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NEKTON IN *ZOSTERA MARINA* (EELGRASS) BEDS AND BARE SOFT-SEDIMENT BOTTOM ON THE ATLANTIC COAST OF NOVA SCOTIA, CANADA: SPECIES-SPECIFIC DENSITY AND DATA CALIBRATIONS FOR SAMPLING GEAR AND DAY-NIGHT DIFFERENCES

by

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ABSTRACT

Wong, M.C., Dowd, M., Bravo, M., Giroux, C., Haverstock, A., Humble, M., MacFarlane, M., Roach, S., and Rowsell, J. 2016. Nekton in *Zostera marina* (eelgrass) beds and bare soft-sediment bottom on the Atlantic Coast of Nova Scotia, Canada: species-specific density and data calibrations for sampling gear and day-night differences. Can. Tech. Rep. Fish. Aquat. Sci. 3155: v + 40 p.

Nekton (i.e., fish and large decapods) are an important component of coastal ecosystems, and knowledge of their density and assemblage structure can provide important insight into ecosystem dynamics. Here we present the results of field surveys of nekton in *Zostera marina* L. (eelgrass) beds and bare soft-sediment bottom on the Atlantic coast of Nova Scotia, Canada. These data will be used as input for a model to determine fish production derived from coastal habitats which is currently being developed. Visual snorkel and trawl transects were used to identify the nekton species present and their density (per m^2). All captured fish were measured and age was determined using length-age information from the regional literature. Calibration ratios to account for different sampling gear and time of day indicated that snorkel transects underestimated densities relative to trawls, pelagic species were not sampled by trawls, and some species densities differed between night and day. Calibration ratios were applied to the data to correct for these differences. 22 species of nekton (5 large decapods, 17 fishes) were captured across both habitat types, and of these, nine hold commercial fishery status in the Canadian Maritimes. Although most species were captured in both habitats, densities were much higher in *Z. marina*. The captured nekton were mainly juveniles, although some older age classes were present. This report provides some of the first data of nekton assemblage structure and density in *Z. marina* and bare soft-sediment bottom for Atlantic Canada, and will be used in the future application of a model to determine nekton production derived from coastal habitats.

RÉSUMÉ

Wong, M.C., Dowd, M., Bravo, M., Giroux, C., Haverstock, A., Humble, M., MacFarlane, M., Roach, S., and Rowsell, J. 2016. Présence de necton dans les herbiers de *Zostera marina* (zostère) et le substrat de sédiments mous dénudés sur la côte atlantique de la Nouvelle-Écosse, au Canada: densité propre à l'espèce et étalonnage des données pour l'engin d'échantillonnage et les différentes heures de la journée. Can. Tech. Rep. Fish. Aquat. Sci. 3155: v + 40 p.

Le necton (p.ex. poissons et décapodes de grande taille) est un élément important des écosystèmes côtiers, et les connaissances quant à sa densité et à sa structure d'assemblage peuvent donner un bon aperçu de la dynamique de l'écosystème. Dans le présent document, nous présentons les résultats des études sur le terrain du necton dans les herbiers de *Zostera marina* L. (zostère) et le substrat de sédiments mous dénudés sur la côte atlantique de la Nouvelle-Écosse, au Canada. Ces données seront utilisées pour un modèle, en cours d'élaboration, qui permettra de déterminer la production piscicole découlant des habitats côtiers. La présence des espèces de necton et leur densité (par m^2) ont été déterminées au moyen de transects échantillonnés par plongée avec tuba et par chalut. On a mesuré tous les poissons capturés et on a déterminé leur âge à l'aide de données sur l'âge selon la taille tirées de documents régionaux. D'après les rapports d'étalonnage qui tiennent compte des différents engins d'échantillonnage et des différentes heures de la journée, les transects échantillonnés par plongée sous-estimaient les densités par rapport à ceux échantillonnés par chalut, les espèces pélagiques n'étaient pas échantillonnées par chalut et la densité de certaines espèces variait le jour et la nuit. Des rapports d'étalonnage ont été appliqués aux données afin de corriger ces différences. Dans les deux types d'habitats, on a capturé 22 espèces de necton (5 décapodes de grande taille et 17 poissons), dont 9 sont visées par la pêche commerciale dans les Maritimes. Bien qu'on ait capturé la plupart des espèces dans les deux habitats, la densité était beaucoup plus élevée dans les herbiers de *Z. marina*. Les espèces de necton capturées constituaient principalement des juvéniles, bien qu'on ait observé certaines classes d'âge supérieures. Les données fournies dans le présent rapport comptent parmi les premières sur la structure d'assemblage et la densité du necton dans les herbiers de *Z. marina* et le substrat de sédiments mous dénudés au Canada atlantique. Elles seront utilisées à l'avenir aux fins d'application d'un modèle pour déterminer la production de necton découlant des habitats côtiers.

