.453	0.000	0.000	0.000	0.524	0.002	0.009
1967	0.000	0.013	0.000	0.050	0.122	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.059	0.010	0.371	0.000	0.000	0.000	0.585	0.036	0.141
1968	0.000	0.206	0.000	0.000	0.040	0.112	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.011	0.566	0.000	0.000	0.011	0.415	0.000	0.013
1969	0.000	0.373	0.000	0.043	0.236	0.138	0.007	0.000	0.000	0.000	0.000	0.000	0.002	0.175	0.552	0.000	0.000	0.000	0.410	0.011	0.070
1970	0.000	0.028	0.000	0.000	0.041	0.019	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.061	0.413	0.000	0.000	0.000	0.275	0.003	0.047
1971	0.000	0.002	0.000	0.008	0.034	0.027	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.008	0.084	0.000	0.000	0.000	0.396	0.010	0.067
1972	0.000	0.006	0.000	0.000	0.150	0.068	0.004	0.000	0.000	0.000	0.000	0.000	0.017	0.032	0.350	0.000	0.000	0.000	0.333	0.053	0.061
1973	0.000	0.208	0.000	0.000	0.007	0.239	0.008	0.000	0.000	0.000	0.000	0.001	0.000	0.004	0.650	0.000	0.000	0.000	0.607	0.022	0.026
1974	N/A	N/A	N/A	N/A	N/A	N/A	0.001	0.000	0.000	0.000	0.000	0.000	0.012	0.075	0.659	0.000	0.000	0.000	0.452	0.085	0.108
1975	0.000	0.072	0.000	0.000	0.080	0.170	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.070	0.409	0.000	0.000	0.000	0.368	0.023	0.084
1976	0.000	0.003	0.000	0.000	0.283	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.023	0.097	0.000	0.000	0.000	0.234	0.000	0.010
1977	N/A	N/A	N/A	N/A	N/A	N/A	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.039	0.536	0.000	0.000	0.000	0.580	0.007	0.061
1978	N/A	N/A	N/A	N/A	N/A	N/A	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.018	0.370	0.000	0.000	0.000	0.371	0.007	0.014
1979	0.000	0.009	0.000	0.687	0.784	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.028	0.479	0.000	0.000	0.000	0.714	0.007	0.023
1980	N/A	N/A	N/A	N/A	N/A	N/A	0.002	0.000	0.000	0.000	0.000	0.003	0.009	0.007	0.640	0.000	0.000	0.001	0.501	0.002	0.015
1981	N/A	N/A	N/A	N/A	N/A	N/A	0.001	0.000	0.000	0.000	0.000	0.000	0.026	0.026	0.395	0.000	0.000	0.000	0.495	0.010	0.004
1982	N/A	N/A	N/A	N/A	N/A	N/A	0.003	0.000	0.000	0.000	0.000	0.000	0.006	0.004	0.771	0.000	0.000	0.000	0.112	0.001	0.001
1983	N/A	N/A	N/A	N/A	N/A	N/A	0.003	0.000	0.000	0.000	0.000	0.000	0.069	0.045	0.203	0.000	0.000	0.000	0.325	0.003	0.003
1984	0.000	0.017	0.000	0.000	0.042	0.013	0.013	0.000	0.000	0.000	0.000	0.001	0.005	0.012	0.622	0.000	0.000	0.000	0.367	0.006	0.006
1985	0.000	0.053	0.000	0.000	0.069	0.020	0.001	0.000	0.000	0.000	0.000	0.002	0.001	0.018	0.430	0.000	0.000	0.000	0.316	0.005	0.027
1986	0.000	0.079	0.000	0.000	0.035	0.012	0.000	0.022	0.000	0.000	0.000	0.002	0.004	0.034	0.256	0.000	0.000	0.000	0.476	0.002	0.005
1987	0.000	0.033	0.000	0.000	0.270	0.141	0.000	0.000	0.000	0.000	0.000	0.001	0.026	0.010	0.238	0.000	0.000	0.000	0.158	0.016	0.017
1988	0.000	0.037	0.000	0.044	0.000	0.020	0.000	0.000	0.000	0.000	0.000	0.006	0.003	0.004	0.488	0.000	0.000	0.000	0.240	0.045	0.170
1989	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.007	0.001	0.005	0.230	0.000	0.000	0.000	0.456	0.003	0.012
1990	0.000	0.062	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.002	0.006	0.290	0.000	0.000	0.000	0.282	0.002	0.017
1991	0.000	0.224	0.000	0.000	0.286	0.016	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.253	0.000	0.000	0.000	0.279	0.014	0.037
1992	0.000	0.000	0.000	0.189	0.233	0.237	0.036	0.000	0.000	0.000	0.001	0.004	0.000	0.027	0.522	0.000	0.000	0.000	0.183	0.048	0.113
1993	0.000	0.099	0.000	0.000	0.040	0.226	0.004	0.000	0.000	0.000	0.000	0.000	0.002	0.008	0.348	0.000	0.000	0.000	0.159	0.005	0.005
1994	0.000	0.107	0.000	0.022	0.000	0.392	0.018	0.000	0.000	0.000	0.000	0.026	0.002	0.024	0.426	0.000	0.000	0.000	0.547	0.002	0.060
1995	0.000	0.199	0.000	0.000	0.000	0.151	0.061	0.019	0.000	0.000	0.009	0.004	0.002	0.003	0.460	0.000	0.000	0.000	0.316	0.043	0.032
1996	0.000	0.085	0.000	0.059	0.009	0.055	0.023	0.000	0.000	0.000	0.003	0.003	0.008	0.077	0.543	0.000	0.000	0.000	0.122	0.015	0.057
1997	0.000	0.021	0.000	0.055	0.031	0.092	0.003	0.016	0.000	0.000	0.000	0.000	0.004	0.004	0.638	0.000	0.000	0.000	0.173	0.002	0.024
1998	0.000	0.222	0.000	0.000	0.046	0.108	0.030	0.000	0.000	0.000	0.002	0.003	0.001	0.092	0.404	0.000	0.000	0.000	0.185	0.001	0.047
1999	0.000	0.109	0.000	0.000	0.000	0.063	0.015	0.003	0.000	0.000	0.001	0.017	0.000	0.013	0.195	0.000	0.000	0.000	0.380	0.003	0.010
2000	0.000	0.200	0.000	0.255	0.049	0.292	0.017	0.000	0.000	0.000	0.001	0.002	0.121	0.014	0.514	0.000	0.000	0.000	0.178	0.167	0.018
2001	0.000	0.237	0.000	0.011	0.219	0.174	0.046	0.000	0.000	0.000	0.002	0.014	0.003	0.050	0.478	0.000	0.000	0.000	0.122	0.008	0.097
2002	0.000	0.218	0.000	0.096	0.095	0.275	0.007	0.011	0.000	0.000	0.000	0.003	0.022	0.020	0.418	0.000	0.000	0.000	0.397	0.021	0.028
2003	0.000	0.103	0.000	0.028	0.146	0.411	0.040	0.000	0.000	0.000	0.016	0.000	0.000	0.009	0.458	0.000	0.000	0.000	0.087	0.000	0.095
2004	0.000	0.066	0.000	0.060	0.280	0.063	0.030	0.000	0.000	0.000	0.012	0.001	0.005	0.024	0.759	0.000	0.000	0.000	0.331	0.003	0.005
2005	0.000	0.113	0.000	0.126	0.112	0.428	0.024	0.000	0.000	0.000	0.011	0.003	0.000	0.009	0.340	0.000	0.000	0.000	0.057	0.012	0.033
2006	0.000	0.222	0.000	0.024	0.132	0.172	0.007	0.000	0.000	0.000	0.008	0.001	0.004	0.011	0.381	0.000	0.000	0.000	0.154	0.002	0.005
2007	0.000	0.461	0.000	0.029	0.066	0.173	0.008	0.000	0.000	0.000	0.001	0.006	0.004	0.008	0.304	0.000	0.000	0.000	0.241	0.000	0.000
2008	0.000	0.082	0.000	0.010	0.168	0.280	0.045	0.000	0.000	0.000	0.005	0.009	0.024	0.020	0.180	0.000	0.000	0.000	0.038	0.034	0.014
2009	0.000	0.338	0.000	0.154	0.087	0.470	0.039	0.003	0.000	0.000	0.021	0.009	0.006	0.041	0.706	0.000	0.000	0.000	0.279	0.007	0.033
2010	0.000	0.281	0.030	0.084	0.153	0.171	0.014	0.001	0.000	0.000	0.005	0.004	0.006	0.056	0.324	0.000	0.000	0.001	0.227	0.005	0.018
Avg	0.000	0.136	0.004	0.056	0.119	0.142	0.012	0.002	0.000	0.000	0.002	0.003	0.012	0.031	0.438	0.000	0.001	0.000	0.324	0.023	0.046
St Dev	0.000	0.118	0.015	0.117	0.141	0.128	0.016	0.005	0.000	0.000	0.005	0.005	0.022	0.032	0.168	0.000	0.004	0.002	0.161	0.051	0.055

Table 26. Yearly Local Index of Collocation (LIC) for all species' comparisons, averages, and standard deviations in fall.

Species Comparison Spring LIC																					
Year	**BS & CS**	**BS & LS**	**BS & RS**	**BS & SS**	**BS & TS**	**BS & WS**	**CS & LS**	**CS & RS**	**CS & SS**	**CS & TS**	**CS & WS**	**LS & RS**	**LS & SS**	**LS & TS**	**LS & WS**	**RS & SS**	**RS & TS**	**RS & WS**	**SS & TS**	**SS & WS**	**TS & WS**
1968	0.000	0.236	0.000	0.000	0.149	0.049	0.002	0.111	0.013	0.020	0.000	0.000	0.000	0.072	0.446	0.000	0.000	0.000	0.482	0.000	0.084
1969	0.000	0.064	0.000	0.017	0.440	0.051	0.000	0.000	0.000	0.000	0.000	0.000	0.016	0.067	0.800	0.000	0.000	0.000	0.375	0.011	0.044
1970	N/A	0.185	N/A	0.030	0.109	0.035	N/A	N/A	N/A	N/A	N/A	N/A	0.027	0.208	0.408	N/A	N/A	N/A	0.379	0.006	0.107
1971	N/A	0.438	0.000	0.000	0.223	0.102	N/A	N/A	N/A	N/A	N/A	0.000	0.008	0.117	0.509	0.000	0.000	0.000	0.399	0.015	0.058
1972	0.000	0.047	0.000	0.032	0.118	0.020	0.002	0.000	0.000	0.000	0.000	0.000	0.029	0.064	0.839	0.000	0.000	0.000	0.413	0.013	0.049
1973	0.000	0.037	0.000	0.000	0.000	0.139	0.005	0.000	0.000	0.000	0.000	0.000	0.010	0.007	0.109	0.000	0.000	0.000	0.525	0.020	0.059
1974	0.000	0.010	0.000	0.000	0.010	0.019	0.001	0.000	0.000	0.000	0.000	0.000	0.002	0.017	0.233	0.000	0.000	0.000	0.387	0.035	0.040
1975	N/A	0.000	0.000	0.000	0.000	0.089	N/A	N/A	N/A	N/A	N/A	0.001	0.004	0.007	0.241	0.000	0.000	0.000	0.535	0.037	0.121
1976	0.000	0.079	0.000	0.000	0.122	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.005	0.023	0.167	0.000	0.000	0.000	0.615	0.004	0.035
1977	N/A	N/A	N/A	N/A	N/A	N/A	0.004	0.008	0.000	0.000	0.000	0.000	0.000	0.009	0.234	0.000	0.000	0.000	0.260	0.001	0.023
1978	0.000	0.000	0.000	0.000	0.021	0.000	0.000	0.047	0.000	0.000	0.000	0.000	0.002	0.027	0.118	0.000	0.000	0.000	0.601	0.002	0.004
1979	0.000	0.006	0.000	0.000	0.181	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.044	0.100	0.000	0.000	0.000	0.327	0.003	0.030
1980	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.096	0.000	0.001	0.000	0.000	0.001	0.004	0.500	0.000	0.000	0.000	0.281	0.005	0.102
1981	N/A	N/A	N/A	N/A	N/A	N/A	0.000	0.000	0.000	0.000	0.000	0.000	0.044	0.049	0.667	0.000	0.000	0.000	0.401	0.003	0.004
1982	0.000	0.013	0.000	0.000	0.134	0.000	0.001	0.106	0.000	0.000	0.000	0.002	0.000	0.016	0.842	0.000	0.000	0.000	0.319	0.000	0.002
1983	N/A	N/A	N/A	N/A	N/A	N/A	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.008	0.458	0.000	0.000	0.000	0.332	0.001	0.012
1984	N/A	N/A	N/A	N/A	N/A	N/A	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.017	0.780	0.000	0.000	0.000	0.099	0.000	0.015
1985	0.000	0.035	0.000	0.000	0.206	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.020	0.746	0.000	0.000	0.000	0.526	0.006	0.008
1986	0.000	0.567	0.000	0.000	0.000	0.001	0.001	0.104	0.000	0.000	0.000	0.000	0.005	0.011	0.451	0.000	0.000	0.000	0.522	0.003	0.007
1987	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.642	0.000	0.000	0.000	0.187	0.000	0.006
1988	N/A	N/A	N/A	N/A	N/A	N/A	0.000	0.073	0.000	0.000	0.000	0.000	0.025	0.024	0.430	0.000	0.000	0.000	0.405	0.004	0.009
1989	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.150	0.000	0.000	0.001	0.000	0.001	0.004	0.277	0.000	0.000	0.000	0.371	0.001	0.044
1990	N/A	N/A	N/A	N/A	N/A	N/A	0.000	0.069	0.000	0.000	0.000	0.001	0.001	0.002	0.554	0.000	0.000	0.000	0.236	0.001	0.012
1991	0.000	0.008	0.000	0.000	0.000	0.000	0.008	0.000	0.000	0.000	0.003	0.000	0.003	0.010	0.223	0.000	0.000	0.000	0.294	0.013	0.025
1992	0.000	0.016	0.000	0.347	0.078	0.016	0.003	0.057	0.000	0.000	0.002	0.000	0.030	0.101	0.843	0.000	0.000	0.000	0.259	0.054	0.050
1993	0.000	0.071	0.000	0.000	0.000	0.034	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.019	0.580	0.000	0.000	0.000	0.213	0.000	0.010
1994	0.000	0.005	0.000	0.000	0.000	0.003	0.000	0.305	0.000	0.000	0.001	0.000	0.000	0.001	0.872	0.000	0.000	0.000	0.255	0.001	0.002
1995	0.000	0.087	0.000	0.000	0.000	0.034	0.024	0.000	0.000	0.000	0.014	0.000	0.004	0.009	0.704	0.000	0.000	0.000	0.299	0.010	0.000
1996	0.000	0.004	0.000	0.000	0.030	0.000	0.003	0.006	0.000	0.000	0.002	0.000	0.000	0.003	0.686	0.000	0.000	0.000	0.074	0.000	0.000
1997	0.000	0.021	0.000	0.000	0.000	0.006	0.002	0.000	0.000	0.000	0.003	0.000	0.000	0.006	0.275	0.000	0.000	0.000	0.414	0.000	0.004
1998	0.000	0.010	0.000	0.008	0.044	0.010	0.011	0.288	0.000	0.000	0.024	0.000	0.000	0.003	0.425	0.000	0.000	0.000	0.230	0.000	0.006
1999	0.000	0.012	0.000	0.000	0.021	0.000	0.001	0.000	0.000	0.000	0.001	0.000	0.001	0.001	0.569	0.000	0.000	0.000	0.128	0.037	0.133
2000	0.000	0.007	0.000	0.000	0.002	0.029	0.038	0.000	0.000	0.000	0.064	0.000	0.000	0.017	0.385	0.000	0.000	0.000	0.062	0.001	0.077
2001	0.000	0.018	0.000	0.025	0.079	0.012	0.001	0.150	0.000	0.000	0.000	0.000	0.003	0.001	0.896	0.000	0.000	0.000	0.181	0.007	0.003
2002	0.000	0.054	0.005	0.057	0.000	0.194	0.009	0.000	0.000	0.000	0.001	0.001	0.000	0.006	0.353	0.000	0.000	0.008	0.430	0.013	0.079
2003	0.000	0.097	0.000	0.239	0.061	0.095	0.001	0.338	0.000	0.000	0.000	0.008	0.001	0.001	0.619	0.000	0.000	0.000	0.375	0.012	0.033
2004	0.000	0.008	0.000	0.031	0.136	0.127	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.006	0.672	0.000	0.000	0.000	0.275	0.007	0.012
2005	0.000	0.007	0.000	0.014	0.008	0.018	0.000	0.021	0.000	0.000	0.001	0.000	0.001	0.000	0.446	0.000	0.000	0.000	0.645	0.001	0.010
2006	0.000	0.011	0.042	0.001	0.014	0.076	0.000	0.000	0.000	0.000	0.001	0.030	0.000	0.021	0.683	0.000	0.000	0.046	0.760	0.011	0.026
2007	0.000	0.001	0.000	0.173	0.286	0.712	0.000	0.000	0.000	0.000	0.015	0.000	0.002	0.031	0.546	0.000	0.000	0.000	0.174	0.124	0.249
2008	0.000	0.018	0.012	0.529	0.366	0.180	0.003	0.000	0.000	0.000	0.005	0.000	0.003	0.010	0.341	0.000	0.000	0.000	0.466	0.343	0.299
2009	0.000	0.249	0.003	0.031	0.059	0.522	0.002	0.013	0.000	0.000	0.003	0.001	0.001	0.021	0.482	0.000	0.000	0.001	0.229	0.079	0.048
2010	0.003	0.159	0.003	0.271	0.046	0.376	0.005	0.192	0.000	0.000	0.017	0.001	0.005	0.049	0.474	0.000	0.000	0.000	0.241	0.035	0.008
Avg	0.000	0.070	0.002	0.049	0.079	0.080	0.004	0.053	0.000	0.001	0.004	0.001	0.006	0.026	0.503	0.000	0.000	0.001	0.348	0.021	0.045
St Dev	0.000	0.124	0.007	0.116	0.109	0.152	0.007	0.090	0.002	0.003	0.011	0.005	0.010	0.039	0.226	0.000	0.000	0.007	0.158	0.056	0.062

Table 27. Yearly Local Index of Collocation (LIC) for all species' comparisons, averages, and standard deviations in spring.

GOM Species Comparison Spring LIC										
Year	**BS & LS**	**BS & SS**	**BS & TS**	**BS & WS**	**LS & SS**	**LS & TS**	**LS & WS**	**SS & TS**	**SS & WS**	**TS & WS**
1968	0.230	0.000	0.149	0.000	0.000	0.066	0.421	0.621	0.000	0.029
1969	0.609	0.022	0.630	0.812	0.316	0.405	0.583	0.356	0.082	0.691
1970	0.000	0.087	0.147	0.000	0.123	0.062	0.577	0.601	0.106	0.144
1971	N/A	N/A	N/A	N/A	0.015	0.004	0.000	0.504	0.163	0.130
1972	N/A	N/A	N/A	N/A	0.022	0.307	0.588	0.449	0.000	0.284
1973	N/A	N/A	N/A	N/A	0.204	0.213	0.985	0.636	0.201	0.225
1974	N/A	N/A	N/A	N/A	0.033	0.315	0.066	0.459	0.621	0.225
1975	N/A	N/A	N/A	N/A	0.114	0.045	0.908	0.554	0.007	0.038
1976	N/A	N/A	N/A	N/A	0.075	0.101	0.710	0.703	0.065	0.012
1977	N/A	N/A	N/A	N/A	0.000	0.035	0.000	0.315	0.057	0.361
1978	0.000	0.000	0.030	0.000	0.000	0.033	0.000	0.631	0.086	0.067
1979	N/A	N/A	N/A	N/A	0.001	0.004	0.000	0.406	0.008	0.052
1980	N/A	N/A	N/A	N/A	0.004	0.078	0.012	0.553	0.127	0.041
1981	N/A	N/A	N/A	N/A	0.028	0.024	0.449	0.399	0.387	0.157
1982	N/A	N/A	N/A	N/A	0.000	0.081	0.000	0.325	0.000	0.098
1983	N/A	N/A	N/A	N/A	0.000	0.009	0.003	0.404	0.018	0.084
1984	N/A	N/A	N/A	N/A	0.000	0.117	0.198	0.112	0.000	0.205
1985	N/A	N/A	N/A	N/A	0.000	0.090	0.108	0.566	0.000	0.014
1986	N/A	N/A	N/A	N/A	0.073	0.165	0.143	0.520	0.047	0.104
1987	N/A	N/A	N/A	N/A	0.004	0.024	0.057	0.196	0.000	0.120
1988	N/A	N/A	N/A	N/A	0.276	0.246	0.159	0.390	0.047	0.177
1989	N/A	N/A	N/A	N/A	0.086	0.071	0.383	0.378	0.001	0.088
1990	N/A	N/A	N/A	N/A	0.023	0.086	0.074	0.311	0.022	0.113
1991	N/A	N/A	N/A	N/A	0.069	0.244	0.353	0.350	0.095	0.185
1992	0.000	0.171	0.000	0.000	0.084	0.094	0.091	0.435	0.271	0.152
1993	N/A	N/A	N/A	N/A	0.001	0.255	0.065	0.218	0.001	0.021
1994	N/A	N/A	N/A	N/A	0.045	0.170	0.164	0.265	0.085	0.054
1995	N/A	N/A	N/A	N/A	0.011	0.227	0.251	0.324	0.036	0.042
1996	0.000	0.000	0.035	0.000	0.012	0.068	0.023	0.070	0.000	0.009
1997	N/A	N/A	N/A	N/A	0.008	0.333	0.190	0.039	0.000	0.220
1998	N/A	N/A	N/A	N/A	0.006	0.046	0.101	0.178	0.000	0.341
1999	0.000	0.000	0.000	0.000	0.359	0.136	0.124	0.126	0.019	0.000
2000	0.000	0.000	0.000	0.000	0.006	0.063	0.599	0.401	0.020	0.000
2001	N/A	N/A	N/A	N/A	0.001	0.000	0.019	0.155	0.000	0.000
2002	0.000	0.385	0.000	0.000	0.047	0.329	0.164	0.392	0.030	0.059
2003	0.000	0.474	0.116	0.000	0.018	0.033	0.007	0.413	0.073	0.367
2004	0.000	0.417	0.728	0.000	0.002	0.031	0.392	0.470	0.139	0.054
2005	0.000	0.029	0.020	0.052	0.014	0.008	0.964	0.767	0.005	0.000
2006	0.000	0.055	0.000	0.026	0.000	0.006	0.977	0.881	0.136	0.122
2007	0.000	0.935	0.000	0.196	0.000	0.125	0.059	0.104	0.217	0.269
2008	0.000	0.664	0.558	0.171	0.004	0.010	0.166	0.447	0.189	0.244
2009	0.007	0.206	0.014	0.010	0.004	0.153	0.101	0.198	0.625	0.056
2010	0.011	0.647	0.086	0.649	0.025	0.233	0.168	0.251	0.565	0.132
Avg	0.050	0.241	0.148	0.113	0.049	0.120	0.265	0.392	0.106	0.135
St Dev	0.154	0.294	0.242	0.242	0.086	0.109	0.297	0.192	0.162	0.134

Table 28. Yearly spring Local Index of Collocation (LIC) for all species' comparisons, averages, and standard deviations in Gulf of Maine.

GOM Species Comparison Fall LIC

Year	BS & LS	BS & SS	BS & TS	BS & WS	LS & SS	LS & TS	LS & WS	SS & TS	SS & WS	TS & WS
1963	0.296	0.147	0.088	0.044	0.017	0.101	0.400	0.482	0.003	0.012
1964	0.192	0.115	0.420	0.103	0.000	0.000	0.535	0.473	0.000	0.000
1965	0.210	0.129	0.347	0.093	0.413	0.193	0.091	0.329	0.237	0.057
1966	0.000	0.000	0.000	0.000	0.000	0.022	0.000	0.549	0.000	0.000
1967	0.147	0.111	0.091	0.000	0.000	0.045	0.000	0.654	0.320	0.523
1968	0.000	0.000	0.062	0.000	0.000	0.023	0.000	0.477	0.000	0.000
1969	0.894	0.000	0.000	0.000	0.000	0.000	0.000	0.474	0.000	0.047
1970	0.000	0.000	0.000	0.000	0.000	0.013	0.000	0.216	0.000	0.000
1971	0.000	0.000	0.039	0.000	0.161	0.121	0.802	0.345	0.000	0.129
1972	0.224	0.000	0.058	0.000	0.080	0.135	0.179	0.421	0.000	0.182
1973	N/A	N/A	N/A	N/A	0.000	0.000	0.154	0.603	0.294	0.020
1974	N/A	N/A	N/A	N/A	0.000	0.166	N/A	0.335	N/A	N/A
1975	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.226	N/A	N/A
1976	0.000	0.000	0.107	N/A	0.000	0.515	N/A	0.187	N/A	N/A
1977	N/A	N/A	N/A	N/A	0.054	0.207	0.000	0.384	0.142	0.019
1978	N/A	N/A	N/A	N/A	0.000	0.002	0.000	0.471	0.036	0.000
1979	N/A	N/A	N/A	N/A	0.006	0.007	0.000	0.352	0.000	0.018
1980	N/A	N/A	N/A	N/A	0.000	0.000	0.969	0.437	0.000	0.000
1981	N/A	N/A	N/A	N/A	0.000	0.215	0.037	0.521	0.000	0.009
1982	N/A	N/A	N/A	N/A	0.000	0.031	0.000	0.076	0.000	0.000
1983	N/A	N/A	N/A	N/A	0.005	0.003	0.243	0.332	0.000	0.020
1984	N/A	N/A	N/A	N/A	0.014	0.062	0.149	0.377	0.005	0.014
1985	N/A	N/A	N/A	N/A	0.000	0.003	0.068	0.319	0.004	0.004
1986	N/A	N/A	N/A	N/A	0.003	0.027	0.038	0.407	0.004	0.012
1987	N/A	N/A	N/A	N/A	0.000	0.004	0.011	0.176	0.000	0.014
1988	N/A	N/A	N/A	N/A	0.000	0.005	0.297	0.215	0.000	0.007
1989	N/A	N/A	N/A	N/A	0.054	0.244	0.100	0.368	0.011	0.051
1990	N/A	N/A	N/A	N/A	0.008	0.060	0.004	0.345	0.004	0.000
1991	0.000	0.000	0.286	0.000	0.000	0.007	0.007	0.298	0.157	0.369
1992	N/A	N/A	N/A	N/A	0.000	0.005	0.699	0.164	0.033	0.012
1993	0.000	0.000	0.107	0.000	0.004	0.013	0.129	0.389	0.011	0.022
1994	0.000	0.000	0.000	0.596	0.016	0.090	0.392	0.577	0.013	0.031
1995	N/A	N/A	N/A	N/A	0.000	0.021	0.041	0.313	0.000	0.020
1996	0.000	0.079	0.000	0.000	0.006	0.115	0.551	0.103	0.008	0.073
1997	0.000	0.124	0.044	0.000	0.020	0.100	0.449	0.206	0.011	0.203
1998	N/A	N/A	N/A	N/A	0.000	0.005	0.022	0.307	0.017	0.099
1999	0.000	0.000	0.000	0.000	0.000	0.018	0.000	0.204	0.000	0.000
2000	0.025	0.000	0.058	0.000	0.000	0.001	0.093	0.246	0.000	0.000
2001	N/A	N/A	N/A	N/A	0.000	0.143	0.351	0.119	0.007	0.129
2002	0.000	0.000	0.105	0.000	0.000	0.018	0.420	0.226	0.026	0.021
2003	0.188	0.161	0.038	0.000	0.024	0.028	0.145	0.372	0.000	0.000
2004	0.000	0.544	0.097	0.000	0.049	0.097	0.111	0.328	0.000	0.000
2005	0.000	0.000	0.649	0.000	0.006	0.000	0.237	0.008	0.000	0.000
2006	0.000	0.074	0.283	0.039	0.001	0.031	0.517	0.162	0.007	0.062
2007	0.035	0.045	0.134	0.611	0.000	0.000	0.199	0.230	0.000	0.000
2008	0.119	0.024	0.225	0.000	0.005	0.127	0.251	0.050	0.000	0.020
2009	0.046	0.658	0.090	0.005	0.001	0.200	0.222	0.183	0.000	0.070
2010	0.114	0.558	0.398	0.023	0.018	0.395	0.892	0.260	0.011	0.043
Avg	0.092	0.103	0.138	0.058	0.021	0.077	0.218	0.319	0.030	0.051
St Dev	0.184	0.183	0.161	0.163	0.065	0.108	0.258	0.148	0.076	0.100

Table 29. Yearly fall Local Index of Collocation (LIC) for all species' comparisons, averages, and standard deviations in Gulf of Maine.

Species Comparison GB Spring LIC															
Year	**BS & LS**	**BS & RS**	**BS & SS**	**BS & TS**	**BS & WS**	**LS & RS**	**LS & SS**	**LS & TS**	**LS & WS**	**RS & SS**	**RS & TS**	**RS & WS**	**SS & TS**	**SS & WS**	**TS & WS**
1968	0.388	N/A	0.000	0.144	0.030	N/A	0.000	0.165	0.757	N/A	N/A	N/A	0.102	0.000	0.115
1969	0.190	N/A	0.000	0.000	0.106	N/A	0.036	0.066	0.852	N/A	N/A	N/A	0.729	0.037	0.070
1970	0.057	N/A	0.000	0.049	0.075	N/A	0.051	0.210	0.690	N/A	N/A	N/A	0.211	0.037	0.133
1971	0.864	N/A	0.000	0.295	0.231	N/A	0.044	0.290	0.480	N/A	N/A	N/A	0.626	0.092	0.126
1972	0.089	N/A	0.181	0.228	0.042	N/A	0.263	0.163	0.605	N/A	N/A	N/A	0.530	0.132	0.081
1973	0.244	N/A	0.000	0.000	0.297	N/A	0.275	0.144	0.749	N/A	N/A	N/A	0.373	0.009	0.076
1974	0.053	N/A	0.000	0.018	0.041	N/A	0.004	0.103	0.765	N/A	N/A	N/A	0.262	0.011	0.045
1975	0.000	N/A	0.000	0.000	0.115	N/A	0.022	0.064	0.814	N/A	N/A	N/A	0.719	0.034	0.114
1976	0.128	N/A	0.000	0.287	0.000	N/A	0.011	0.051	0.256	N/A	N/A	N/A	0.250	0.000	0.064
1977	N/A	N/A	N/A	N/A	N/A	N/A	0.000	0.044	0.407	N/A	N/A	N/A	0.000	0.000	0.023
1978	N/A	N/A	N/A	N/A	N/A	N/A	0.018	0.046	0.122	N/A	N/A	N/A	0.645	0.008	0.008
1979	N/A	N/A	N/A	N/A	N/A	N/A	0.005	0.049	0.180	N/A	N/A	N/A	0.183	0.000	0.033
1980	N/A	N/A	N/A	N/A	N/A	N/A	0.018	0.006	0.105	N/A	N/A	N/A	0.038	0.000	0.534
1981	N/A	N/A	N/A	N/A	N/A	N/A	0.306	0.394	0.457	N/A	N/A	N/A	0.221	0.083	0.145
1982	0.050	N/A	0.000	0.527	0.000	N/A	0.000	0.120	0.762	N/A	N/A	N/A	0.316	0.012	0.041
1983	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.023	0.742	N/A	N/A	N/A	N/A	N/A	0.023
1984	N/A	N/A	N/A	N/A	N/A	N/A	0.000	0.027	0.647	N/A	N/A	N/A	0.000	0.000	0.000
1985	0.135	N/A	0.000	0.480	0.000	N/A	0.124	0.156	0.899	N/A	N/A	N/A	0.336	0.070	0.029
1986	0.704	N/A	0.000	0.000	0.004	N/A	0.006	0.008	0.124	N/A	N/A	N/A	0.652	0.005	0.036
1987	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.005	0.639	N/A	N/A	N/A	N/A	N/A	0.031
1988	N/A	N/A	N/A	N/A	N/A	N/A	0.074	0.037	0.592	N/A	N/A	N/A	0.070	0.205	0.058
1989	N/A	N/A	N/A	N/A	N/A	N/A	0.000	0.332	0.728	N/A	N/A	N/A	0.000	0.018	0.068
1990	N/A	N/A	N/A	N/A	N/A	N/A	0.000	0.000	0.510	N/A	N/A	N/A	0.000	0.002	0.008
1991	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.014	0.556	N/A	N/A	N/A	N/A	N/A	0.011
1992	0.048	N/A	0.445	0.414	0.038	N/A	0.067	0.059	0.864	N/A	N/A	N/A	0.933	0.096	0.081
1993	0.152	N/A	0.000	0.000	0.073	N/A	0.000	0.074	0.734	N/A	N/A	N/A	0.426	0.005	0.051
1994	0.064	N/A	0.000	0.000	0.014	N/A	0.000	0.053	0.806	N/A	N/A	N/A	0.000	0.000	0.006
1995	N/A	N/A	N/A	N/A	N/A	N/A	0.028	0.019	0.835	N/A	N/A	N/A	0.384	0.022	0.000
1996	0.024	N/A	0.000	0.000	0.000	N/A	0.000	0.005	0.897	N/A	N/A	N/A	0.707	0.000	0.000
1997	0.279	N/A	0.000	0.000	0.009	N/A	0.010	0.008	0.750	N/A	N/A	N/A	0.873	0.000	0.000
1998	0.082	0.000	0.123	0.329	0.005	0.000	0.060	0.072	0.901	0.000	0.000	0.000	0.535	0.005	0.006
1999	0.163	N/A	0.000	0.134	0.000	N/A	0.000	0.005	0.406	N/A	N/A	N/A	0.507	0.832	0.467
2000	0.190	N/A	N/A	0.002	0.027	N/A	N/A	0.505	0.327	N/A	N/A	N/A	N/A	N/A	0.094
2001	0.144	N/A	0.065	0.279	0.054	N/A	0.064	0.042	0.567	N/A	N/A	N/A	0.422	0.130	0.077
2002	0.038	0.007	0.000	0.000	0.029	0.008	0.000	0.000	0.571	0.000	0.000	0.027	0.981	0.137	0.135
2003	0.380	N/A	0.118	0.000	0.109	N/A	0.023	0.000	0.495	N/A	N/A	N/A	0.000	0.141	0.000
2004	0.085	N/A	0.000	0.000	0.383	N/A	0.022	0.052	0.756	N/A	N/A	N/A	0.092	0.024	0.022
2005	0.016	N/A	0.000	0.000	0.052	N/A	0.000	0.000	0.715	N/A	N/A	N/A	0.810	0.047	0.064
2006	0.005	0.014	0.000	0.000	0.081	0.082	0.000	0.000	0.810	0.000	0.000	0.058	0.000	0.000	0.004
2007	0.003	N/A	0.399	0.318	0.894	N/A	0.031	0.207	0.251	N/A	N/A	N/A	0.373	0.381	0.344
2008	0.381	N/A	0.030	0.047	0.482	N/A	0.053	0.155	0.358	N/A	N/A	N/A	0.546	0.748	0.452
2009	0.147	0.000	0.289	0.257	0.507	0.000	0.001	0.044	0.340	0.000	0.000	0.007	0.593	0.002	0.209
2010	0.074	N/A	0.019	0.095	0.240	N/A	0.101	0.426	0.190	N/A	N/A	N/A	0.048	0.395	0.037
Avg	0.173	0.005	0.058	0.130	0.131	0.022	0.044	0.099	0.582	0.000	0.000	0.023	0.372	0.095	0.091
St Dev	0.201	0.007	0.121	0.166	0.202	0.040	0.076	0.124	0.240	0.000	0.000	0.026	0.299	0.188	0.127

Table 30. Yearly spring Local Index of Collocation (LIC) for all species' comparisons, averages, and standard deviations in George's Bank.

Species Comparison GB Fall LIC															
Year	**BS & LS**	**BS & RS**	**BS & SS**	**BS & TS**	**BS & WS**	**LS & RS**	**LS & SS**	**LS & TS**	**LS & WS**	**RS & SS**	**RS & TS**	**RS & WS**	**SS & TS**	**SS & WS**	**TS & WS**
1963	0.252	N/A	0.134	0.481	0.142	N/A	0.061	0.107	0.878	N/A	N/A	N/A	0.148	0.040	0.069
1964	0.322	N/A	0.137	0.289	0.284	N/A	0.090	0.140	0.521	N/A	N/A	N/A	0.566	0.523	0.616
1965	0.388	N/A	0.045	0.054	0.349	N/A	0.061	0.055	0.856	N/A	N/A	N/A	0.340	0.060	0.196
1966	0.343	N/A	0.047	0.044	0.038	N/A	0.252	0.193	0.471	N/A	N/A	N/A	0.589	0.013	0.038
1967	0.021	0.000	0.000	0.347	0.007	0.000	0.000	0.028	0.442	0.000	0.000	0.000	0.141	0.024	0.194
1968	0.211	N/A	N/A	0.071	0.125	N/A	N/A	0.024	0.582	N/A	N/A	N/A	N/A	N/A	0.031
1969	0.081	N/A	0.530	0.084	0.182	N/A	0.031	0.130	0.802	N/A	N/A	N/A	0.211	0.100	0.219
1970	0.078	N/A	0.000	0.052	0.046	N/A	0.003	0.136	0.454	N/A	N/A	N/A	0.589	0.009	0.097
1971	0.103	N/A	0.000	0.013	0.198	N/A	0.000	0.014	0.683	N/A	N/A	N/A	0.625	0.024	0.015
1972	0.011	N/A	0.000	0.237	0.112	N/A	0.058	0.017	0.828	N/A	N/A	N/A	0.237	0.139	0.038
1973	0.252	N/A	0.000	0.000	0.266	N/A	0.000	0.005	0.720	N/A	N/A	N/A	0.575	0.007	0.008
1974	N/A	N/A	N/A	N/A	N/A	N/A	0.022	0.034	0.687	N/A	N/A	N/A	0.756	0.144	0.147
1975	0.112	N/A	0.000	0.103	0.192	N/A	0.000	0.106	0.693	N/A	N/A	N/A	0.497	0.000	0.097
1976	0.018	N/A	0.000	0.629	0.000	N/A	0.000	0.018	0.264	N/A	N/A	N/A	0.313	0.000	0.000
1977	N/A	N/A	N/A	N/A	N/A	N/A	0.016	0.032	0.675	N/A	N/A	N/A	0.739	0.009	0.071
1978	N/A	N/A	N/A	N/A	N/A	N/A	0.021	0.033	0.467	N/A	N/A	N/A	0.391	0.022	0.018
1979	0.022	N/A	0.891	0.930	0.018	N/A	0.021	0.063	0.639	N/A	N/A	N/A	0.904	0.019	0.044
1980	N/A	N/A	N/A	N/A	N/A	N/A	0.098	0.034	0.530	N/A	N/A	N/A	0.730	0.008	0.028
1981	N/A	N/A	N/A	N/A	N/A	N/A	0.085	0.160	0.631	N/A	N/A	N/A	0.267	0.031	0.023
1982	N/A	N/A	N/A	N/A	N/A	N/A	0.050	0.020	0.570	N/A	N/A	N/A	0.150	0.004	0.008
1983	N/A	N/A	N/A	N/A	N/A	N/A	0.498	0.239	0.290	N/A	N/A	N/A	0.442	0.014	0.009
1984	0.019	N/A	0.000	0.221	0.014	N/A	0.048	0.040	0.699	N/A	N/A	N/A	0.000	0.063	0.027
1985	0.132	N/A	0.000	0.221	0.028	N/A	0.016	0.135	0.437	N/A	N/A	N/A	0.333	0.042	0.120
1986	0.159	N/A	0.000	0.092	0.012	N/A	0.016	0.146	0.441	N/A	N/A	N/A	0.872	0.003	0.009
1987	0.112	N/A	0.000	0.572	0.149	N/A	0.175	0.071	0.803	N/A	N/A	N/A	0.147	0.042	0.034
1988	0.000	N/A	0.365	0.000	0.020	N/A	0.008	0.003	0.778	N/A	N/A	N/A	0.828	0.235	0.288
1989	0.000	N/A	0.000	0.000	0.000	N/A	0.000	0.012	0.584	N/A	N/A	N/A	0.595	0.004	0.015
1990	0.112	N/A	0.000	0.000	0.000	N/A	0.006	0.003	0.466	N/A	N/A	N/A	0.341	0.010	0.011
1991	0.420	N/A	0.000	0.971	0.024	N/A	0.000	0.408	0.354	N/A	N/A	N/A	0.033	0.010	0.028
1992	0.000	N/A	1.000	0.412	0.368	N/A	0.000	0.175	0.602	N/A	N/A	N/A	0.412	0.368	0.306
1993	0.178	N/A	0.000	0.030	0.328	N/A	0.020	0.013	0.600	N/A	N/A	N/A	0.309	0.076	0.006
1994	0.231	N/A	0.316	0.000	0.391	N/A	0.009	0.115	0.628	N/A	N/A	N/A	0.000	0.024	0.228
1995	0.392	N/A	0.000	0.000	0.407	N/A	0.015	0.011	0.559	N/A	N/A	N/A	0.518	0.543	0.288
1996	0.235	N/A	0.000	0.027	0.168	N/A	0.065	0.082	0.762	N/A	N/A	N/A	0.511	0.059	0.126
1997	0.108	N/A	0.000	0.029	0.128	N/A	0.085	0.014	0.848	N/A	N/A	N/A	0.115	0.009	0.023
1998	0.323	N/A	0.000	0.058	0.189	N/A	0.005	0.168	0.759	N/A	N/A	N/A	0.000	0.000	0.093
1999	0.132	N/A	0.000	0.000	0.104	N/A	0.000	0.016	0.244	N/A	N/A	N/A	0.902	0.012	0.019
2000	0.262	N/A	0.643	0.069	0.475	N/A	0.336	0.027	0.832	N/A	N/A	N/A	0.014	0.607	0.035
2001	0.316	0.000	0.120	0.327	0.209	0.000	0.038	0.069	0.663	0.000	0.000	0.000	0.579	0.087	0.143
2002	0.385	N/A	0.241	0.102	0.451	N/A	0.100	0.040	0.791	N/A	N/A	N/A	0.824	0.083	0.053
2003	0.171	N/A	0.115	0.212	0.407	N/A	0.000	0.090	0.571	N/A	N/A	N/A	0.121	0.000	0.152
2004	0.221	N/A	0.066	0.316	0.147	N/A	0.040	0.087	0.665	N/A	N/A	N/A	0.711	0.032	0.017
2005	0.312	0.000	0.192	0.218	0.598	0.000	0.000	0.017	0.522	0.000	0.000	0.000	0.243	0.022	0.011
2006	0.557	N/A	0.055	0.295	0.323	N/A	0.059	0.025	0.409	N/A	N/A	N/A	0.000	0.014	0.000
2007	0.518	0.000	0.157	0.170	0.230	0.000	0.050	0.048	0.253	0.000	0.000	0.000	0.577	0.000	0.000
2008	0.154	N/A	0.052	0.296	0.369	N/A	0.124	0.036	0.337	N/A	N/A	N/A	0.000	0.307	0.036
2009	0.427	0.000	0.126	0.116	0.538	0.000	0.031	0.035	0.758	0.037	0.000	0.000	0.679	0.034	0.039
2010	0.618	0.142	0.213	0.224	0.489	0.051	0.088	0.111	0.573	0.000	0.000	0.012	0.424	0.086	0.083
Avg	0.212	0.024	0.136	0.203	0.208	0.009	0.057	0.075	0.596	0.006	0.000	0.002	0.411	0.084	0.087
St Dev	0.163	0.058	0.240	0.236	0.172	0.021	0.093	0.077	0.172	0.015	0.000	0.005	0.278	0.147	0.114

Table 31. Yearly fall Local Index of Collocation (LIC) for all species’ comparisons, averages and standard deviations in George’s Bank.

Species Comparison SNE Spring LIC																					
Year	**BS & CS**	**BS & LS**	**BS & RS**	**BS & SS**	**BS & TS**	**BS & WS**	**CS & LS**	**CS & RS**	**CS & SS**	**CS & TS**	**CS & WS**	**LS & RS**	**LS & SS**	**LS & TS**	**LS & WS**	**RS & SS**	**RS & TS**	**RS & WS**	**SS & TS**	**SS & WS**	**TS & WS**
1968	N/A	0.171	N/A	N/A	0.093	0.093	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.022	0.328	N/A	N/A	N/A	N/A	N/A	0.096
1969	N/A	0.045	N/A	0.000	0.000	0.000	N/A	N/A	N/A	N/A	N/A	N/A	0.145	0.237	0.797	N/A	N/A	N/A	0.145	0.047	0.062
1970	N/A	0.192	N/A	0.000	0.000	0.000	N/A	N/A	N/A	N/A	N/A	N/A	0.000	0.190	0.360	N/A	N/A	N/A	0.277	0.000	0.786
1971	N/A	0.459	N/A	0.000	0.000	0.000	N/A	N/A	N/A	N/A	N/A	N/A	0.021	0.152	0.528	N/A	N/A	N/A	0.755	0.083	0.100
1972	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.000	0.959	N/A	N/A	N/A	N/A	N/A	0.007
1973	N/A	0.039	N/A	N/A	0.000	0.000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.000	0.135	N/A	N/A	N/A	N/A	N/A	0.043
1974	0.000	0.010	N/A	0.000	0.000	0.000	0.000	N/A	0.000	0.000	0.000	N/A	0.025	0.025	0.246	N/A	N/A	N/A	1.000	0.169	0.169
1975	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.001	N/A	0.017	0.585	N/A	0.000	0.000	N/A	N/A	0.000
1976	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.000	N/A	0.061	0.090	N/A	0.000	0.000	N/A	N/A	0.148
1977	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.017	0.220	N/A	N/A	N/A	N/A	N/A	0.211
1978	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.000	0.002	0.012	0.474	0.000	0.000	0.000	0.000	0.000	0.000
1979	N/A	N/A	N/A	N/A	N/A	N/A	0.004	N/A	0.000	0.000	0.000	N/A	0.000	0.311	0.111	N/A	N/A	N/A	0.000	0.000	0.000
1980	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.037	0.568	N/A	N/A	N/A	N/A	N/A	0.005
1981	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.006	0.757	N/A	N/A	N/A	N/A	N/A	0.005
1982	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.000	0.882	N/A	N/A	N/A	N/A	N/A	0.006
1983	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.650	N/A	N/A	N/A	N/A	N/A	N/A
1984	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.000	N/A	0.000	0.797	N/A	0.000	0.000	N/A	N/A	0.009
1985	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.000	0.755	N/A	N/A	N/A	N/A	N/A	0.021
1986	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.871	N/A	N/A	N/A	N/A	N/A	N/A
1987	N/A	0.000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.709	N/A	N/A	N/A	N/A	N/A	N/A
1988	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.019	0.434	N/A	N/A	N/A	N/A	N/A	0.040
1989	N/A	0.000	N/A	0.000	0.000	0.000	N/A	N/A	N/A	N/A	N/A	N/A	0.000	0.001	0.316	N/A	N/A	N/A	0.000	0.000	0.670
1990	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.000	0.672	N/A	N/A	N/A	N/A	N/A	0.132
1991	N/A	0.009	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.195	N/A	N/A	N/A	N/A	N/A	N/A
1992	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.115	0.850	N/A	N/A	N/A	N/A	N/A	0.051
1993	N/A	0.094	0.000	N/A	0.000	0.000	N/A	N/A	N/A	N/A	N/A	0.000	N/A	0.002	0.654	N/A	0.000	0.000	N/A	N/A	0.000
1994	N/A	0.000	N/A	N/A	0.000	0.000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.000	0.914	N/A	N/A	N/A	N/A	N/A	0.028
1995	N/A	0.095	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.817	N/A	N/A	N/A	N/A	N/A	N/A
1996	N/A	0.009	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.678	N/A	N/A	N/A	N/A	N/A	N/A
1997	N/A	0.000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.369	N/A	N/A	N/A	N/A	N/A	N/A
1998	N/A	0.023	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.623	N/A	N/A	N/A	N/A	N/A	N/A
1999	N/A	0.000	N/A	0.000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.000	N/A	0.800	N/A	N/A	N/A	N/A	0.000	N/A
2000	0.000	0.003	N/A	N/A	0.000	0.000	0.392	N/A	N/A	0.000	0.285	N/A	N/A	0.003	0.712	N/A	N/A	N/A	N/A	N/A	0.000
2001	N/A	0.007	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.945	N/A	N/A	N/A	N/A	N/A	N/A
2002	N/A	0.082	N/A	N/A	0.000	0.000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.074	0.353	N/A	N/A	N/A	N/A	N/A	0.835
2003	N/A	0.097	0.000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.000	N/A	N/A	0.768	N/A	N/A	0.000	N/A	N/A	N/A
2004	N/A	0.001	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.827	N/A	N/A	N/A	N/A	N/A	N/A
2005	N/A	0.008	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.439	N/A	N/A	N/A	N/A	N/A	N/A
2006	N/A	0.053	0.963	N/A	0.172	0.172	N/A	N/A	N/A	N/A	N/A	0.015	N/A	0.056	0.652	N/A	0.000	0.152	N/A	N/A	0.049
2007	N/A	0.028	N/A	N/A	0.000	0.000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.072	0.905	N/A	N/A	N/A	N/A	N/A	0.052
2008	N/A	0.061	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.720	N/A	N/A	N/A	N/A	N/A	N/A
2009	N/A	0.472	0.055	0.000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.000	0.000	N/A	0.697	0.000	N/A	0.011	N/A	0.004	N/A
2010	0.013	0.200	0.013	N/A	N/A	N/A	0.000	0.000	N/A	N/A	0.000	0.000	N/A	N/A	0.528	N/A	N/A	0.005	N/A	N/A	N/A
Avg	0.004	0.080	0.206	0.000	0.020	0.020	0.099	0.000	0.000	0.000	0.071	0.002	0.021	0.053	0.597	0.000	0.000	0.019	0.311	0.034	0.131
St Dev	0.008	0.126	0.424	0.000	0.052	0.052	0.196	N/A	0.000	0.000	0.142	0.005	0.047	0.081	0.248	0.000	0.000	0.050	0.406	0.059	0.236

Table 32. Yearly spring Local Index of Collocation (LIC) for all species' comparisons , averages and standard deviations in Southern New England.