INTRODUCTION

Seagrass beds provide multiple ecosystem services, including coastal protection, erosion control, carbon sequestration, water purification, provision of raw materials and food, and the maintenance of fish populations and fisheries (Barbier et al. 2011). The role of seagrass beds and other coastal structured habitats in supporting nekton (i.e., fish and large decapods) assemblages has been a strong research focus for many years (e.g., Heck et al. 1989; Connolly 1994; Edgar and Shaw 1995; Jenkins and Wheatley 1998; Guidetti 2000). Typically, seagrass beds are characterized by higher abundances and diversity of nekton relative to nearby bare soft-sediments that lack structure (Heck et al. 1989; Connolly 1994; Edgar and Shaw 1995; Jenkins and Wheatley 1998; Guidetti 2000; Joseph et al. 2006). Enhanced abundance results in part from the structural complexity of the seagrass plants, which can reduce predator foraging efficiency and provide spatial refuges for prey (Orth et al. 1984; Ryer 1998; Hovel and Lipcius 2001; Wong 2013). Also, the high diversity and production of fauna in seagrass beds provides important food resources for nekton within this habitat (e.g., Burchmore et al. 1984; Edgar and Shaw 1995; Wong et al. 2011; Wong and Dowd 2015). Seagrass beds thus function as nursery and feeding grounds for nekton (Pollard 1984; Beck et al. 2001; Gillanders et al. 2003; Heck et al. 2003) and can make important contributions to offshore fish populations and fisheries (Jackson et al. 2001).

Knowledge of nekton assemblages in coastal ecosystems is essential to fully understand ecosystem function and the provision of ecosystem services. Information of nekton assemblage structure and species-specific abundances can enhance the understanding and prediction of the response of nekton to perturbations (Deegan et al. 2002; Fodrie et al. 2010). Furthermore, knowledge of coastal nekton assemblages is necessary to implement and evaluate management and policy strategies related to conservation, monitoring, and fisheries. In Canada, this information is particularly relevant for the amended Department of Fisheries and Oceans (DFO) Fisheries Act (2012). The Act includes provisions that prohibit serious harm to the productivity of commercial, recreational, and aboriginal (CRA) fisheries, where serious harm is defined as “the death of fish, or the permanent alteration to, or destruction of fish habitat”. Proponents of a project can apply to DFO to authorize serious harm, where the Department will consider (among other factors) contributions to fisheries productivity and the planned mitigation or offsetting of the serious harm. This implies the need for models to predict nekton production derived from habitats for use in compensation activities or as baseline data. We (M.C. Wong and M. Dowd) are currently developing a model framework to estimate nekton production that is relevant for coastal ecosystems (Wong and Dowd in prep.). A strength of this model is that it requires only minimal field data for model input, consisting of species-specific density in one age class. However, despite the importance of coastal habitats in the maintenance of nekton populations, few data for the Atlantic coast of Nova Scotia (NS) are available for the application of this model.