Species Comparison SNE Fall LIC																					
Year	**BS & CS**	**BS & LS**	**BS & RS**	**BS & SS**	**BS & TS**	**BS & WS**	**CS & LS**	**CS & RS**	**CS & SS**	**CS & TS**	**CS & WS**	**LS & RS**	**LS & SS**	**LS & TS**	**LS & WS**	**RS & SS**	**RS & TS**	**RS & WS**	**SS & TS**	**SS & WS**	**TS & WS**
1963	N/A	0.355	0.036	0.267	N/A	0.292	N/A	N/A	N/A	N/A	N/A	0.000	0.000	N/A	0.324	0.000	N/A	0.000	N/A	0.025	N/A
1964	N/A	0.270	0.000	N/A	0.000	0.132	N/A	N/A	N/A	N/A	N/A	0.000	N/A	0.029	0.656	N/A	0.000	0.000	N/A	N/A	0.036
1965	N/A	0.030	0.170	N/A	0.000	0.021	N/A	N/A	N/A	N/A	N/A	0.003	N/A	0.000	0.538	N/A	0.000	0.000	N/A	N/A	0.000
1966	N/A	0.192	0.000	0.000	0.000	0.158	N/A	N/A	N/A	N/A	N/A	0.000	0.000	0.118	0.455	0.000	0.000	0.000	0.000	0.000	0.024
1967	N/A	0.000	0.000	0.000	0.000	0.000	N/A	N/A	N/A	N/A	N/A	0.000	0.834	0.000	0.243	0.000	0.000	0.000	0.000	0.000	0.000
1968	N/A	0.257	0.000	N/A	0.000	0.000	N/A	N/A	N/A	N/A	N/A	0.000	N/A	0.039	0.344	N/A	0.000	0.125	N/A	N/A	0.000
1969	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.000	N/A	0.000	0.000	N/A	0.000	0.000	N/A	N/A	0.000
1970	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.000	N/A	0.310	N/A	N/A	N/A	N/A	0.000	N/A
1971	N/A	0.007	N/A	N/A	0.000	0.244	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.000	0.110	N/A	N/A	N/A	N/A	N/A	0.305
1972	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.000	0.000	0.000	0.244	0.000	0.000	0.000	0.000	0.000	0.000
1973	N/A	N/A	N/A	N/A	N/A	N/A	0.101	0.000	0.000	0.000	0.000	0.000	0.008	0.000	0.206	0.000	0.000	0.000	0.000	0.000	0.000
1974	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.000	N/A	N/A	0.642	N/A	N/A	0.000	N/A	N/A	N/A
1975	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.000	0.000	0.000	0.044	0.000	0.000	0.000	0.000	0.000	0.000
1976	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.000	0.020	0.090	N/A	N/A	N/A	0.000	0.000	0.898
1977	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.000	0.016	0.138	0.511	0.000	0.000	0.000	0.435	0.000	0.183
1978	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.000	0.052	0.014	0.323	0.000	0.000	0.000	0.000	0.015	0.055
1979	N/A	N/A	N/A	N/A	N/A	N/A	0.000	0.000	N/A	0.000	0.000	0.000	N/A	0.058	0.443	N/A	0.000	0.000	N/A	N/A	0.079
1980	N/A	N/A	N/A	N/A	N/A	N/A	0.007	0.000	N/A	0.000	0.000	0.000	N/A	0.000	0.306	N/A	0.000	0.008	N/A	N/A	0.000
1981	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.000	N/A	0.000	0.163	N/A	0.000	0.000	N/A	N/A	0.000
1982	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.001	N/A	N/A	0.782	N/A	N/A	0.000	N/A	N/A	N/A
1983	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.180	N/A	N/A	N/A	N/A	N/A	N/A
1984	N/A	N/A	N/A	N/A	N/A	N/A	0.000	0.000	N/A	N/A	0.000	0.000	N/A	N/A	0.141	N/A	N/A	0.000	N/A	N/A	N/A
1985	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.000	N/A	0.658	N/A	N/A	N/A	N/A	0.000	N/A
1986	N/A	N/A	N/A	N/A	N/A	N/A	0.005	1.000	N/A	N/A	0.000	0.005	N/A	N/A	0.212	N/A	N/A	0.000	N/A	N/A	N/A
1987	N/A	N/A	N/A	N/A	N/A	N/A	0.000	N/A	0.000	0.000	0.000	N/A	0.097	0.000	0.036	N/A	N/A	N/A	0.000	0.118	0.064
1988	N/A	0.224	0.000	0.000	N/A	0.020	N/A	N/A	N/A	N/A	N/A	0.000	0.298	N/A	0.423	0.000	N/A	0.000	N/A	0.778	N/A
1989	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.197	N/A	N/A	N/A	N/A	N/A	N/A
1990	N/A	N/A	N/A	N/A	N/A	N/A	0.000	N/A	N/A	0.000	0.000	N/A	N/A	0.000	0.184	N/A	N/A	N/A	N/A	N/A	0.050
1991	0.000	0.366	0.000	N/A	0.000	0.000	0.000	0.000	N/A	0.000	0.000	0.000	N/A	0.000	0.512	N/A	0.000	0.000	N/A	N/A	0.063
1992	N/A	N/A	N/A	N/A	N/A	N/A	0.047	N/A	N/A	N/A	0.015	N/A	N/A	N/A	0.567	N/A	N/A	N/A	N/A	N/A	N/A
1993	N/A	N/A	N/A	N/A	N/A	N/A	0.063	N/A	N/A	N/A	0.000	N/A	N/A	N/A	0.195	N/A	N/A	N/A	N/A	N/A	N/A
1994	N/A	0.067	N/A	N/A	0.000	0.424	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.020	0.397	N/A	N/A	N/A	N/A	N/A	0.219
1995	N/A	N/A	N/A	N/A	N/A	N/A	0.155	0.000	0.000	N/A	0.063	0.024	0.003	N/A	0.456	0.000	N/A	0.000	N/A	0.009	N/A
1996	N/A	N/A	N/A	N/A	N/A	N/A	0.105	0.000	0.000	0.000	0.011	0.000	0.006	0.020	0.515	0.000	0.000	0.000	0.000	0.131	0.025
1997	N/A	N/A	N/A	N/A	N/A	N/A	0.006	0.000	N/A	N/A	0.000	0.000	N/A	N/A	0.838	N/A	N/A	0.000	N/A	N/A	N/A
1998	N/A	N/A	N/A	N/A	N/A	N/A	0.070	N/A	N/A	0.000	0.013	N/A	N/A	0.006	0.196	N/A	N/A	N/A	N/A	N/A	0.036
1999	0.000	0.134	N/A	N/A	N/A	0.011	0.032	N/A	N/A	N/A	0.000	N/A	N/A	N/A	0.219	N/A	N/A	N/A	N/A	N/A	N/A
2000	0.000	0.032	0.000	0.000	0.000	0.078	0.021	0.000	0.000	0.000	0.004	0.000	0.154	0.037	0.210	0.000	0.000	0.000	0.000	0.068	0.125
2001	0.000	0.004	0.000	N/A	N/A	0.040	0.149	0.000	N/A	N/A	0.032	0.000	N/A	N/A	0.214	N/A	N/A	0.000	N/A	N/A	N/A
2002	0.000	0.080	0.000	N/A	N/A	0.102	0.043	0.000	N/A	N/A	0.000	0.007	N/A	N/A	0.248	N/A	N/A	0.000	N/A	N/A	N/A
2003	0.000	0.131	N/A	N/A	N/A	0.428	0.176	N/A	N/A	N/A	0.228	N/A	N/A	N/A	0.555	N/A	N/A	N/A	N/A	N/A	N/A
2004	0.000	0.010	N/A	N/A	N/A	0.070	0.216	N/A	N/A	N/A	0.109	N/A	N/A	N/A	0.775	N/A	N/A	N/A	N/A	N/A	N/A
2005	0.000	0.141	N/A	N/A	0.000	0.029	0.100	N/A	N/A	0.000	0.078	N/A	N/A	0.118	0.409	N/A	N/A	N/A	N/A	N/A	0.646
2006	0.000	0.307	0.000	N/A	N/A	0.164	0.010	0.000	N/A	N/A	0.039	0.006	N/A	N/A	0.405	N/A	N/A	0.000	N/A	N/A	N/A
2007	0.000	0.529	N/A	N/A	N/A	0.197	0.043	N/A	N/A	N/A	0.008	N/A	N/A	N/A	0.364	N/A	N/A	N/A	N/A	N/A	N/A
2008	0.000	0.052	0.000	0.000	N/A	0.054	0.301	0.000	0.000	N/A	0.051	0.000	0.167	N/A	0.105	0.000	N/A	0.000	N/A	0.000	N/A
2009	0.000	0.299	0.000	0.000	0.000	0.365	0.492	0.000	0.000	0.000	0.474	0.000	0.000	0.000	0.782	0.000	0.000	0.000	0.949	0.000	0.000
2010	0.000	0.277	0.000	0.000	0.310	0.111	0.166	0.000	0.000	0.000	0.071	0.004	0.000	0.011	0.321	0.000	0.000	0.000	0.000	0.000	0.018
Avg	0.000	0.171	0.014	0.033	0.026	0.134	0.089	0.063	0.000	0.000	0.046	0.002	0.086	0.024	0.355	0.000	0.000	0.004	0.106	0.060	0.109
St Dev	0.000	0.147	0.044	0.094	0.089	0.137	0.114	0.250	0.000	0.000	0.101	0.005	0.198	0.040	0.214	0.000	0.000	0.022	0.280	0.178	0.213

Table 33. Yearly fall Local Index of Collocation (LIC) for all species' comparisons, averages, and standard deviations in Southern New England.

Species Comparison MAB Spring LIC

Year	CS & LS	CS & RS	CS & WS	LS & RS	LS & WS	RS & WS
1968	0.000	0.289	0.000	0.000	0.346	0.000
1969	0.000	0.000	0.000	0.000	0.709	0.000
1970	N/A	N/A	N/A	N/A	0.000	N/A
1971	N/A	N/A	N/A	0.000	N/A	N/A
1972	0.016	0.000	0.000	0.000	0.000	0.000
1973	0.011	0.000	0.000	0.001	0.055	0.000
1974	0.004	0.000	0.000	0.000	0.075	0.000
1975	N/A	N/A	N/A	0.000	0.000	0.000
1976	0.011	0.000	N/A	0.000	N/A	N/A
1977	0.014	0.008	N/A	0.000	N/A	N/A
1978	0.000	0.048	N/A	0.000	N/A	N/A
1979	0.010	0.000	N/A	0.000	N/A	N/A
1980	0.000	0.109	N/A	0.000	N/A	N/A
1981	0.000	0.000	0.000	0.000	0.679	0.000
1982	0.005	0.422	0.000	0.023	0.650	0.000
1983	0.028	0.000	N/A	0.000	N/A	N/A
1984	0.008	N/A	0.000	N/A	0.233	N/A
1985	0.000	0.000	0.000	0.000	0.344	0.000
1986	0.003	0.131	0.000	0.000	0.237	0.000
1987	0.024	0.000	0.014	0.001	0.882	0.000
1988	0.000	0.079	0.000	0.000	0.362	0.000
1989	0.001	0.150	0.003	0.000	0.524	0.000
1990	0.005	0.070	0.000	0.022	0.728	0.000
1991	0.013	0.000	0.014	0.001	0.507	0.000
1992	0.053	0.057	0.126	0.000	0.588	0.000
1993	0.001	0.000	0.037	0.000	0.345	0.000
1994	0.000	0.322	0.008	0.000	0.450	0.000
1995	0.080	0.000	0.147	0.000	0.689	0.000
1996	0.007	0.006	0.006	0.000	0.911	0.000
1997	0.006	0.000	0.047	0.000	0.448	0.000
1998	0.047	0.299	0.138	0.002	0.484	0.000
1999	0.004	0.000	0.017	0.002	0.551	0.000
2000	0.122	0.000	0.466	0.001	0.336	0.000
2001	0.002	0.150	0.017	0.001	0.288	0.000
2002	0.059	0.000	0.046	0.009	0.461	0.000
2003	0.002	0.348	0.003	0.025	0.683	0.000
2004	0.000	0.000	0.000	0.000	0.589	0.000
2005	0.002	0.022	0.014	0.000	0.672	0.000
2006	0.001	0.000	0.033	0.003	0.360	0.000
2007	0.001	0.000	0.095	0.000	0.310	0.000
2008	0.010	0.000	0.059	0.000	0.404	0.000
2009	0.008	0.014	0.045	0.005	0.650	0.000
2010	0.023	0.193	0.210	0.006	0.425	0.004
Avg	0.014	0.070	0.045	0.002	0.444	0.000
St Dev	0.025	0.116	0.090	0.006	0.239	0.001

Table 34. Yearly spring Local Index of Collocation (LIC) for all species' comparisons, averages, and standard deviations in Mid-Atlantic Bight.

Species Comparison MAB Fall LIC						
Year	**CS & LS**	**CS & RS**	**CS & WS**	**LS & RS**	**LS & WS**	**RS & WS**
1963	N/A	N/A	N/A	N/A	N/A	N/A
1964	N/A	N/A	N/A	N/A	N/A	N/A
1965	N/A	N/A	N/A	N/A	N/A	N/A
1966	N/A	N/A	N/A	N/A	N/A	N/A
1967	0.000	0.000	N/A	0.000	N/A	N/A
1968	0.000	0.000	0.000	0.000	0.337	0.000
1969	0.198	0.000	N/A	0.000	N/A	N/A
1970	0.000	0.000	N/A	0.000	N/A	N/A
1971	0.000	0.000	N/A	0.000	N/A	N/A
1972	0.026	0.000	0.015	0.000	0.112	0.000
1973	0.065	0.000	N/A	0.009	N/A	N/A
1974	0.052	0.000	N/A	0.000	N/A	N/A
1975	0.000	0.000	N/A	0.000	N/A	N/A
1976	0.008	0.000	N/A	0.000	N/A	N/A
1977	0.000	0.000	N/A	0.000	N/A	N/A
1978	0.081	0.000	N/A	0.000	N/A	N/A
1979	0.007	0.000	N/A	0.000	N/A	N/A
1980	0.078	0.000	N/A	0.105	N/A	N/A
1981	0.004	0.000	0.000	0.000	0.239	0.000
1982	0.071	0.000	N/A	0.000	N/A	N/A
1983	0.104	0.000	N/A	0.000	N/A	N/A
1984	0.131	0.000	N/A	0.005	N/A	N/A
1985	0.002	0.000	N/A	0.006	N/A	N/A
1986	0.000	0.000	N/A	0.000	N/A	N/A
1987	0.000	0.000	N/A	0.023	N/A	N/A
1988	0.000	0.000	N/A	0.163	N/A	N/A
1989	0.005	0.000	N/A	0.034	N/A	N/A
1990	0.000	0.000	N/A	0.077	N/A	N/A
1991	0.003	0.000	N/A	0.000	N/A	N/A
1992	0.497	0.000	N/A	0.058	N/A	N/A
1993	0.001	0.000	0.000	0.000	0.000	0.000
1994	0.090	0.000	0.000	0.128	0.125	0.000
1995	0.229	0.019	0.054	0.000	0.282	0.000
1996	0.005	0.000	0.000	0.009	0.059	0.000
1997	0.034	0.019	N/A	0.025	N/A	N/A
1998	0.080	0.000	N/A	0.011	N/A	N/A
1999	0.033	0.003	0.124	0.042	0.054	0.000
2000	0.152	0.000	0.000	0.023	0.093	0.000
2001	0.086	0.000	0.018	0.029	0.257	0.000
2002	0.011	0.012	N/A	0.008	N/A	N/A
2003	0.142	0.000	0.026	0.000	0.374	0.000
2004	0.068	0.000	0.000	0.006	0.185	0.000
2005	0.025	0.000	0.000	0.023	0.017	0.000
2006	0.020	0.000	0.164	0.000	0.591	0.000
2007	0.012	0.000	0.000	0.022	0.000	0.000
2008	0.031	0.000	N/A	0.040	N/A	N/A
2009	0.047	0.003	N/A	0.033	N/A	N/A
2010	0.013	0.001	N/A	0.001	N/A	N/A
Avg	0.055	0.001	0.027	0.020	0.182	0.000
St Dev	0.088	0.004	0.050	0.036	0.166	0.000

Table 35. Yearly fall Local Index of Collocation (LIC) for all species' comparisons, averages, and standard deviations in Mid-Atlantic Bight.

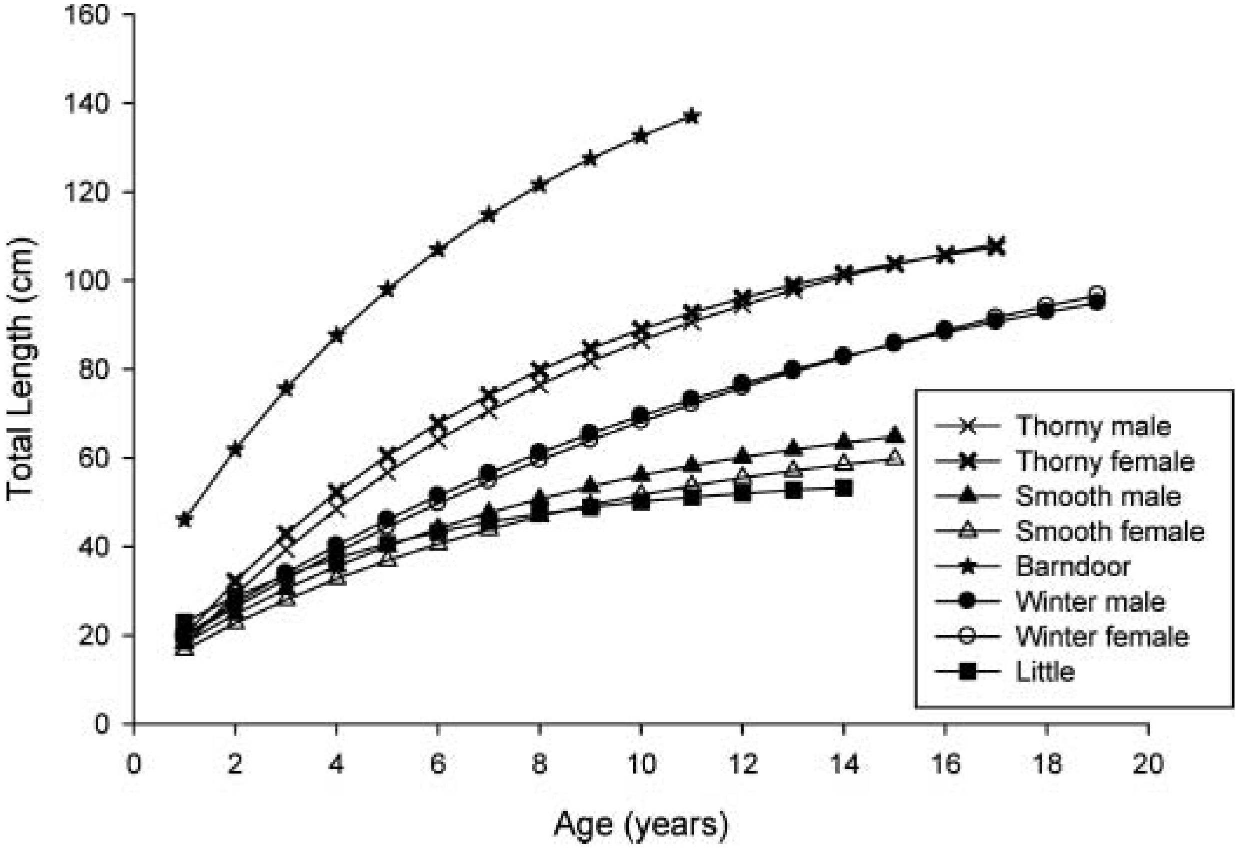


Figure 1. Von Bertalanffy growth curves fit to length and age for five skate species in the NW Atlantic using published von Bertalanffy parameters (Hogan et al. 2013).

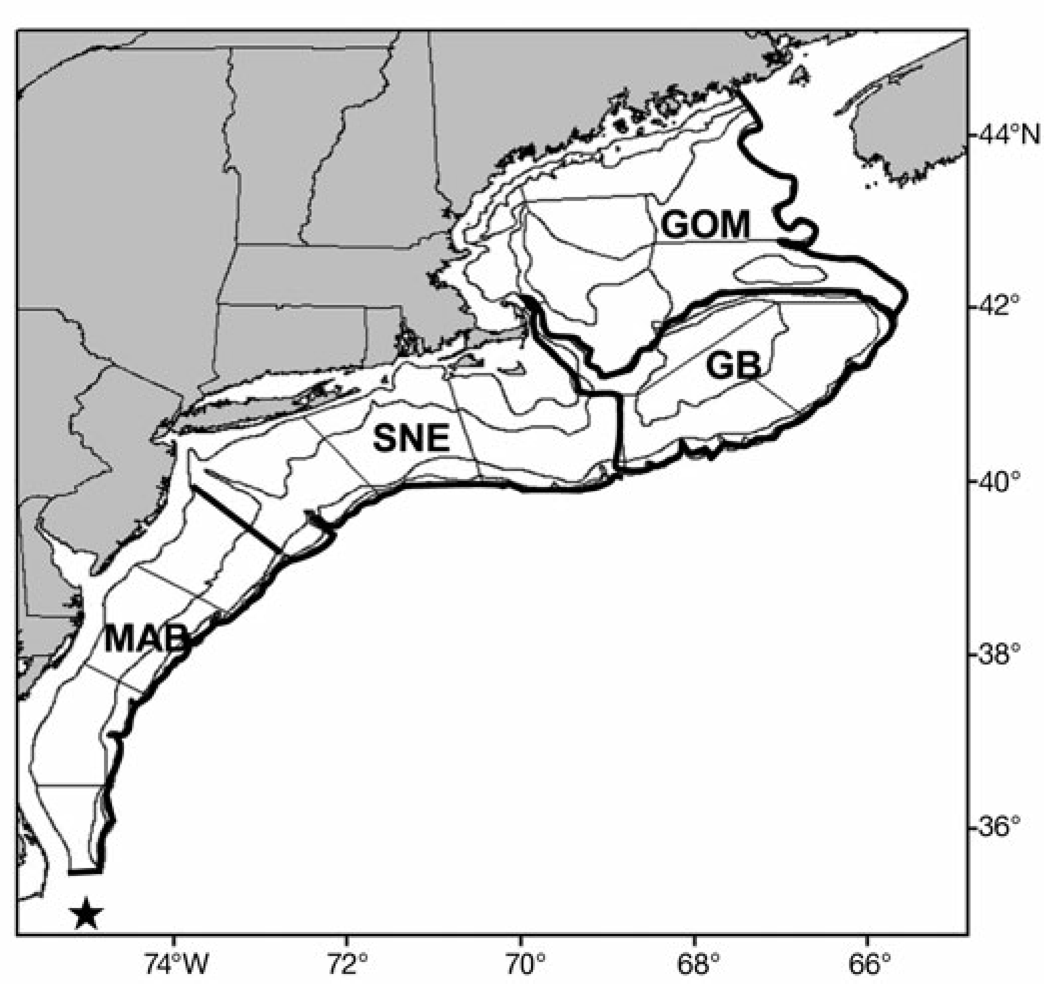


Figure 2. Map of the NEFSC bottom trawl survey strata isolines and four main ecosystems, Gulf of Maine (GOM), George's Bank (GB), Southern New England (SNE) and Mid-Atlantic Bight (from Nye et al. 2009).

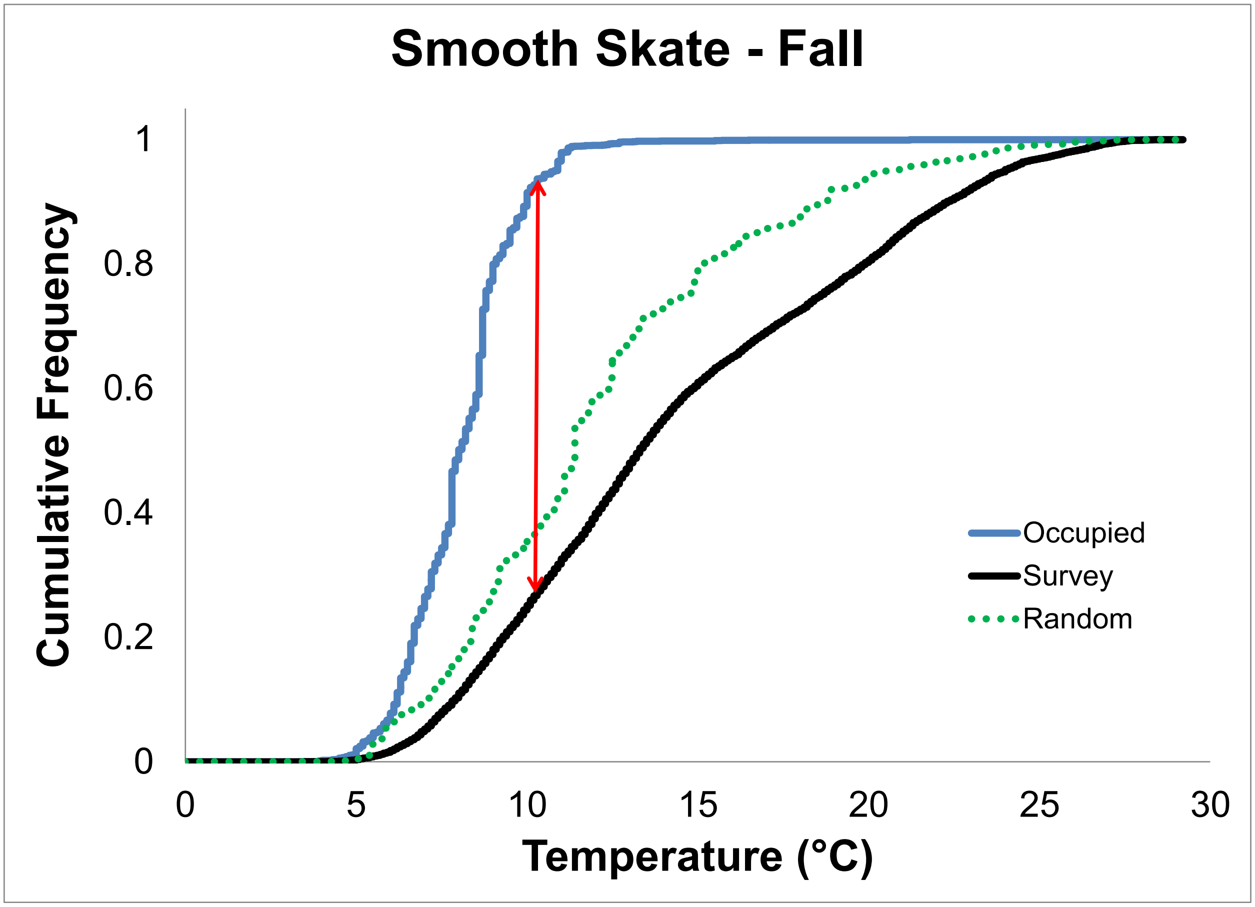


Figure 3. A sample CDF of available (survey) and occupied temperature for smooth skate ($p<0.01$). The dotted random CDF is a bootstrapped randomization. The red line shows the largest vertical distance between the available and occupied CDFs.

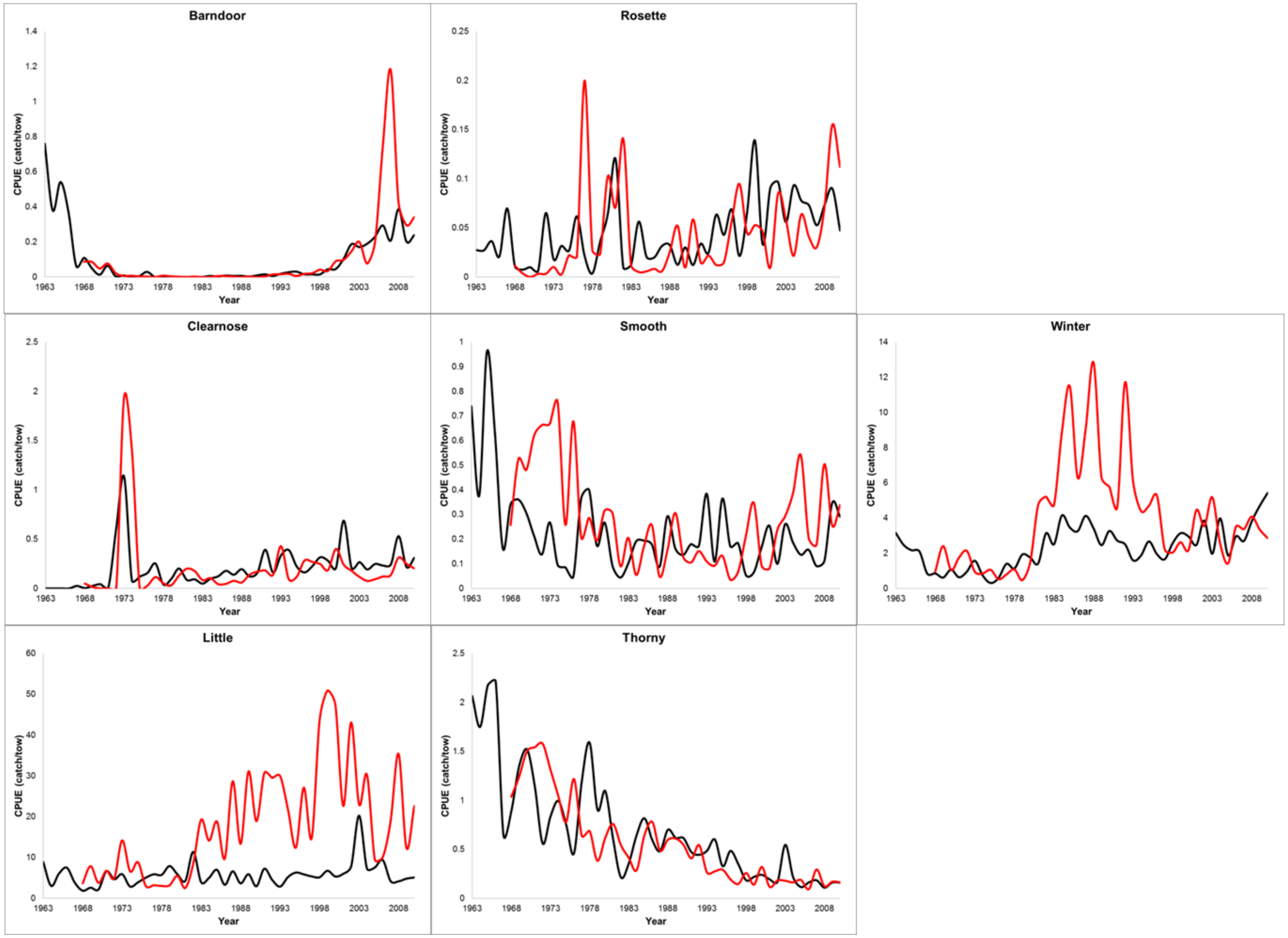


Figure 4. Yearly CPUE (catch/tow) for all seven species for both fall (black line) and spring (red line) for the entire geographic scale of the survey.

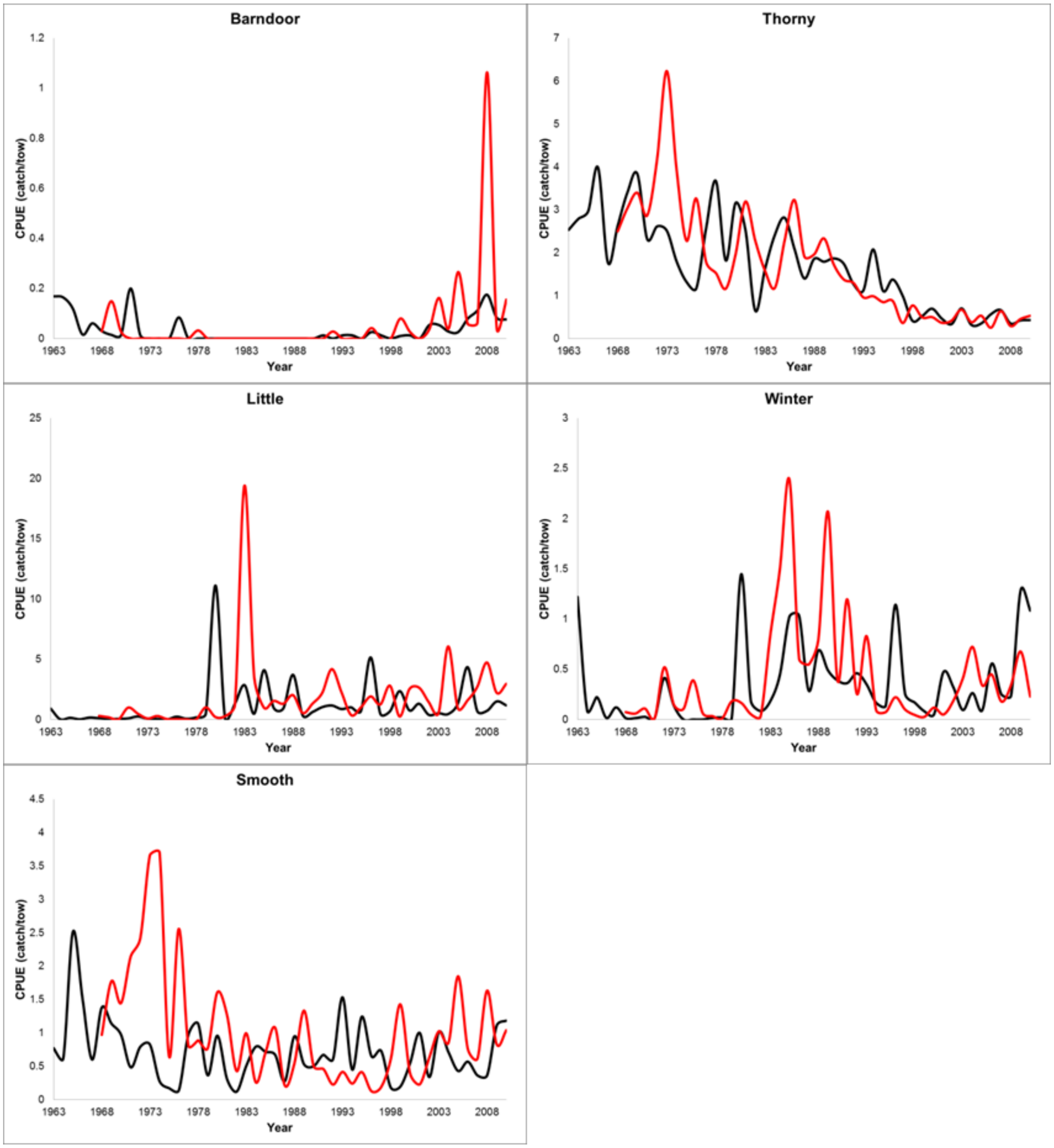


Figure 5. Yearly CPUE (tow/catch) for each occupying species in Gulf of Maine for both spring (red line) and fall (black line).

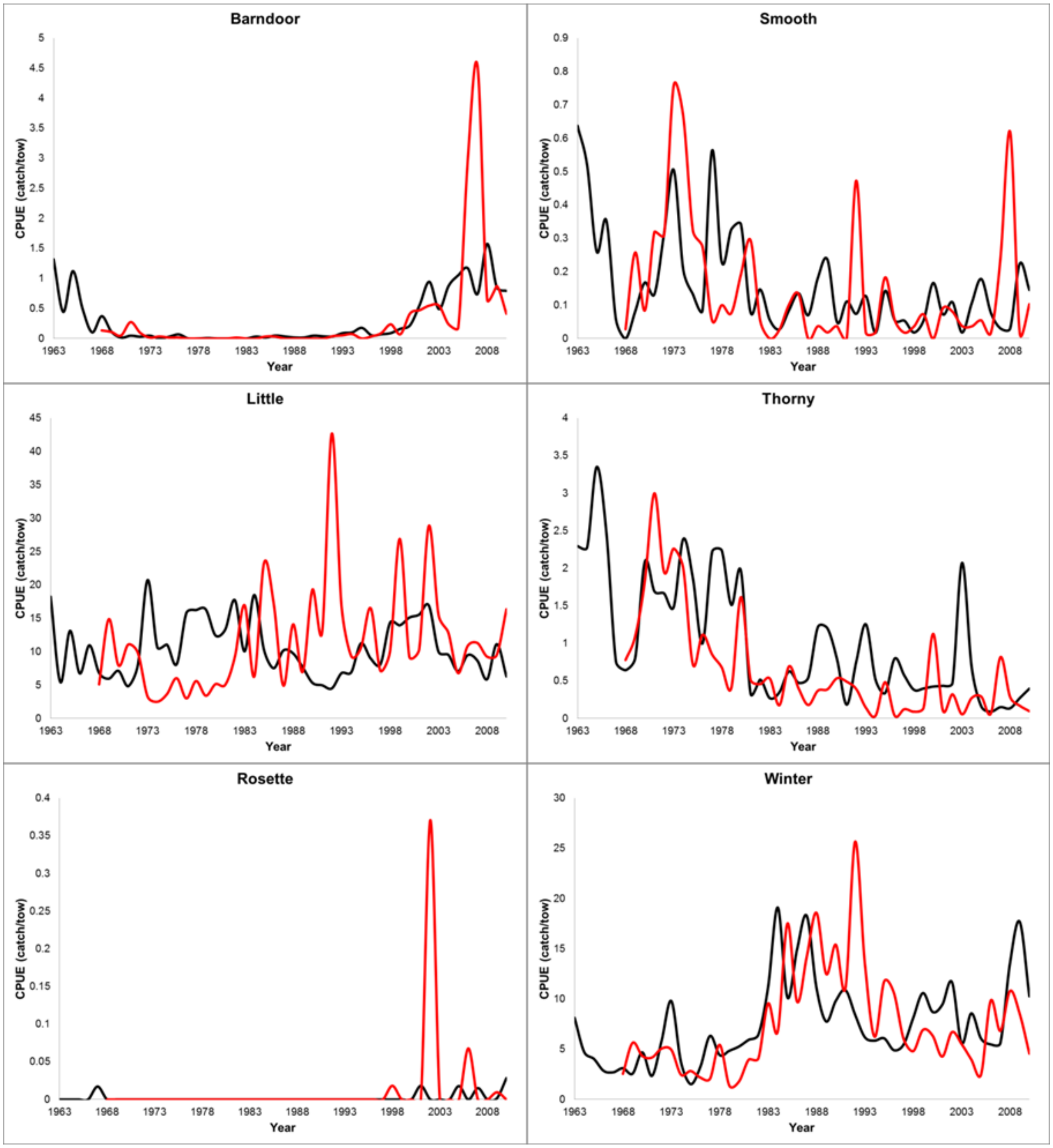


Figure 6. Yearly CPUE (catch/tow) for all occupying species in George's Bank for both spring (red line) and fall (black line).

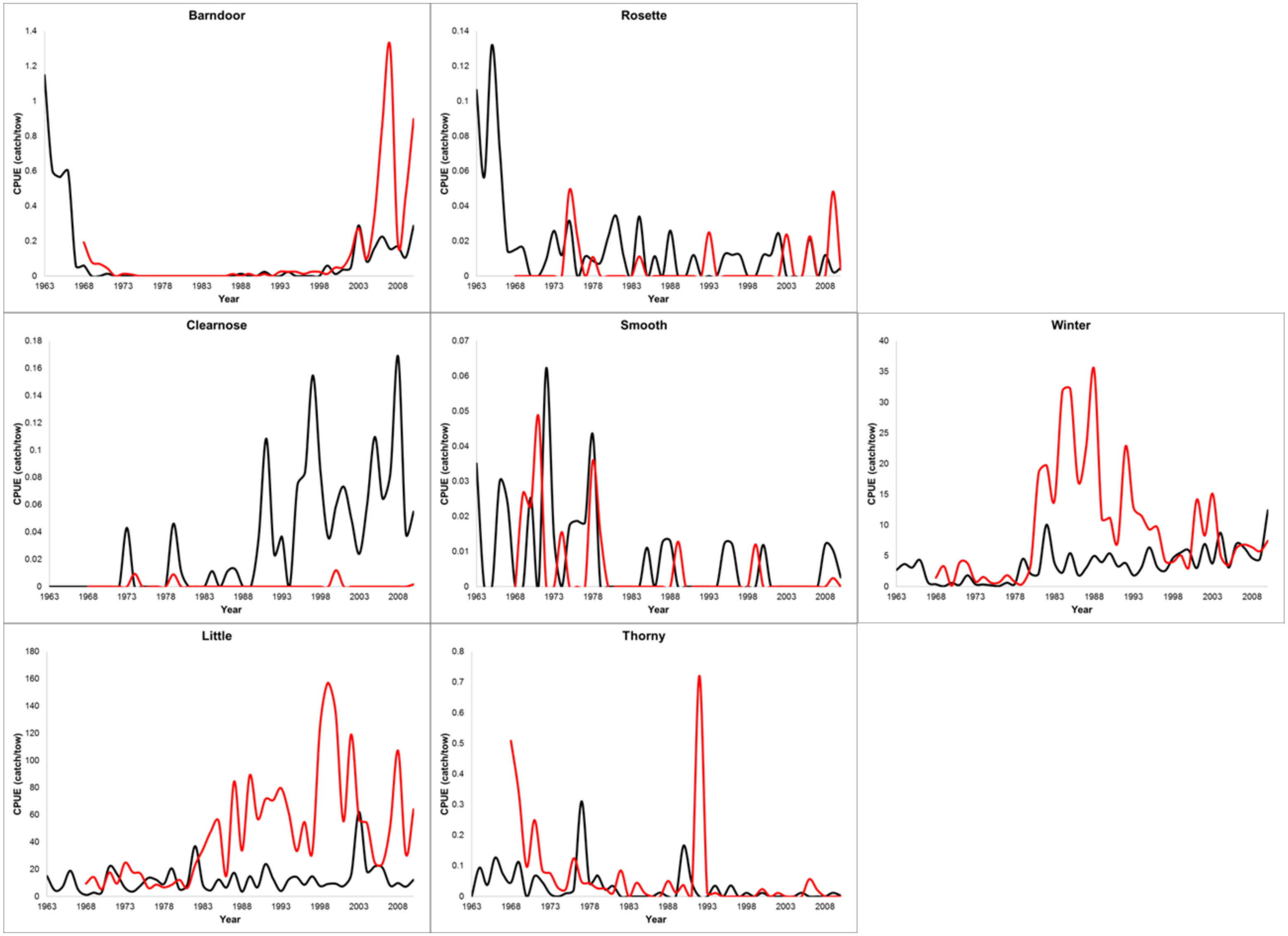
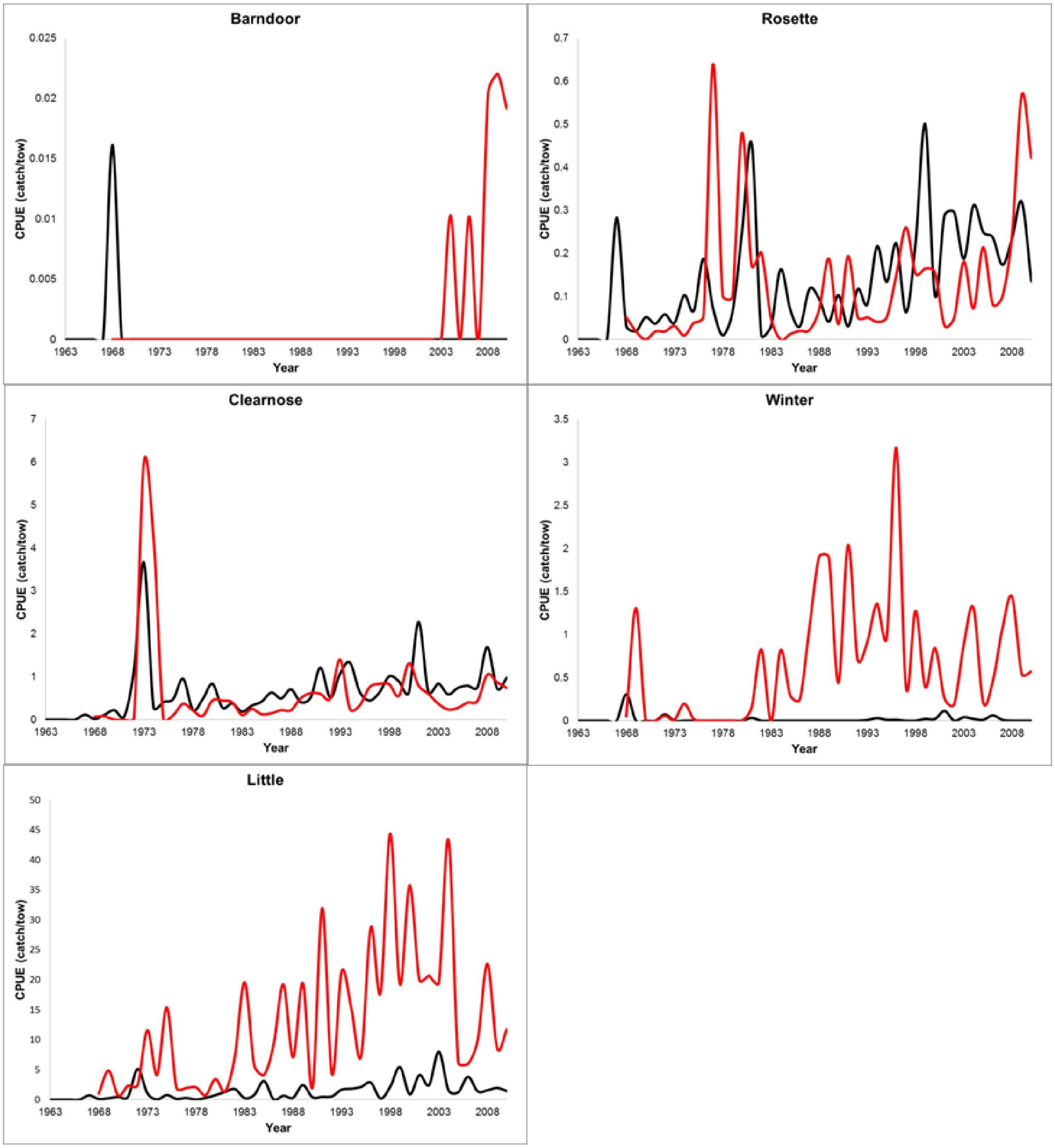


Figure 7. Yearly CPUE (catch/tow) for all occupying species in Southern New England for both spring (red line) and fall (black line).


Barndoor

Rosette

Clearnose

Winter

Little

Figure 8. Yearly CPUE (catch/tow) for each occupying species in the Mid-Atlantic Bight for both spring (red line) and fall (black line).