The objective of our study was to determine through field sampling the species-specific densities of nekton in seagrass (*Zostera marina* L., eelgrass) beds and adjacent bare soft-sediment bottom on the Atlantic coast of NS, and to calibrate the data for sampling gear and day-night differences in order to ready the data for use in the production model. The results of this field sampling and data pre-processing are presented in this report. Specifically, we present: (1) the raw and calibrated field data of species-specific nekton densities, in *Z. marina* beds and bare soft-sediment bottom, (2) species-specific calibration ratios used to account for the different sampling gears and differences in nekton density between day and night, (3) size frequency data and literature information used to determine age class of captured nekton, and (4) detailed description of the habitat characteristics and environmental conditions at each sampling site.

MATERIALS AND METHODS

FIELD SITES

Nekton (fish and large decapod) density was sampled in *Zostera marina* (eelgrass) beds and adjacent bare soft-sediment bottom on the Atlantic coast of Nova Scotia, Canada (Figure 1). Eight *Z. marina* beds were sampled along the south shore and eastern shore of NS. At seven sites, adjacent bare soft-sediments were also sampled; at one site (Second Peninsula), nearby bare sediments were not available for sampling. The field sites were purposely chosen to span a gradient of environmental conditions, and ranged from beds in shallow water (~1.5 m deep at mean high tide) with low water exchange and high sediment silt and organic content, to beds in relatively deeper water (~4-6 m deep at mean high tide) with high water exchange and low silt and organic content (Table 1). Additionally, one site (Lower Three Fathom Harbour) was located within a lagoon with highly restricted water exchange, and another (East Petpeswick) on an elevated sand/mud flat adjacent to a channel. At most sites, the *Z. marina* beds were mono-typic and continuous with little fragmentation.

SITE CHARACTERISTICS

Sampling of various site characteristics was conducted in July to August 2013 to coincide with the nekton sampling. Plant and sediment characteristics were sampled using snorkelling or scuba diving depending on the water depth at each site. Ten sampling stations at approximately the same depth within each habitat were haphazardly determined. Stations within the *Z. marina* bed were restricted to be >2m from any seagrass-bare soft-sediment interface (Bologna 2006; Wong and Dowd 2015). All stations were separated by at least 5m. To sample *Z. marina* shoot density, a 0.25 x 0.25m quadrat was placed on the bottom and all shoots within the quadrat were counted. For aboveground biomass samples collected by snorkelers, a 10 cm diameter x 2 cm high PVC ring was placed over the blades within the quadrat, and all shoots were then collected by hand and placed in a plastic bag. A 10 cm diameter x 12 cm deep hand core (with a valve on top to create suction) was then taken within the PVC ring to collect belowground plant components, and placed in a plastic bag. For samples collected by divers, the hand core was open on both ends and so aboveground plant components were pulled up into the core prior to insertion into the sediments to sample belowground plant components. The core was then capped on both ends and transported to the surface. Plant samples were refrigerated 1-3 days until processing. When processed, plant components were rinsed in salt water and separated (if necessary). Aboveground and belowground components were dried separately at 60 °C for 24-48h and weighed to determine dry biomass per m^2 (Duarte and Kirkman 2001). Canopy height was determined at each sampling station by extending a handful of leaves to their maximum height, and measuring the height of the tallest 80% (Duarte and Kirkman 2001).