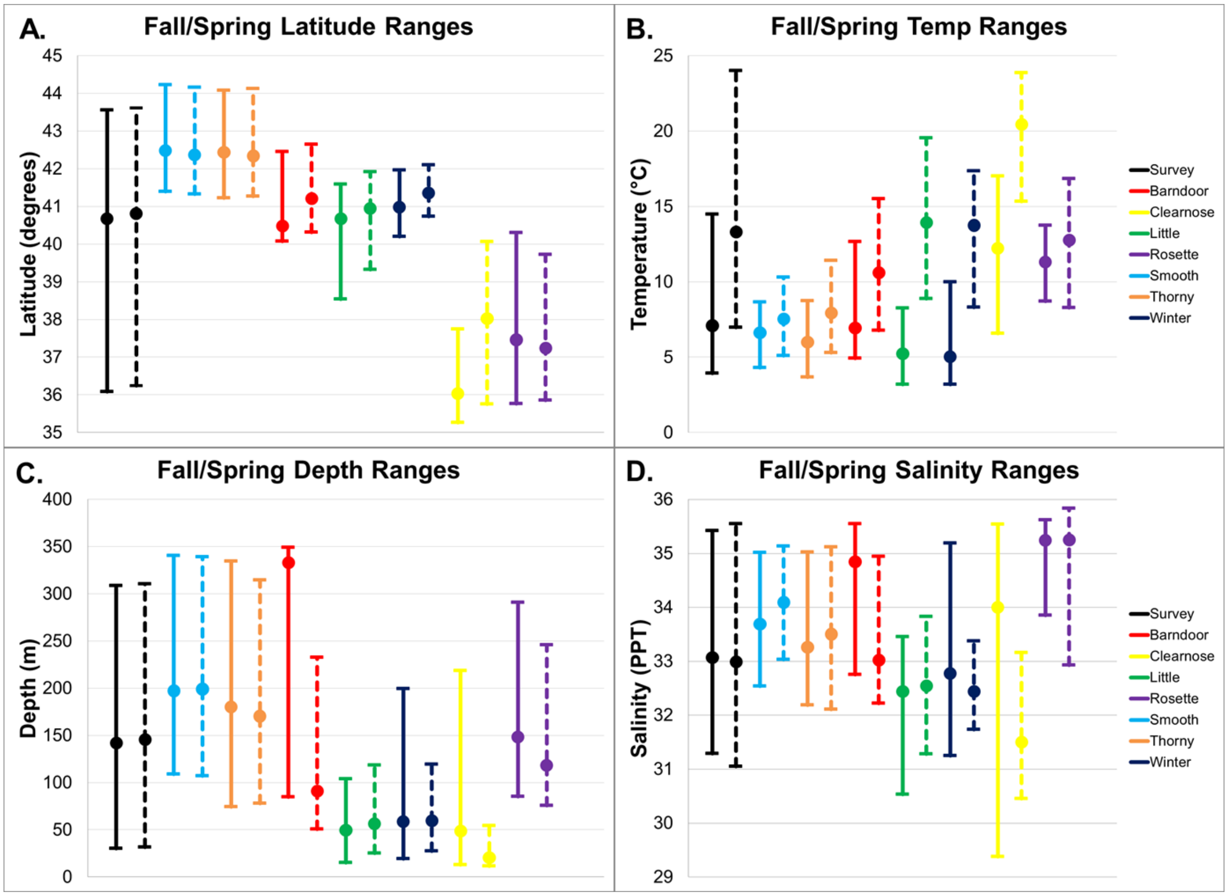


Figure 9. Habitat range (circle = mean) for the survey and all seven skate species for both spring (solid line) and fall (dotted line) for each of the four environmental variables; A- Latitude, B- Temperature, C- Depth, D- Salinity. Bars delineate the 5% and 95% occupation based on the CDFs.

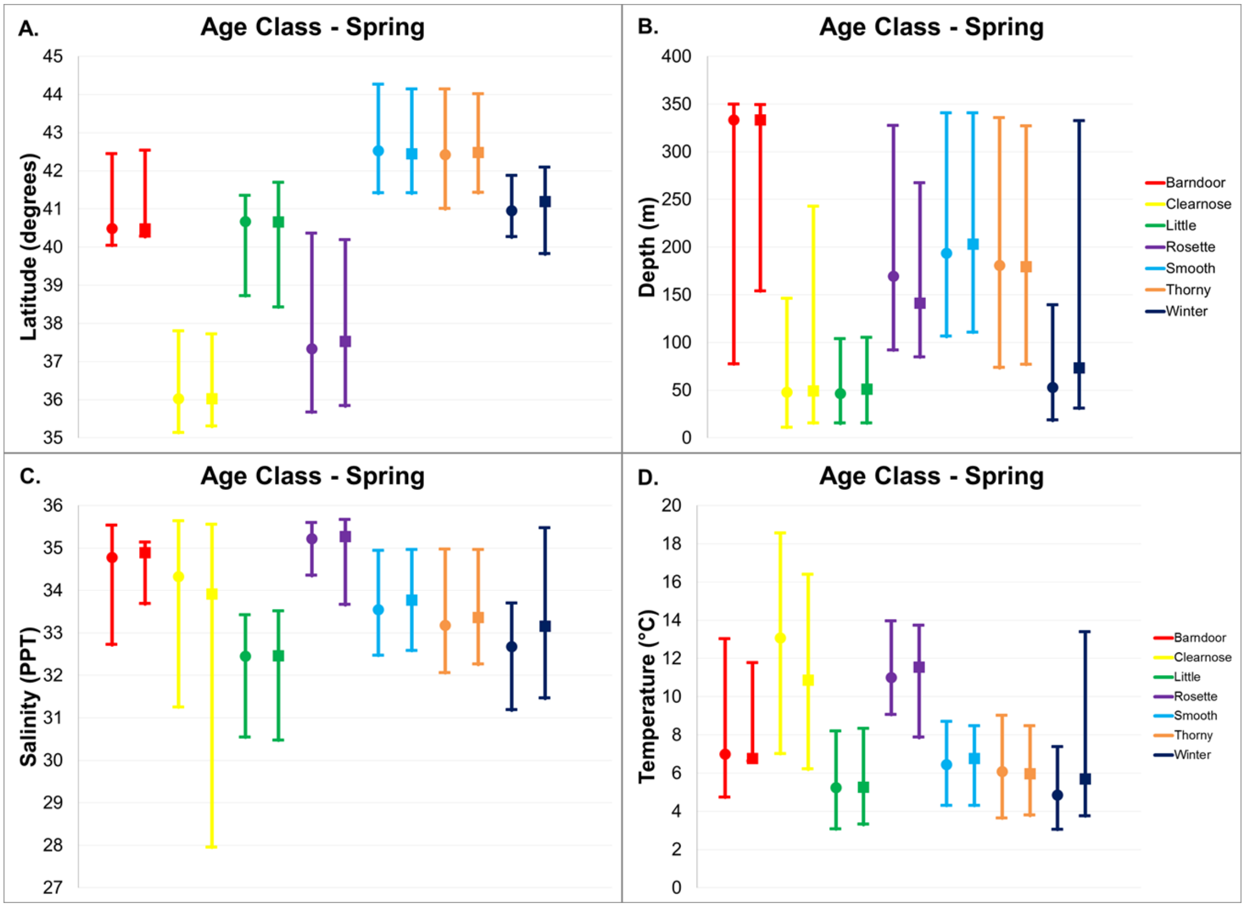


Figure 10. Habitat range for each species' immature and mature groups (circle = immature, square = mature) in spring for each of the four environmental variables; A- Latitude, B- Depth, C- Salinity, D- Temperature. Bars delineate the 5% and 95% occupation based on the CDFs.

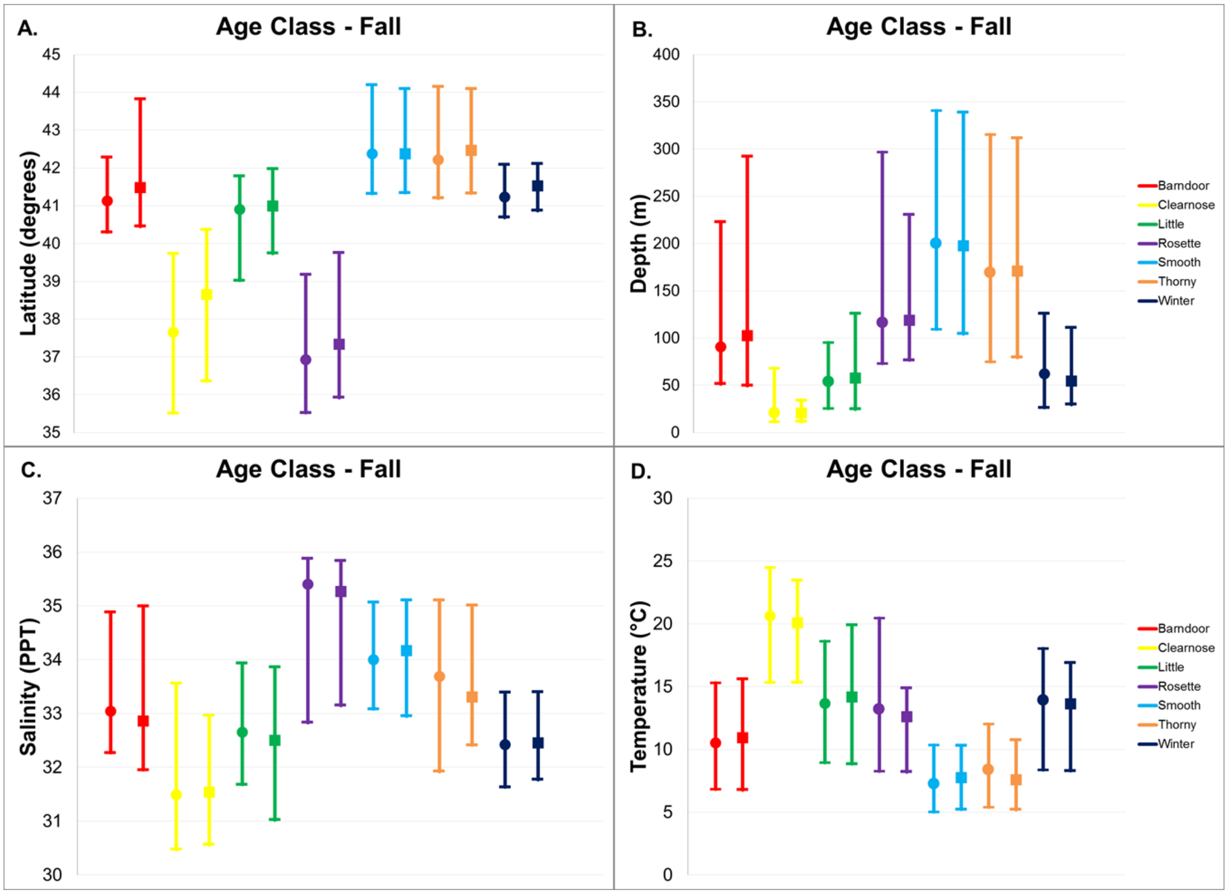


Figure 11. Habitat range for each species' immature and mature groups (circle = immature, square = mature) in fall for each of the four environmental variables; A- Latitude, B- Depth, C- Salinity, D- Temperature. Bars delineate the 5% and 95% occupation based on the CDFs.

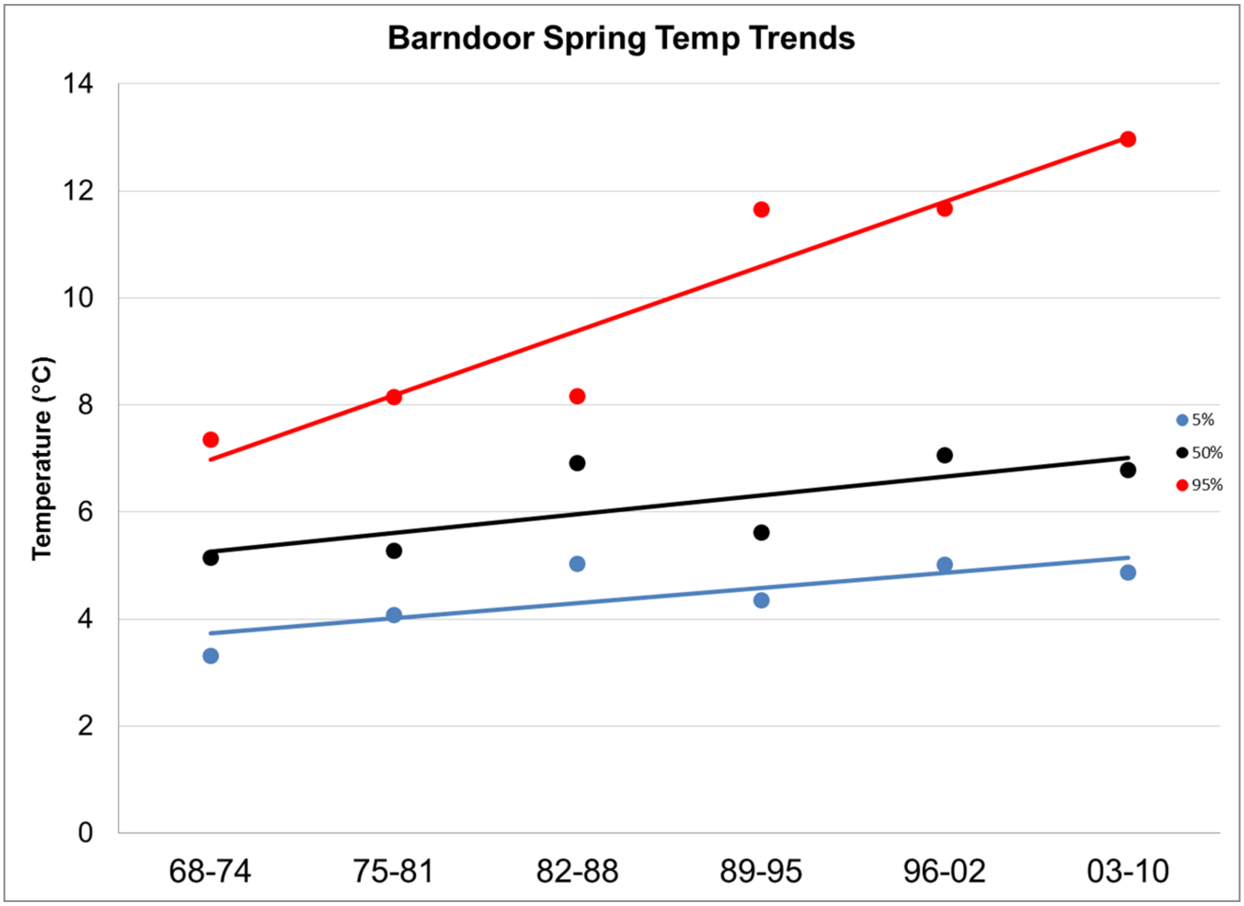


Figure 12. Spring temporal trends in occupied barndoor skate temperature ranges values. 5% (line: $y = 0.2831x + 3.4507$, $R^2 = 0.6174$, $p = 0.064$), 50% (line: $y = 0.3509x + 4.9053$, $R^2 = 0.5527$, $p = 0.09$), 95% (line: $y = 1.2043x + 5.78$, $R^2 = 0.9013$, $p = 0.003$).

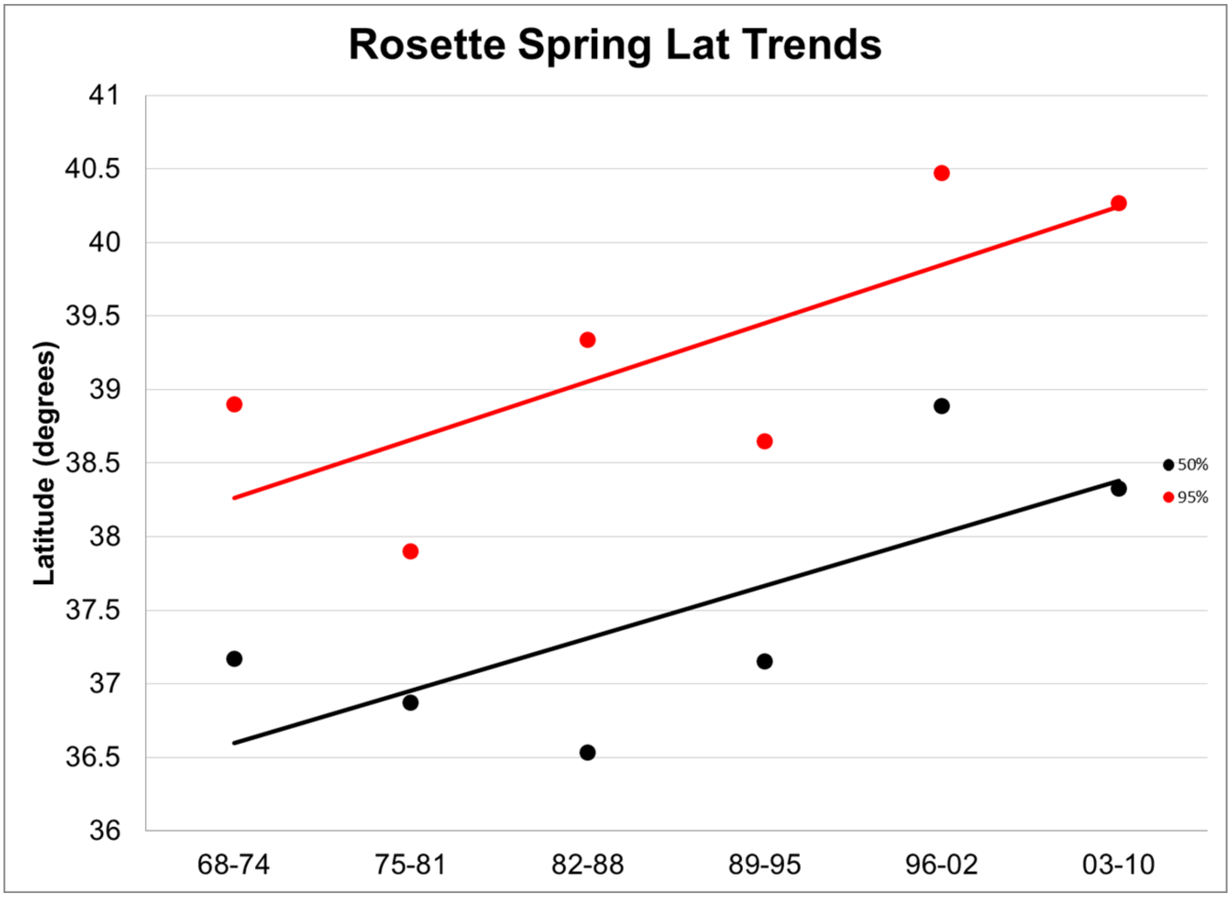


Figure 13. Spring temporal trends in occupied rosette skate latitudinal range values. 50% (line: $y = 0.3566x + 36.242$, $R^2 = 0.5311$, $p = 0.1$), 95% (line: $y = 0.3963x + 37.868$, $R^2 = 0.5676$, $p = 0.08$).

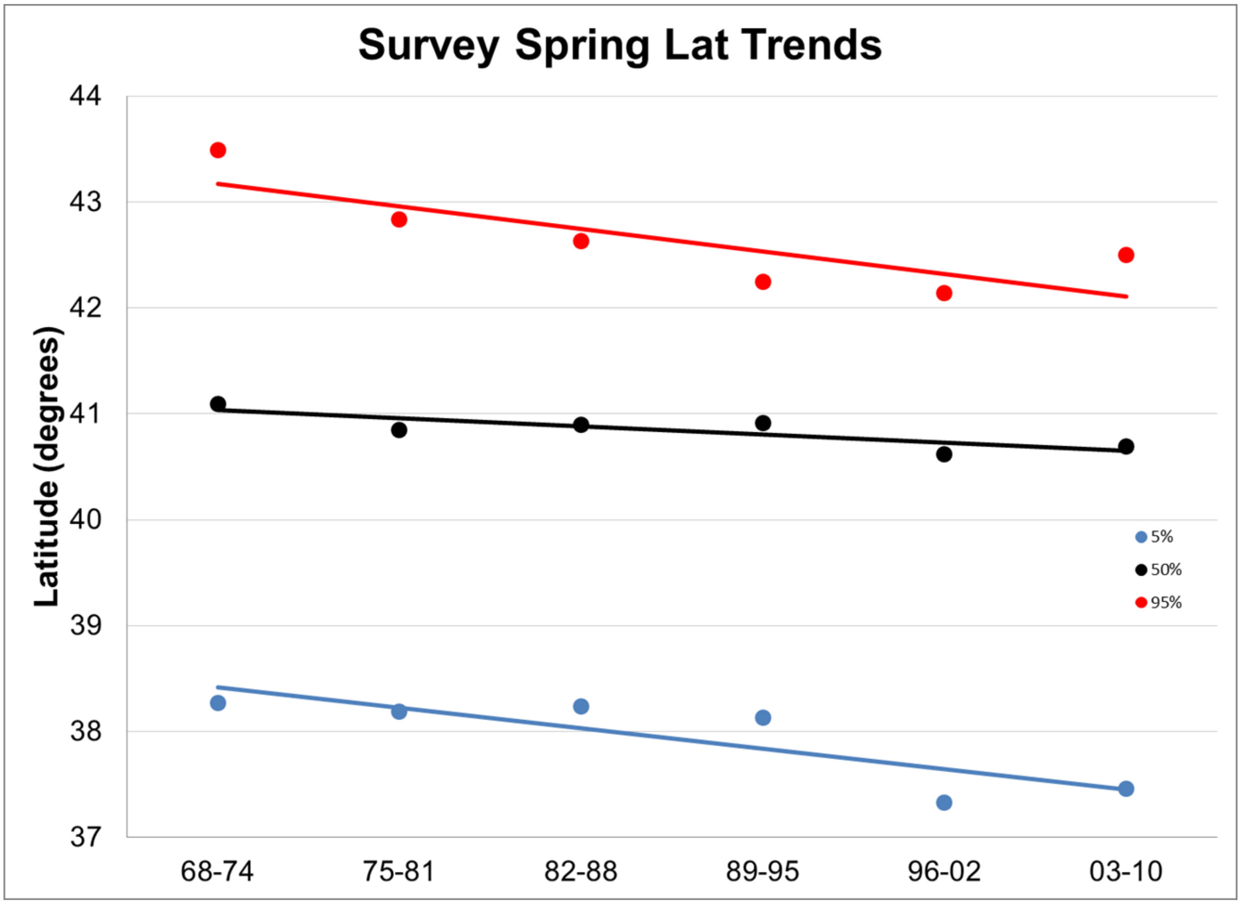


Figure 14. Spring temporal survey latitudinal trends. 5% (line: $y = -0.1926x + 38.611$, $R^2 = 0.7211$, p= 0.03), 50% (line: $y = -0.0766x + 41.111$, $R^2 = 0.7229$, p= 0.032), 95% (line: $y = -0.2123x + 43.385$, $R^2 = 0.6659$, p = 0.048).

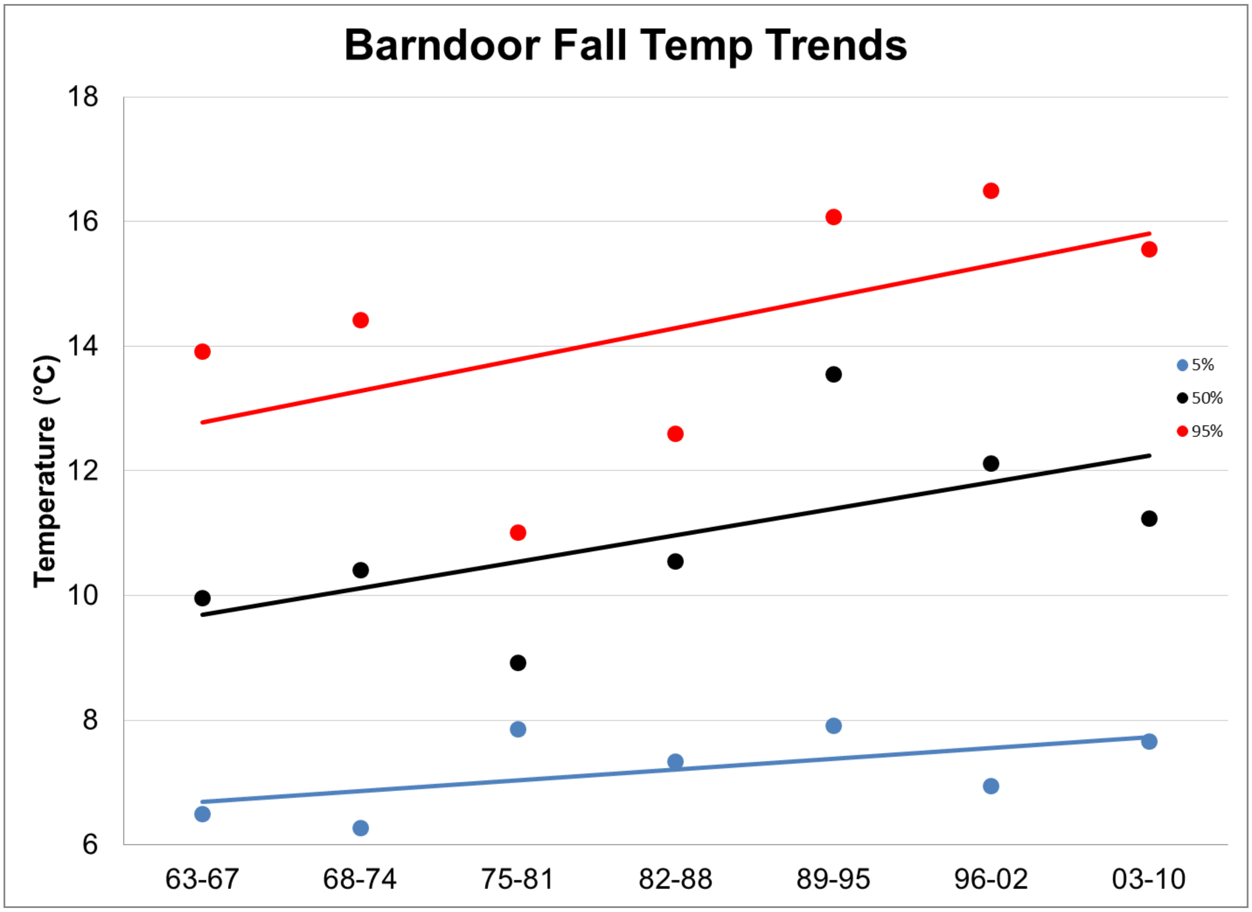


Figure 15. Fall temperature trends in the 3 occupied habitat values for barndoor skate (5% (line: $y = 0.1739x + 6.5143$, $R^2 = 0.327$, $p = 0.179$), 50% (line: $y = 0.4246x + 9.2657$, $R^2 = 0.3668$, $p = 0.149$), 95% (line: $y = 0.5046x + 12.274$, $R^2 = 0.3042$, $p = 0.199$)).

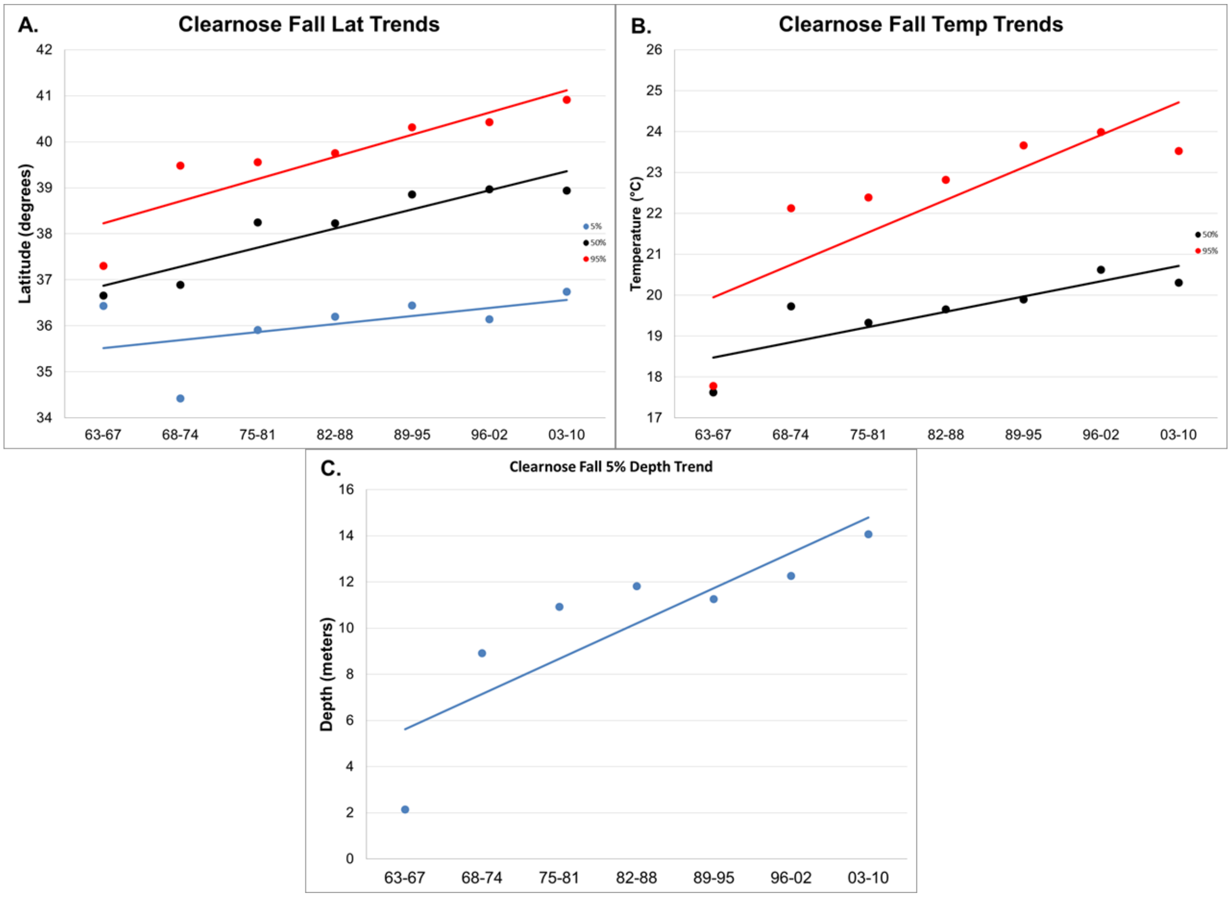


Figure 16. Fall temporal trends in occupied clearnose skate latitude (A. 5% (line: y = 0.175x + 35.34, $R^2 = 0.2465$, p = 0.257), 50% (line: y = 0.4146x + 36.456, $R^2 = 0.8572$, p = 0.002), 95% (line: y = 0.4814x + 37.751, $R^2 = 0.7918$, p = 0.007)), temperature (B. 50% (line: y = 0.3721x + 18.106, $R^2 = 0.6867$, p = 0.02), 95% (line: y = 0.7943x + 19.151, $R^2 = 0.6555$, p = 0.027)) and depth (C. 5% (line: y = 1.5289x + 4.0814, $R^2 = 0.7268$, p=0.014)) range values.

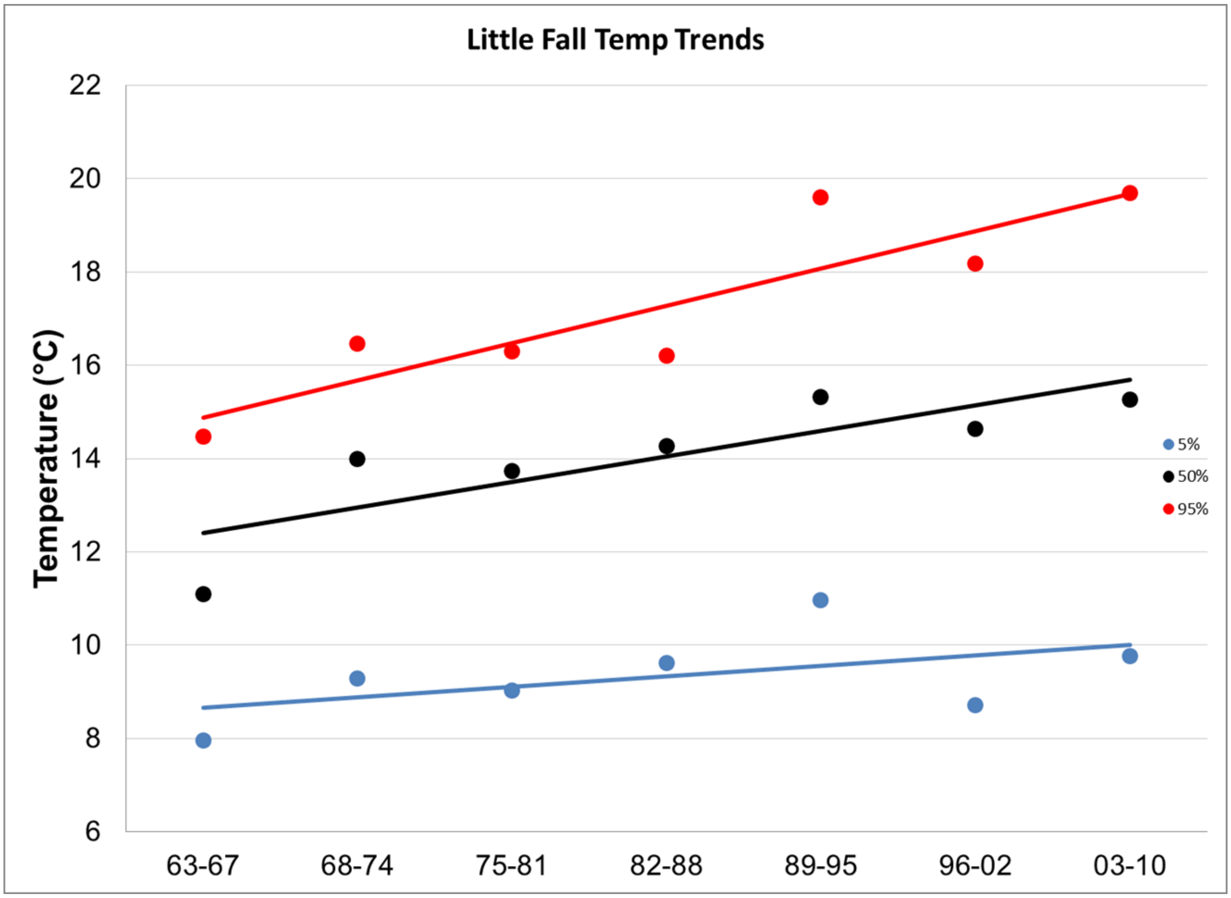


Figure 17. Fall temporal trends in occupied little skate temperature range values. 5% (line: $y = 0.2232x + 8.4386$, $R^2 = 0.2624$, $p = 0.239$), 50% (line: $y = 0.5479x + 11.853$, $R^2 = 0.6853$, $p = 0.021$) 95% (line: $y = 0.7996x + 14.08$, $R^2 = 0.7888$, $p = 0.007$).

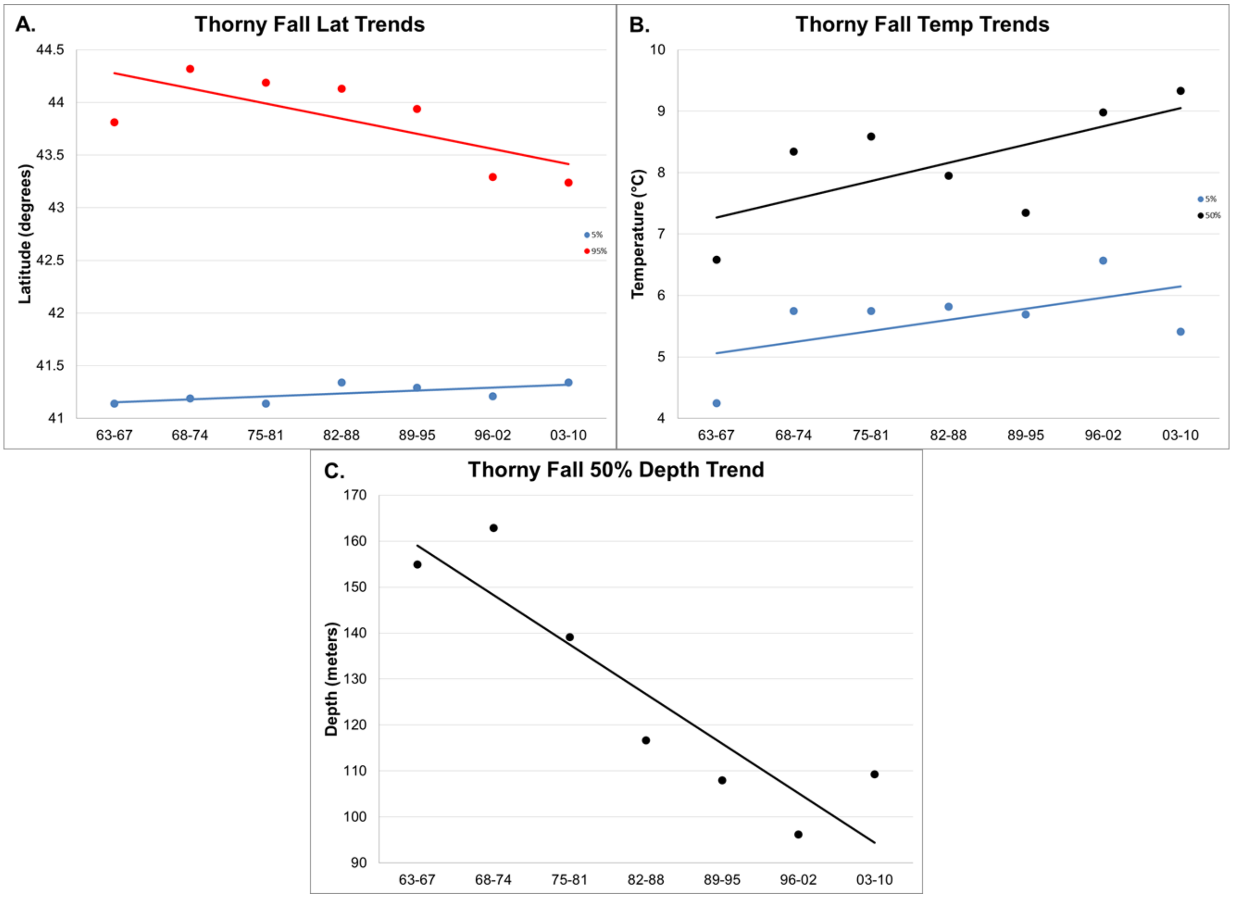


Figure 18. Fall temporal trends in occupied thorny skate latitudinal (A. 5% (line: $y = 0.0282x + 41.123$, $R^2 = 0.487$, $p = 0.08$), 95% (line: $y = -0.1436x + 44.42$, $R^2 = 0.5199$, $p = 0.067$)), temperature (B. 5% (line: $y = 0.1807x + 4.8829$, $R^2 = 0.3152$, $p = 0.189$), 50% (line: $y = 0.2961x + 6.9757$, $R^2 = 0.4499$, $p = 0.099$)) and depth (C. 50% (line: $y = -10.759x + 169.75$, $R^2 = 0.8222$, $p = 0.004$)) range values.

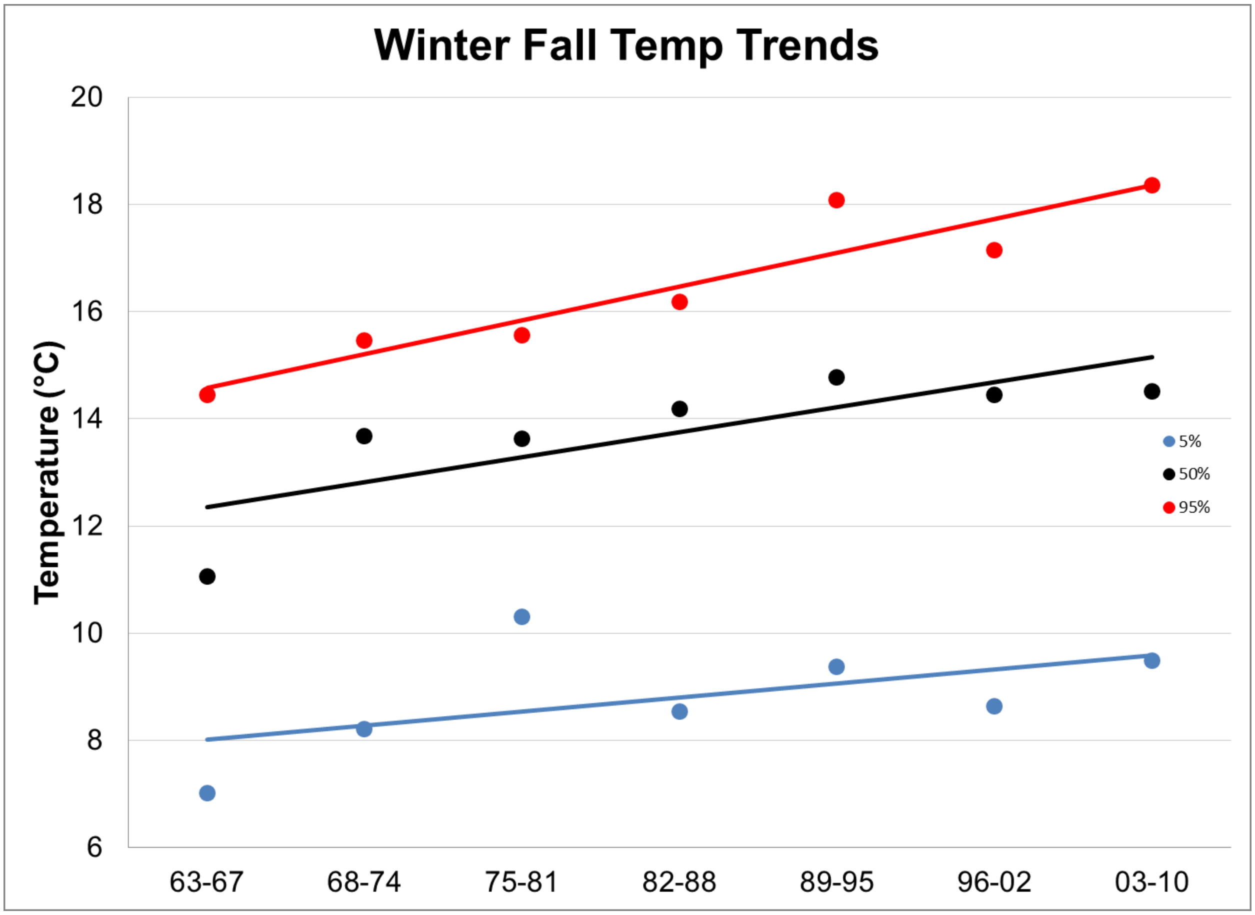


Figure 19. Fall temporal trends in occupied winter skate temperature range values. 5% (line: $y = 0.2611x + 7.7543$, $R^2 = 0.2857$, $p = 0.21$), 50% (line: $y = 0.465x + 11.896$, $R^2 = 0.6331$, $p = 0.032$), 95% (line: $y = 0.63x + 13.943$, $R^2 = 0.8779$, $p = 0.0019$).

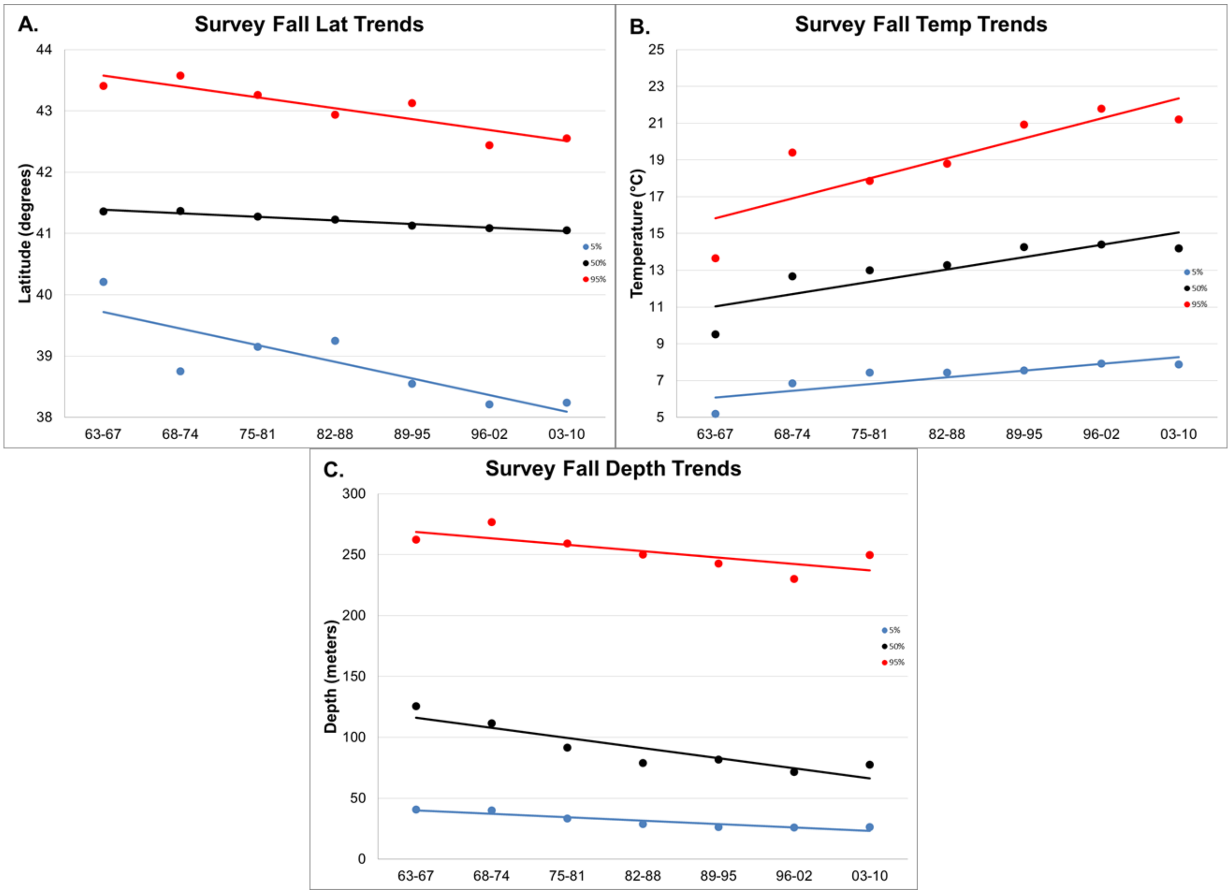


Figure 20. Fall temporal trends in survey latitudinal (A. 5% (line: $y = -0.2711x + 39.993$, $R^2 = 0.6957$, $p = 0.0196$), 50% (line: $y = -0.0586x + 41.45$, $R^2 = 0.9647$, $p = 0.0001$), 95% (line: $y = -0.1782x + 43.757$, $R^2 = 0.8122$, $p = 0.0055$)), temperature (B. 5% (line: $y = 0.3679x + 5.7086$, $R^2 = 0.7065$, $p = 0.018$), 50% (line: $y = 0.6704x + 10.369$, $R^2 = 0.7274$, $p = 0.015$), 95% (line: $y = 1.0875x + 14.74$, $R^2 = 0.7145$, $p = 0.0167$)) and depth (C. 5% (line: $y = -2.8289x + 43.009$, $R^2 = 0.8664$, $p = 0.002$), 50% (line: $y = -8.3125x + 124.56$, $R^2 = 0.8108$, $p = 0.006$), 95% (line: $y = -5.2714x + 274.12$, $R^2 = 0.5791$, $p = 0.047$)) range values.

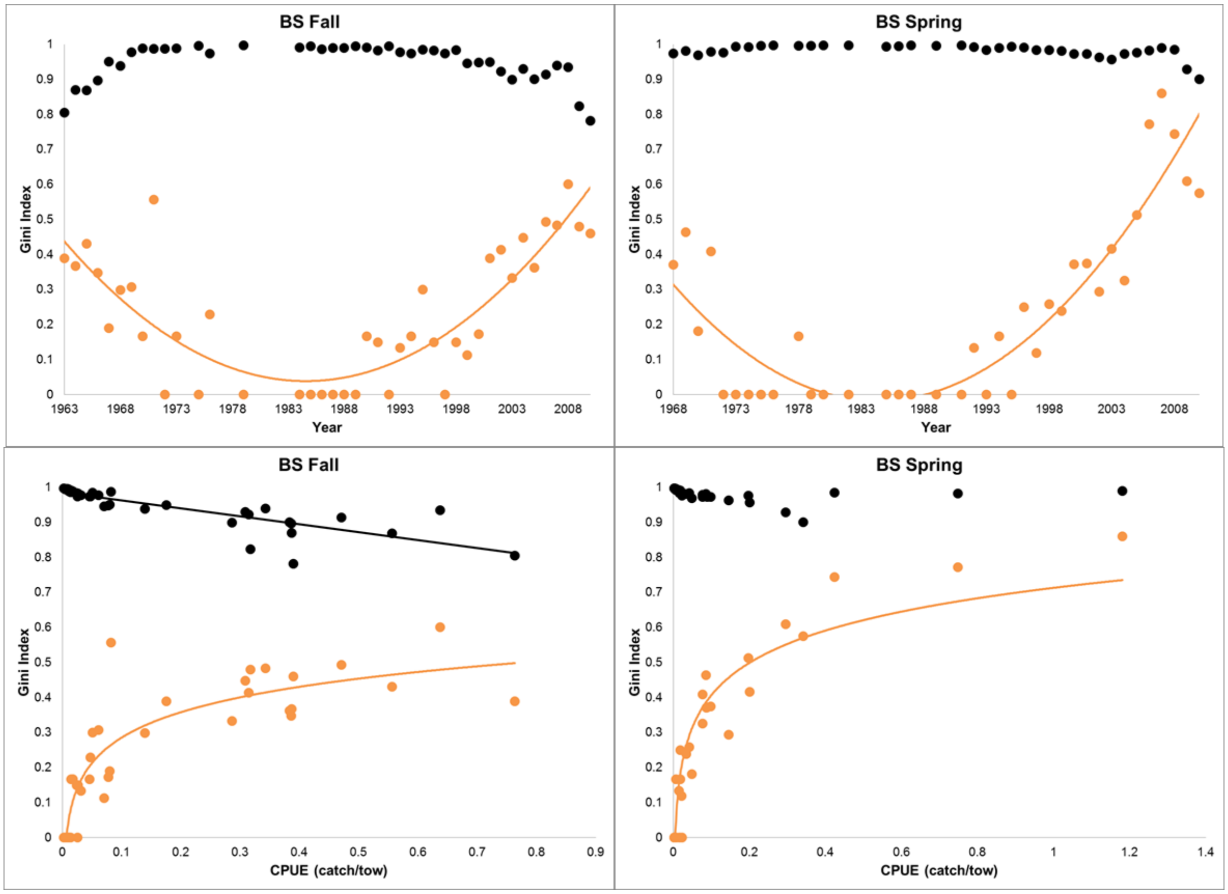


Figure 21. Seasonal Gini index values for barndoor skate aggregation within the domain (black) and within the population (orange) vs time and CPUE. (Fall barndoor vs year Population, $y = 0.0009x^2 - 3.4035x + 3377.3$, $R^2 = 0.7059$) (Fall barndoor vs CPUE Domain, $y = -0.2262x + 0.9858$, $R^2 = 0.6925$, $p = 0.0001$) (Fall barndoor vs CPUE Population, $y = 0.1045\ln(x) + 0.5264$, $R^2 = 0.8109$, $p=0.0001$)(Spring barndoor vs year Population, $y = 0.0012x^2 - 4.9429x + 4904.2$, $R^2 = 0.8128$) (Spring barndoor vs CPUE Pop, $y = 0.1331\ln(x) + 0.7132$, $R^2 = 0.8931$, $p=0.0001$).