Cores to determine sediment particle size and organic content were taken at every second sampling station using two 3 cm diameter x 5 cm deep syringe cores (n=5). Both core samples were combined within one plastic bag, frozen for ~1 month prior to analyses, and then thawed and mixed within each plastic bag immediately prior to processing. To determine the percent organic matter within sediments, 1g of each sample was dried at 60°C for 24 – 48 h, weighed to determined total dry mass, combusted at 500°C for 6 h, and reweighed to determine ash mass (Luczak et al. 1997). To determine percent particle size, standard procedures at the Geological Survey of Canada Atlantic's Sedimentology Laboratory were used (O. Brown, Pers. Comm.). Briefly, this procedure began with 5 ml (silty sites) or 6-7 ml (sandy sites) of sediment placed in a Vulcan tube. 1 ml of 35% hydrogen peroxide was added every 2-3 h to remove organic matter. Samples were then dried overnight at 60°C and then at 100°C the following morning for 3h to deactivate the hydrogen peroxide. If the sample contained a gravel fraction, the sample was cooled and then wet sieved on a 2mm sieve to remove gravel particles. Approximately 30 ml of deionized water was added to the remaining sample, which was then centrifuged at 2160 RPM for 90 minutes. The overlying water was decanted, samples frozen overnight, and then freeze-dried for 24-72 h to remove any remaining moisture. Samples were then analyzed using the Beckman Coulter Laser to determine sediment particle size distribution. The gravel fraction determined by sieving was added to the total final weight of the sample, and percent content of gravel, sand, and silt/clay fractions were determined.

Continuous water temperature recordings were measured using temperature loggers (TidbiT v2; Onset Computer Corporation, Bourne, MA, USA) deployed in the *Z. marina* beds. Temperature was assumed similar in the adjacent bare soft-sediment bottom. Mean temperature was calculated from July 16 to August 12 2013, the sampling period.

SAMPLING OF NEKTON ASSEMBLAGES

Nekton assemblages were sampled during the day at mid to high tide by using visual snorkel or trawl transects. The sampling method depended on the site characteristics: shallow sites were sampled using visual snorkel transects, while deeper sites were sampled by trawling (Table 1). At two sites (Crescent Beach and Second Peninsula), both snorkel and trawl transects were conducted to provide calibrations between sampling gear (calibrations described further below).

Trawl transects were conducted using a beam trawl (frame: 1m wide x 0.5m high, net: 3m long and 4 x 4mm mesh openings with knotted end) which was towed by a boat for 50m at an approximate speed of 2km h^{-1}. Two to three replicate transects were sampled at each site and habitat combination. Replicate transects were conducted at least >25m apart to ensure independent sampling. Transects were run using GPS and compass bearings. At the end of each tow, nekton were emptied from the trawl into tanks onboard the boat. Fish and large decapods were identified to species, counted, and measured prior to release.

Visual snorkel transects were conducted by individual observers who snorkeled 30 – 90m long x 1m wide transects. Transects varied in distance according to the different sized beds at each site, although most transects were between 30-60m in length. Preliminary analyses indicated no relationship between area sampled per transect and various nekton measures, including richness, diversity, and species-specific densities. Thus, all transect data were used in subsequent analyses. Transects were swum using GPS and compass bearings. Six to sixteen replicate transects were located >10m within the *Z. marina* bed or bare soft-sediment bottom to avoid any edge effects. Observers slowly swam on the surface at 0.03 – 0.08 m s^{-1}, adjusting swimming speed depending on the *Z. marina* density and canopy height. The top of the *Z. marina* canopy was sometimes gently manipulated to observe cryptic benthic fish. All benthic fishes, pelagic fishes, and large decapods (i.e., crabs and shrimp) were identified, counted and length was estimated. Observer identification and counts were standardized using preliminary training prior to field sampling. For both snorkel and trawl data, the density of nekton per transect was determined for each species by summing the total number observed per transect divided by the total area sampled per transect.

AGE CLASS OF NEKTON

The model input required from field sampling is species-specific abundance (i.e., normalized per unit area, here m^{-2}) of nekton in one age class. All captured nekton were measured and age class was determined using length-age information from the regionally appropriate literature (Table 2). For most species, the majority captured were YOY-Y1 (i.e., one year old or less, hereafter Y1), so Y1 age class was used. For the relatively few cases where some species were observed at multiple age classes, Y1 equivalents were determined using the Leslie-matrix from an age structured population matrix model (i.e., Wong and Dowd in prep.). Spawning location and time of year of spawning was also identified from the literature (Table 2) to determine if smaller larval fish not easily captured in the snorkel or trawl transects were present during the sampling period and subsequently under sampled.