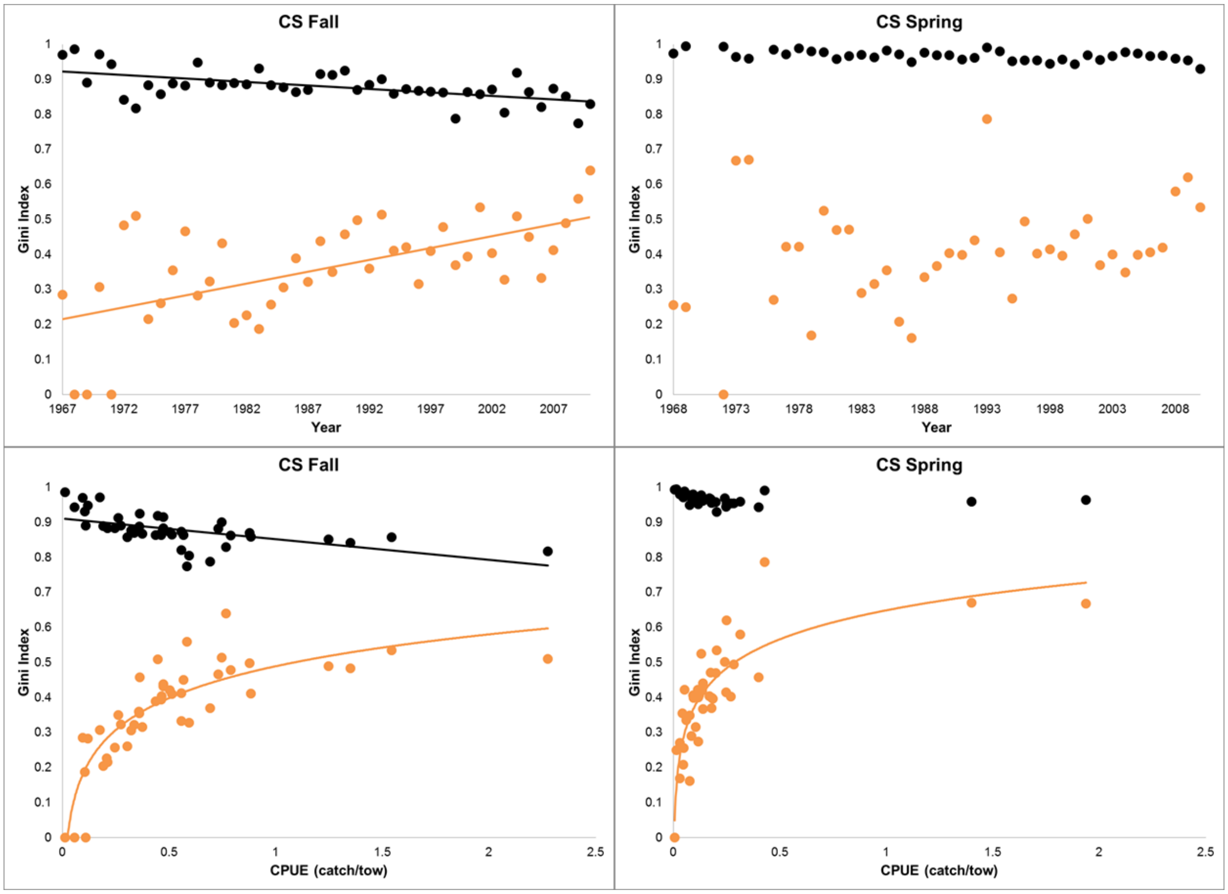


Figure 22. Seasonal Gini index values for clearnose skate aggregation within the domain (black) and within the population (orange) vs time and CPUE (Fall clearnose vs year Domain, $y = -0.002x + 4.8876$, $R^2 = 0.3317$, $p = 0.0001$) (Fall clearnose vs year Population, $y = 0.0068x - 13.122$, $R^2 = 0.3775$, $p = 0.0001$) (Fall clearnose vs CPUE Domain, $y = -0.0589x + 0.9108$, $R^2 = 0.3158$, $p = 0.0001$) (Fall clearnose vs CPUE Population, $y = 0.1313\ln(x) + 0.4894$, $R^2 = 0.7353$, $p=0.0001$) (Spring clearnose vs CPUE Population, $y = 0.1193\ln(x) + 0.649$, $R^2 = 0.7115$, $p=0.0001$).

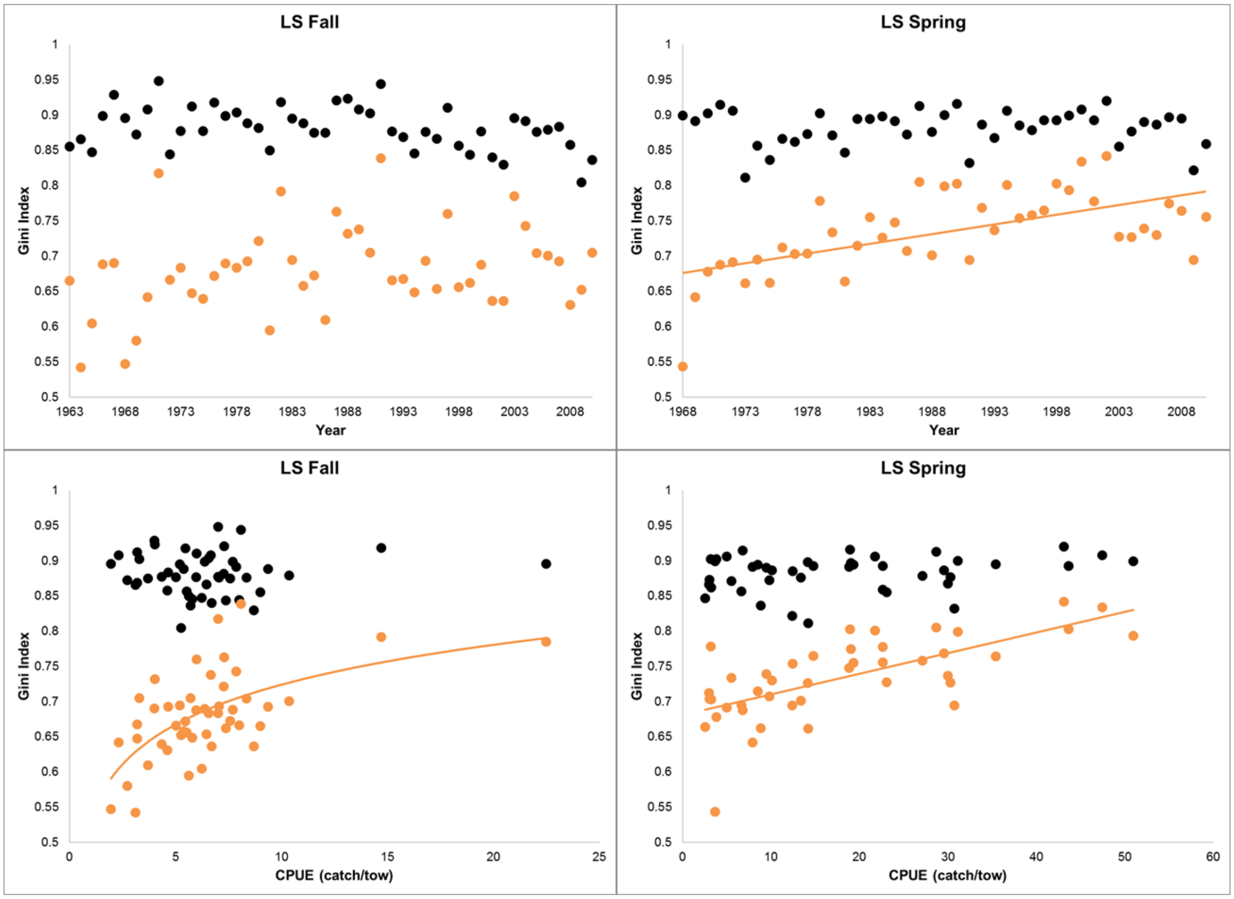


Figure 23. Seasonal Gini index values for little skate aggregation within the domain (black) and within the population (orange) vs time and CPUE (Fall little vs CPUE Population, $y = 0.0817\ln(x) + 0.5361$, $R^2 = 0.3534$, $p=0.0001$)(Spring little vs year Population, $y = 0.0028x - 4.7483$, $R^2 = 0.3711$, $p = 0.0001$) (Spring little vs CPUE Population, $y = 0.0029x + 0.6811$, $R^2 = 0.462$, $p= 0.0001$).

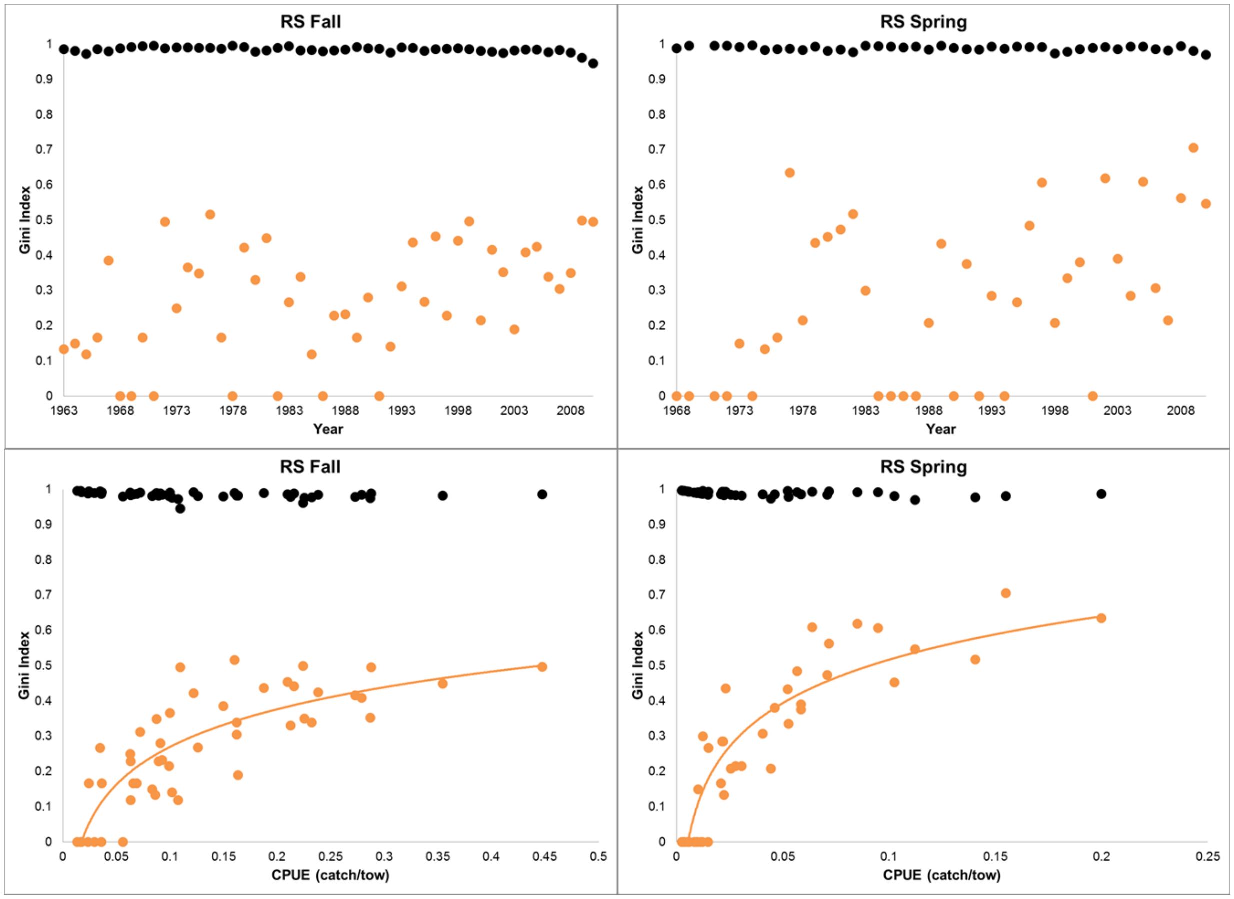


Figure 24. Seasonal Gini index values for rosette skate aggregation within the domain (black) and within the population (orange) vs time and CPUE. (Fall rosette vs CPUE Population, $y = 0.1539\ln(x) + 0.6244$, $R^2 = 0.6897$, $p=0.0001$) (Spring rosette vs CPUE Population, $y = 0.1775\ln(x) + 0.926$, $R^2 = 0.8236$, $p=0.0001$).

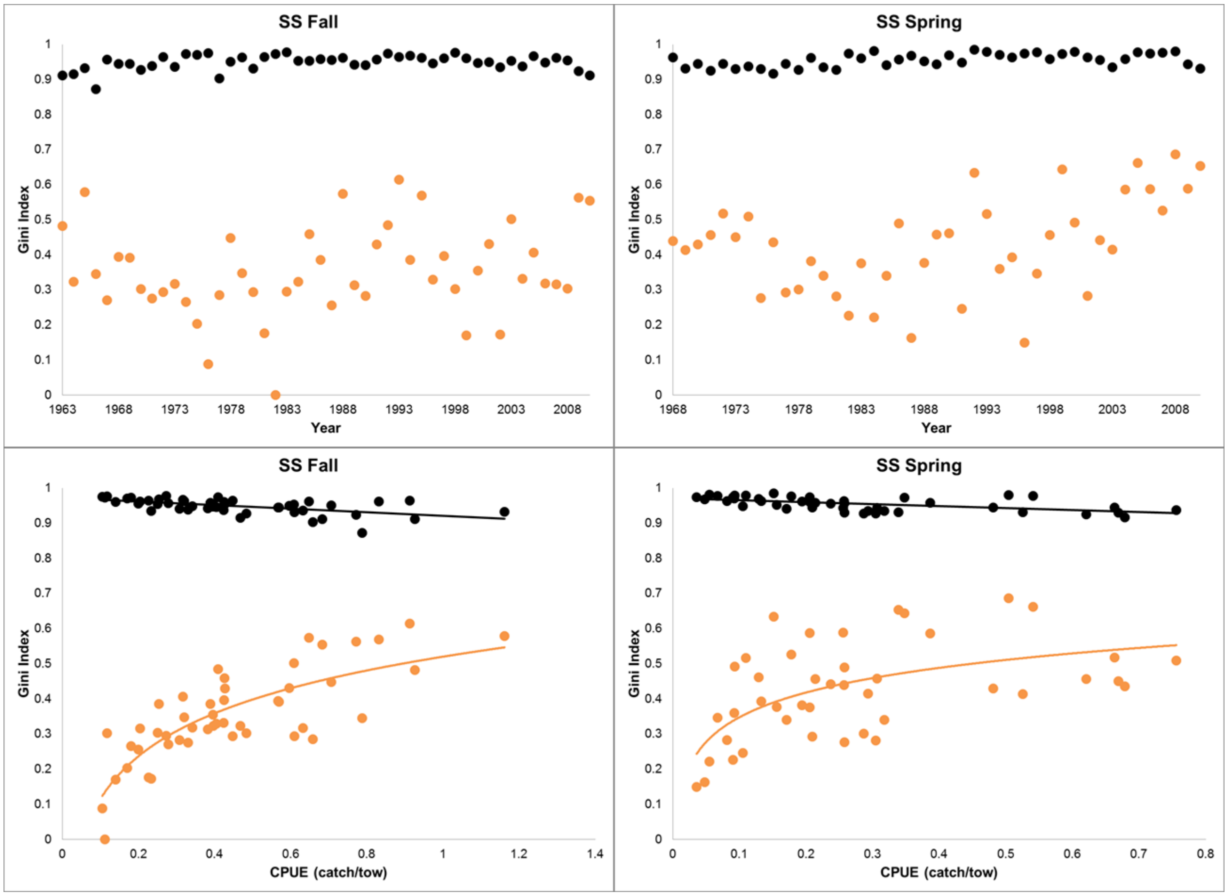


Figure 25. Seasonal Gini index values for smooth skate aggregation within the domain (black) and within the population (orange) vs time and CPUE. (Fall smooth vs CPUE Domain, y = -0.0504x + 0.9718, R² = 0.3183, p = 0.0001) (Fall smooth vs CPUE Population, y = 0.1759ln(x) + 0.5202, R² = 0.6322, p=0.0001) (Fall smooth vs CPUE Domain, y = -0.056x + 0.9708, R² = 0.3229, p = 0.0001) (Spring smooth vs CPUE Population, y = 0.1013ln(x) + 0.5812, R² = 0.3245, p=0.0001).

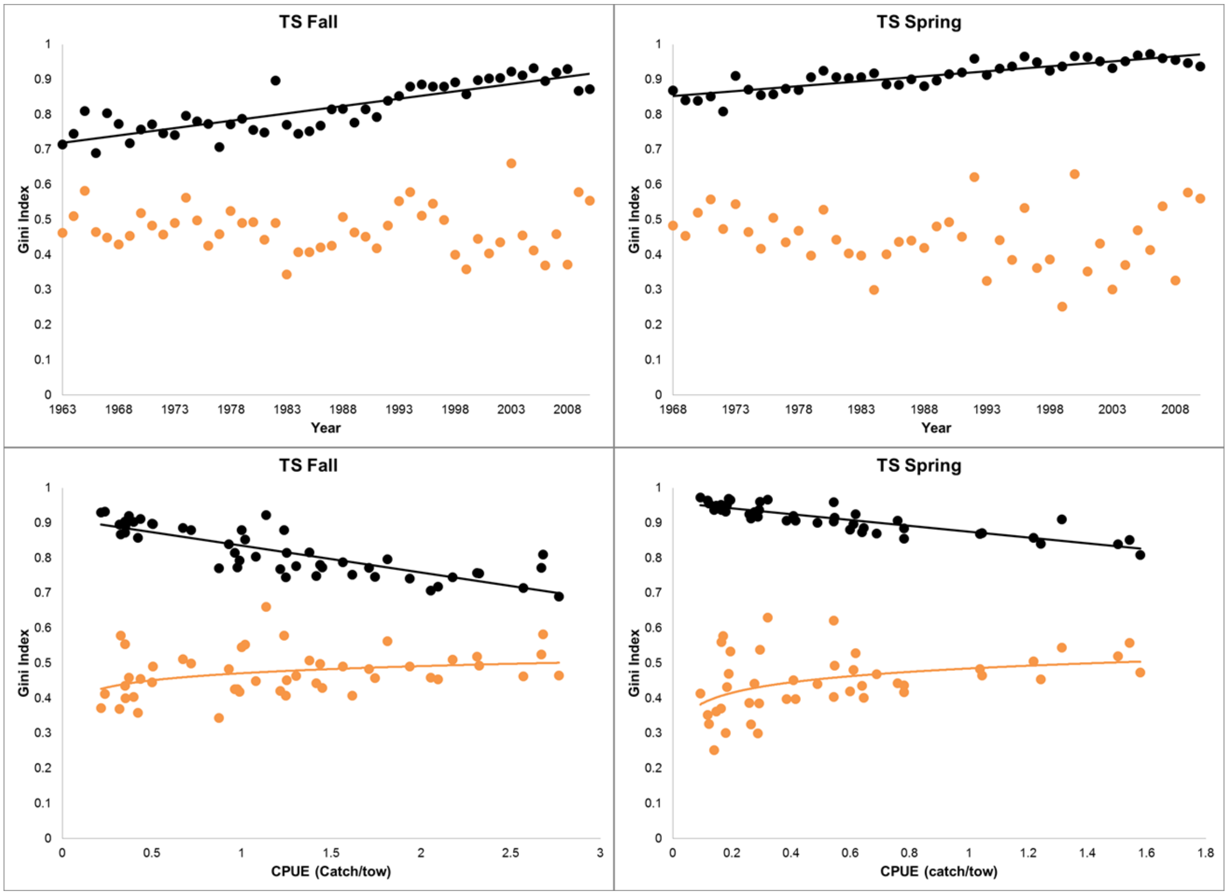


Figure 26. Seasonal Gini index values for thorny skate aggregation within the domain (black) and within the population (orange) vs time and CPUE. (Fall thorny vs year Domain, $y = 0.0042x - 7.4945$, $R^2 = 0.7155$, $p = 0.0001$) (Fall thorny vs CPUE Domain, $y = -0.0769x + 0.9131$, $R^2 = 0.6727$, $p = 0.0001$) (Fall thorny vs CPUE Population, $y = 0.0293\ln(x) + 0.4716$, $R^2 = 0.1052$, $p=0.025$)(Spring thorny vs year Domain, $y = 0.0028x - 4.7434$, $R^2 = 0.7519$, $p = 0.0001$) (Spring thorny vs CPUE Domain, $y = -0.0832x + 0.9585$, $R^2 = 0.7387$, $p=0.0001$) (Spring thorny vs CPUE Population, $y = 0.0431\ln(x) + 0.4851$, $R^2 = 0.1627$, $p=0.007$).

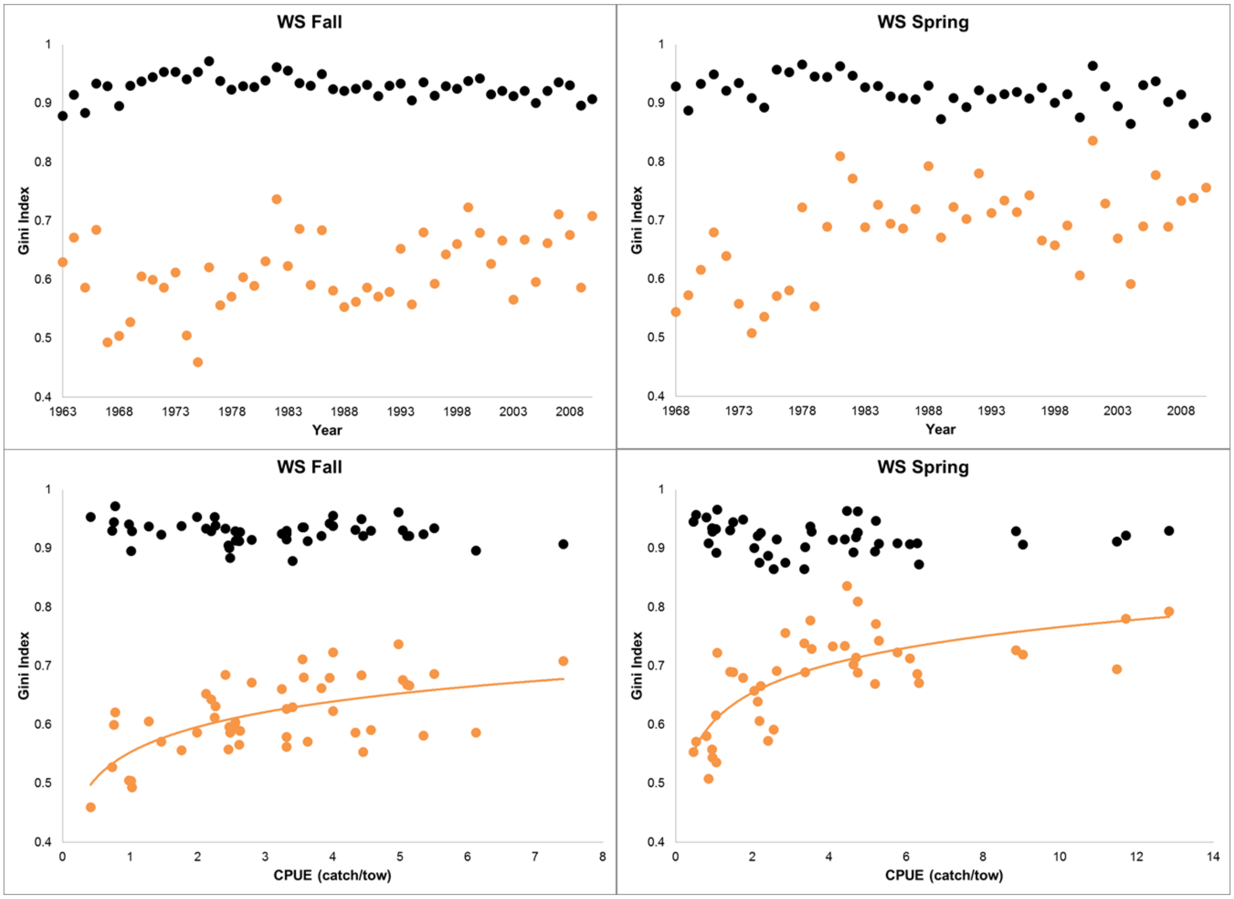


Figure 27. Seasonal Gini index values for winter skate aggregation within the domain (black) and within the population (orange) vs time and CPUE. (Fall winter vs CPUE Population, $y = 0.0623\ln(x) + 0.553$, $R^2 = 0.3953$, $p = 0.0001$) (Spring winter vs CPUE Population, $y = 0.0693\ln(x) + 0.6067$, $R^2 = 0.5387$, $p=0.0001$).

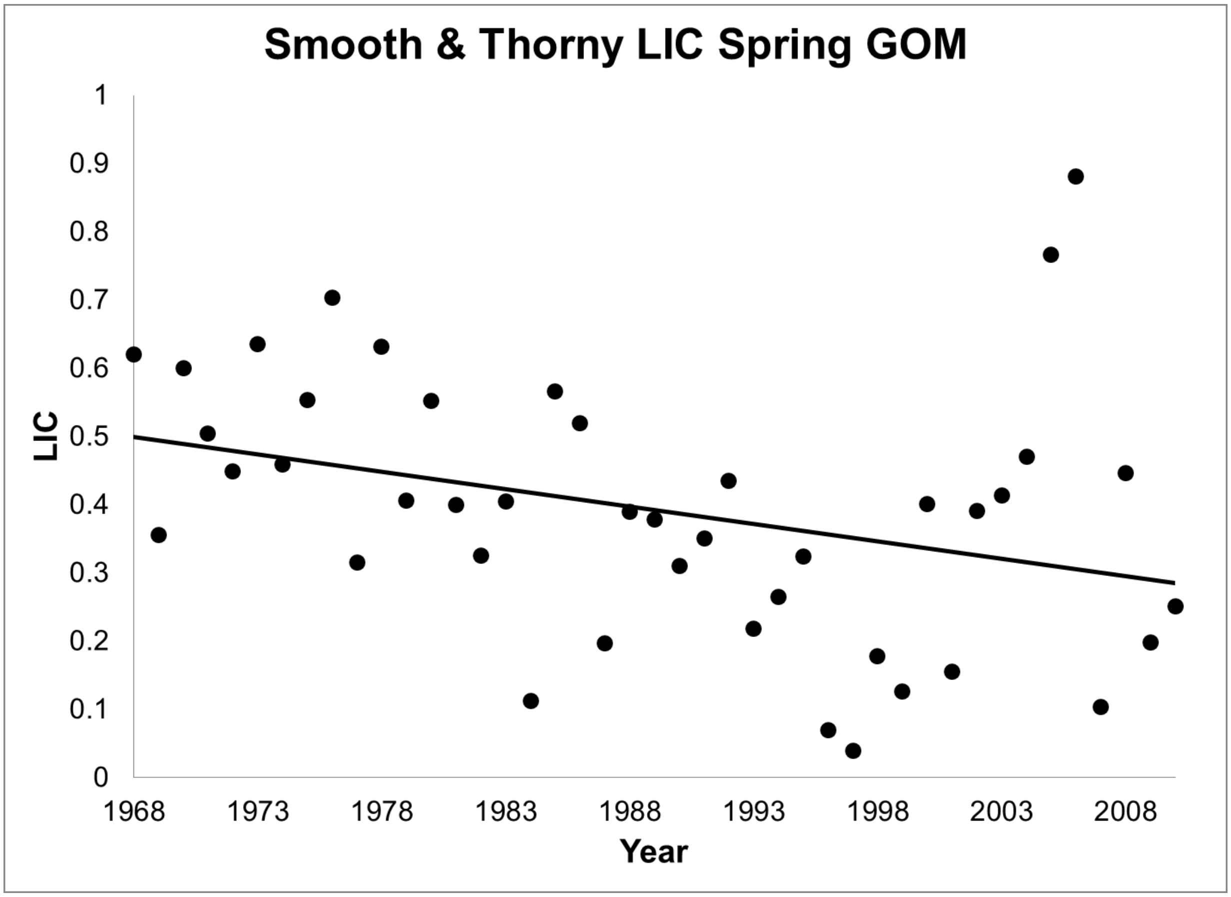


Figure 28. Spring LIC values for smooth & thorny skates in the Gulf of Maine ($y = -0.0051x + 10.574$, $R^2 = 0.1121$, $p = 0.028$).

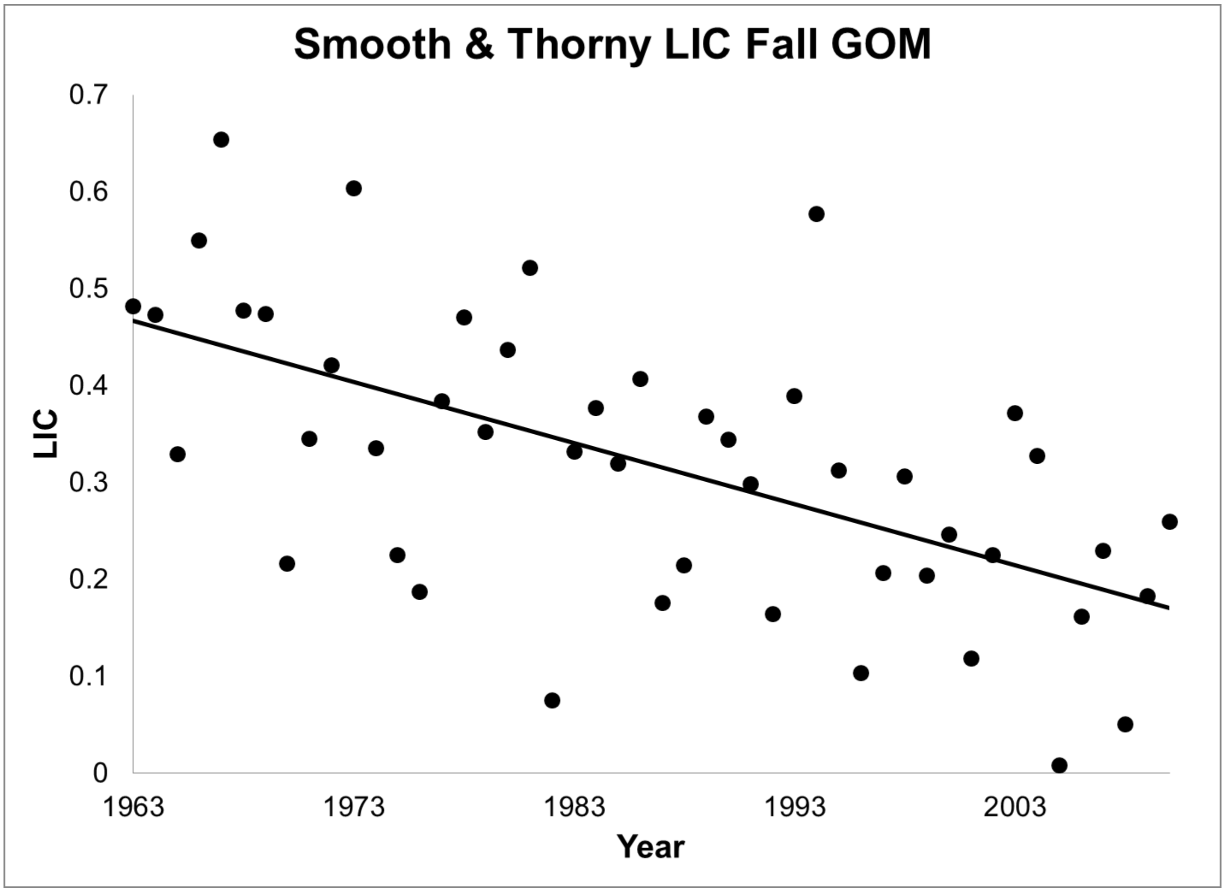


Figure 29. Fall LIC values for smooth vs thorny skate in the Gulf of Maine (y = -0.0063x + 12.826, $R^2 = 0.3541$, p = 0.0001).

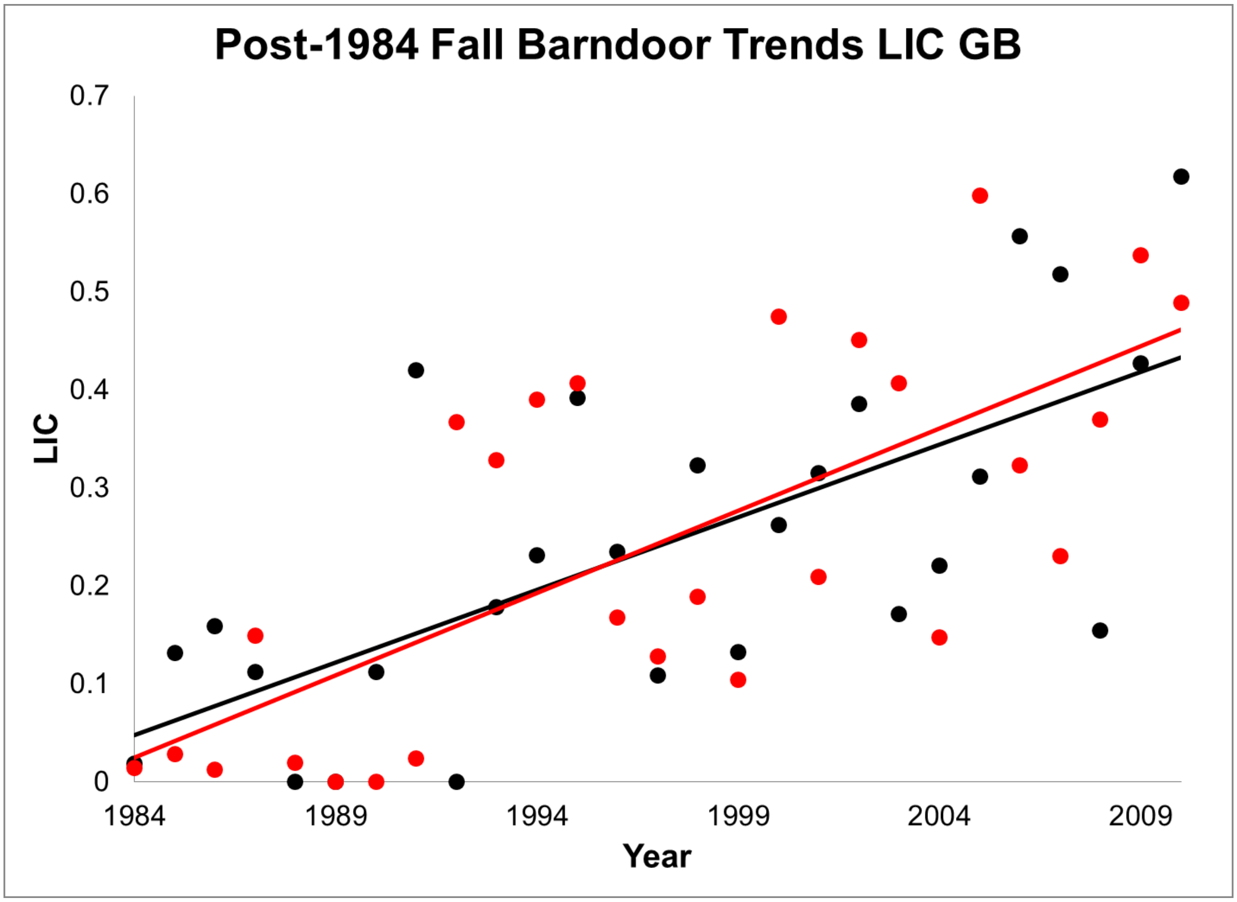


Figure 30. Fall LIC values for barndoor & little (black (y = 0.0148x - 29.336, R² = 0.4676, p = 0.0001) and barndoor & winter skate (red (y = 0.0168x - 33.261, R² = 0.5017, p = 0.0001) from 1984 to 2010 on George's Bank.

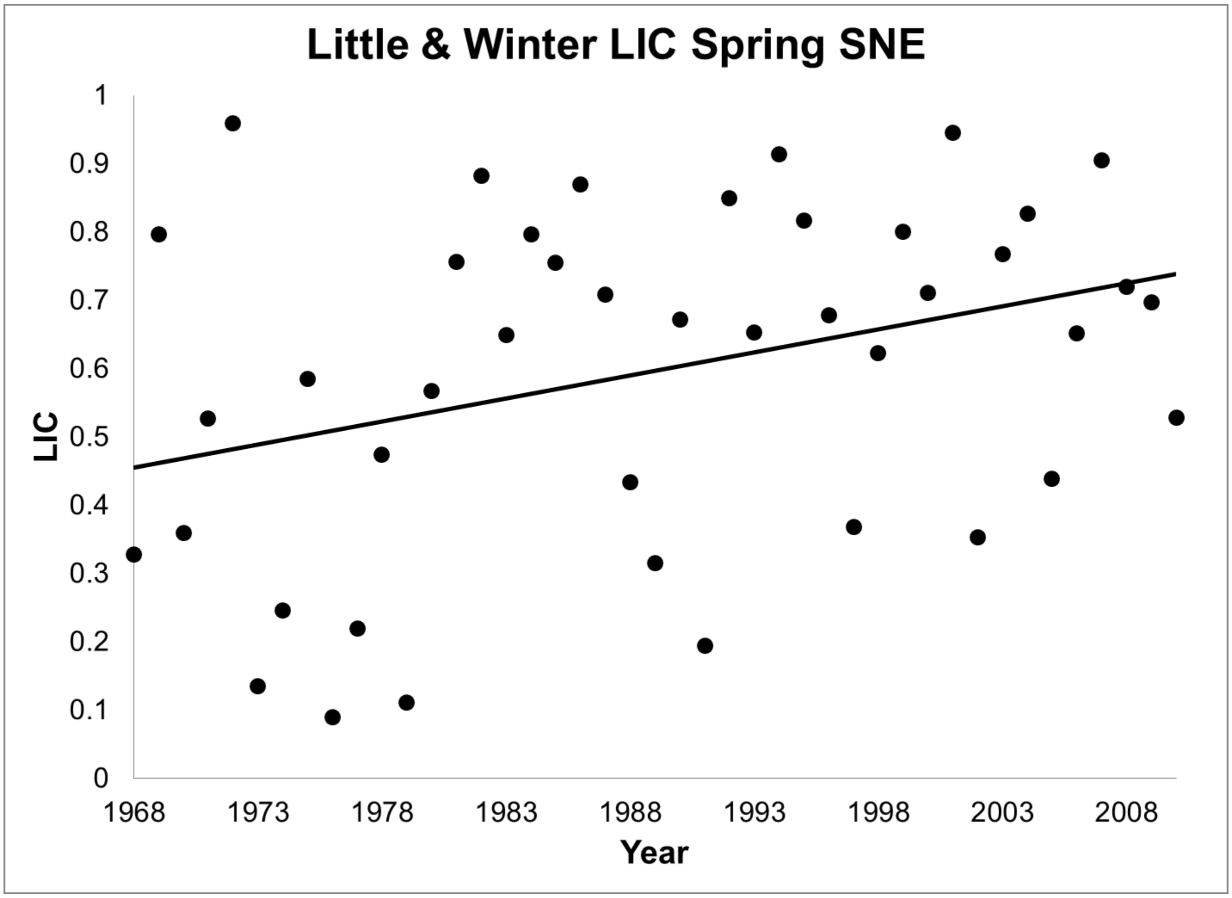


Figure 31. Spring LIC values for little & winter skate ($y = 0.0067x - 12.824$, $R^2 = 0.1172$, $p = 0.025$) in Southern New England.

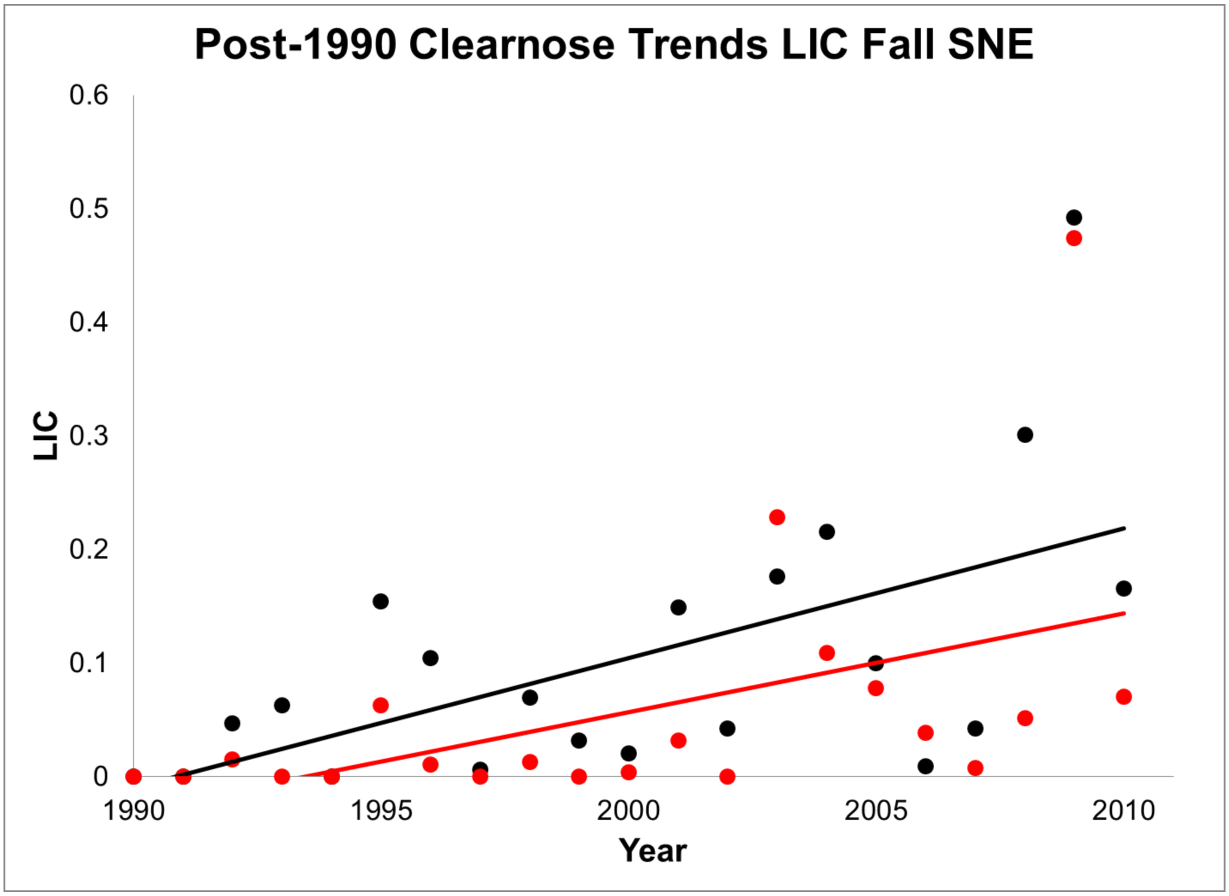


Figure 32. LIC value trends for clearnose & little (black (y = 0.0114x - 22.718, R² = 0.3426, p = 0.0053) and clearnose &winter skates (red (y = 0.0087x - 17.38, R² = 0.2421, p = 0.0235) from 1990 to 2010.

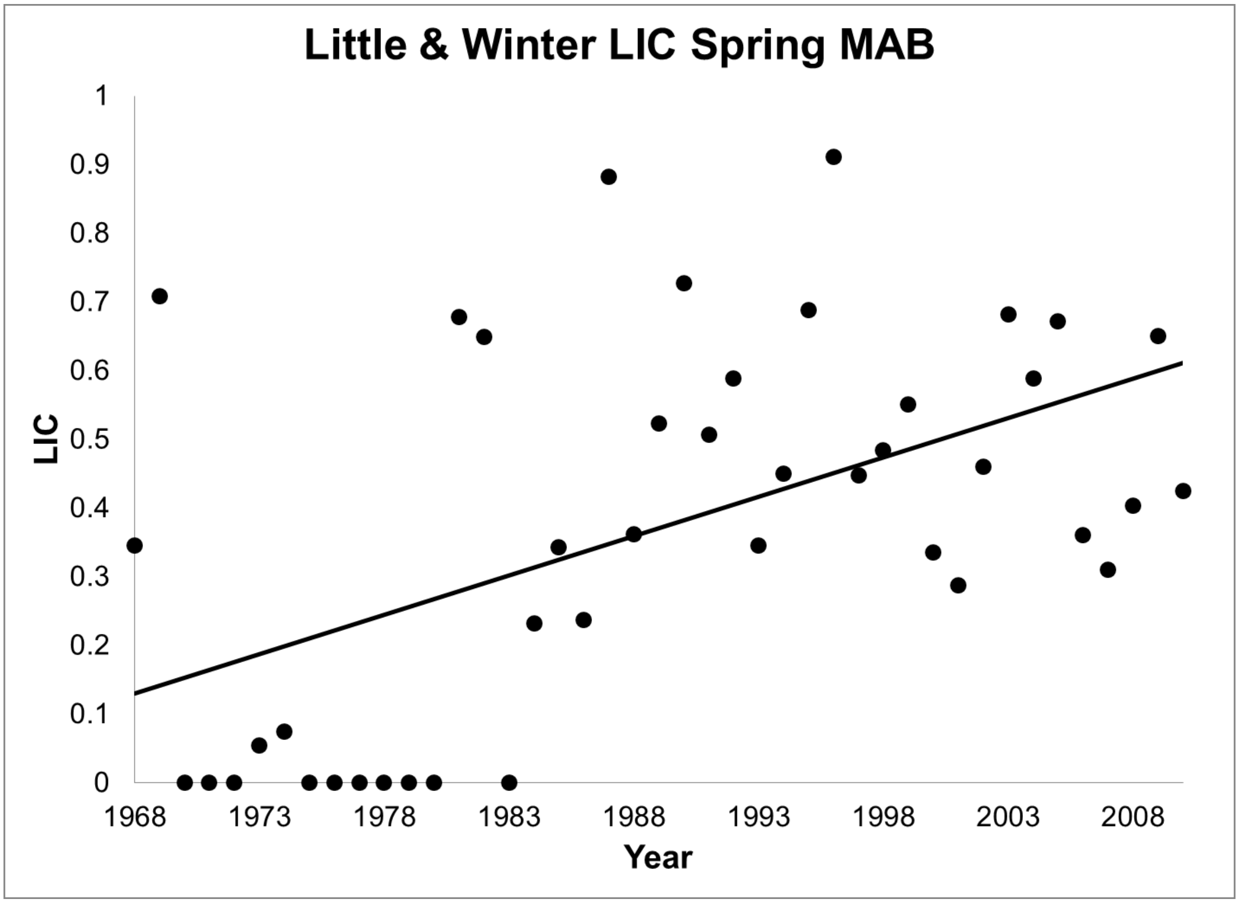


Figure 33. Spring LIC values for little & winter skate ($y = 0.0115x - 22.424$, $R^2 = 0.2757$, $p = 0.0003$) in the Mid-Atlantic Bight.