CALIBRATION OF NEKTON DENSITY TO ACCOUNT FOR SAMPLING GEAR DIFFERENCES

The field data of species-specific density per one age class were calibrated to ensure comparability of data from snorkel and trawl transects. Appropriate calibrations were developed by conducting both visual snorkel transects and trawl transects to sample nekton density at two field sites (Crescent Beach where both *Z. marina* and bare soft-sediment bottom were sampled, and Second Peninsula where only *Z. marina* was sampled). Captured nekton were aged according to length and the Y1 equivalents determined as above. The calibration ratios were determined by dividing species-specific mean density determined from snorkel transects by mean density determined from trawl transects, at each site and habitat combination. Calibration ratios were averaged across the two sites where *Z. marina* was sampled. To further ensure the entire nekton assemblage present was sampled, unbaited fyke nets (5.5m long leader with 3.2m long chamber consisting of 5 hoops 0.6m diameter, 4mm x 4mm mesh) were also deployed for 24h at each site (n = 2-3). These data were used to account for species observed in fyke nets but not in trawls or snorkel transects. Fishing area of the fyke nets was estimated based on literature information for specific species when necessary (see references in Table 5). Species-specific calibrations for sampling gear differences are discussed in further detail in the results section.

ACCOUNTING FOR NEKTON DENSITY AT NIGHT

Field sampling was conducted during the daytime, and so the data required calibration to account for differences in nekton densities that might occur at night. To do this, additional replicate trawls (n=6) were conducted in July 2014 (using the methods described above) in the day and at night in the *Z. marina* bed at one field site (Crescent Beach). Captured nekton were aged by length and Y1 equivalents were determined as described previously. Species-specific mean density in the day was divided by mean density at night to determine calibration ratios. We assumed that the day-night calibrations determined using trawl data would be similar for snorkel data, and for bare sediment. Calibrations for pelagic species not captured by the trawl were determined from the literature (see references in Table 6).

The day-night calibration ratios were used to generate a nighttime dataset from the field collected daytime data at each sampling site. Species captured only at night were added into the generated night dataset, based on their mean density from the calibration trawls. Day-night calibration ratios were applied to the daytime field data that had already been calibrated for gear differences.

FINAL DATA PRODUCT FOR USE IN THE PRODUCTION MODEL

The generated nighttime dataset and the daytime dataset were averaged to produce the final calibrated dataset that accounted for both gear and day-night differences. Calibrated species-specific densities for each replicate within each site and habitat combination were available. Mean density across replicates per site and habitat could be used within the production model. However, we elected to use species-specific mean density pooled across all sites per habitat. This produced the best representative value for species densities across a gradient of environmental conditions. These data are now ready for use in the production model, and we present them here.

ERROR ASSOCIATED WITH MEAN DENSITY

For our calibrated field data of species-specific mean density per site, the associated error includes replicate error, error from the snorkel-trawl calibration, and error from the day-night calibrations. These three sources of error for the mean density estimates were included in the overall error associated with the field data by first determining variance for each species-specific density estimate across replicate transects per site and habitat. Then, using the known properties of variance, the replication variances were scaled by the square of the calibration constants. The standard error (SE) was then determined per site. The mean SE across all sites per habitat was then determined for use with our mean species-specific densities pooled across sites. This was necessary because if data were first pooled across sites to calculate initial mean density and associated variance, the calibration ratios could not be applied, given they differ per sampling method (and thus by site).

RESULTS

SITE CHARACTERISTICS

The sampling sites spanned a gradient of environmental conditions typical of those in coastal bays on the Atlantic coast of NS (Table 1). Two *Z. marina* beds (Lower Three Fathom Harbour and East Petpeswick) were located in shallow waters, where mean depth at high tide was 1 – 1.5 m. The seagrass at East Petpeswick was often exposed at low tide. Three beds were located in intermediate depths of ~ 2.5m (Crescent Beach, Second Peninsula, Strawberry Island), while the remaining *Z. marina* beds were located in greater depths up to 4m (Cable Island, Croucher Island, Inner Sambro Island). Bare soft-sediments were usually found in similar depths to the adjacent *Z. marina* beds, although bare soft-sediments at two sites (Inner Sambro Island and Strawberry Island) were relatively deeper (4 and 8m at Inner Sambro Island, and 2.5 and 3.7m at Strawberry Island, in *Z. marina* and bare habitat, respectively).

Mean water temperature during the sampling period ranged from 13 to 22 °C (Table 1). Sites close to the open ocean (Inner Sambro Island, Cable Island) were lower in water temperature relative to sites within bays, sites well protected with reduced water exchange, or very shallow sites (Crescent Beach, Croucher Island, Strawberry Island, Second Peninsula, East Petpeswick). Highest water temperature (22 °C) was observed at Lower Three Fathom Harbour, a lagoon with restricted water exchange.

The percent sediment silt/clay content ranged from 2 to 90% in *Z. marina* and 3 to 75% in bare soft-sediment bottom (Table 1). The *Z. marina* bed at Second Peninsula had exceptionally high sediment silt/clay content (90%). Generally, adjacent bare sediments had lower sediment silt/clay contents than the nearby *Z. marina* beds. Exceptions were at Lower Three Fathom Harbour (26 and 75% in *Z. marina*, and bare soft-sediment bottom, respectively) and East Petpeswick (10% and 30% in *Z. marina* and bare soft-sediment bottom, respectively), where bare soft-sediments were more landwards from the channel (East Petpeswick) or lagoon opening (Lower 3 Fathom Harbour) relative to the *Z. marina* beds. Sediment organic content ranged from 1 to 20% in *Z. marina* and 1 to 5% in bare soft-sediment bottom. Organic content increased with silt/clay content as expected. Sediments at only two sites contained a significant gravel fraction in *Z. marina* beds (Lower 3Fathom Harbour and Strawberry Island) and bare soft-sediment bottom (Inner Sambro Island and Strawberry Island).

Z. marina shoot density ranged from 300 to 1200 shoots m^{-2} across the sites during the sampling period (Table 1). Highest shoot density was observed at Croucher Island, while lower shoot densities tended to be observed at sites with high sediment silt/clay content. Aboveground biomass ranged from 74 to 500 dry g m^{-2}, and belowground biomass from 275 to 1300 dry g m^{-2}. Canopy height ranged from 23 to 63 cm, and it tended to be longest at sites that had higher coloured dissolved organic matter (CDOM) and suspended particles (Lower 3 Fathom Harbour and Second Peninsula, M. Wong pers. obs.), rather than scale with depth as might be expected.

NEKTON SPECIES PRESENCE AND HABITAT ASSOCIATIONS

Twenty-two species of nekton (5 large decapods, 17 fishes) were captured in *Z. marina* beds and on bare soft-sediment bottom (Table 3). Nine species (sand lance, eel, silverside, tomcod, pollock, winter flounder, white hake, rock crab, lobster) hold commercial fishery status in Maritimes Canada (includes provinces of New Brunswick, Nova Scotia, Prince Edward Island). 16 species (sand lance, eel, killifish, tomcod, grubby, rock gunnel, winter flounder, pipefish, cunner, three and fourspine sticklebacks, rock and green crab, sand and grass shrimp, and lobster) are predominantly found inshore, although several of these migrate offshore in the winter (Table 3). Many of these species prefer habitats characterized by macrophytes (eelgrass beds, macroalgal beds, marsh grasses). Three species utilize inshore habitats only as YOY or juveniles (silverside, pollock, white hake) prior to moving offshore as adults. A few species (eel, threespine stickleback, killifish) inhabit both fresh and saltwater. The nekton assemblage was comprised of species that associate with the sea bottom (e.g., flounder, grubby, sticklebacks, rock gunnels) and species found higher in the water column (e.g., pollock, silversides). Many species showed high affinity to *Z. marina* beds compared to bare soft-sediment bottom, and included rock crab, grass shrimp, eel, tomcod, grubby, pipefish, white hake, and sticklebacks (Fig. 2A-2D). Species that were found equally on *Z. marina* and bare soft-sediment bottom included green crabs, lobster, sand shrimp, winter flounder, and cunner. Most species were captured in both *Z. marina* and bare soft-sediment bottom, although rock crab, snailfish, and scad were only found in *Z. marina*, and sea raven and sand lance were only present on bare soft-sediment bottom. Some species were rare and only found at one site (sand lance, sea raven, snailfish, and scad).

NEKTON AGE CLASSES

The captured nekton were often dominated by Y1 age class (Table 4). The proportion of the total catch per species that was comprised of Y1 was either 1 or very high (>0.80) for grass shrimp, sand lance, eel, sea raven, silverside, tomcod, grubby, pollock, pipefish, cunner, white hake, snailfish, and scad (Table 4). Note that eel were Y2 but in their first year in the inshore. A wide range of nekton sizes were captured for several species (eel, cunner, sticklebacks, crabs, pipefish, rock gunnel, sand shrimp, grubby, tomcod; Figure 3). For species not captured as Y1, the proportion of the total catch was 0.20 in Y6 for lobster, 1 in Y2 for killifish, 0.471 in Y2 for winter flounder, and 1 in Y2 for fourspine stickleback. Information on spawning timing and location from the literature indicates that cunner were the only species that may have been present as YOY too small for capture by the trawl.

CALIBRATIONS TO ACCOUNT FOR SAMPLING GEAR DIFFERENCES

The calibration ratios to account for sampling gear differences are presented in Table 5. These ratios indicated that the densities of several benthic nekton (tomcod, grubby, pipefish, sticklebacks, sand shrimp, grass shrimp) in *Z. marina* beds estimated by trawl transects were 4 to 70 times higher than estimates from snorkel transects. On bare soft-sediment bottom, density of sand shrimp was 90 times lower in snorkel than trawl transects. In contrast, green crabs on bare soft-sediment bottom were 20 times lower in the trawls relative to snorkel transects. Data were appropriately calibrated using these ratios as described in Table 5.

Pelagic species (silversides and pollock) were often observed during snorkel transects but generally not caught by trawls. This was accounted for by adding the mean density across sites where the species were observed in snorkel transects to the trawl data (Table 5). The mesh size on the trawl net was too large to capture some fish (mainly smaller eels, i.e., elvers) observed during snorkel transects, so eel density from trawl data in *Z. marina* was adjusted based on the calibration ratio. If no eels were observed in the trawl, a mean density calculated from the calibration sites was added to sites with similar conditions to where the calibration snorkel and trawl surveys were conducted. Further additions to both trawl and snorkel data were made when species caught in the fyke nets were not captured by snorkel or trawl transects at the site (Table 5). Some nekton (i.e., rock crab, lobster, sand lance, sea raven, rock gunnel, winter flounder, cunner, snailfish, and scad) were either judged adequately sampled by the methods used (based on calibration ratios) or were rarely found, and so no adjustments were made for these species.

ACCOUNTING FOR NEKTON DENSITY AT NIGHT

Trawls conducted in both the day and night indicated that several nekton species were higher in density at night relative to the day in *Z. marina*. These species were eel, green crab, grubby, rock gunnel, sand shrimp, tomcod, and winter flounder (Figure 4). In contrast, a few species were lower in density at night relative to the day (sticklebacks, grass shrimp). Calibration ratios developed from these data were used to adjust the field data (calibrated for gear differences) that was collected only in the daytime in order to generate nighttime estimates (Table 6). Day and night datasets were then averaged to produce the final dataset. Some species were not captured in our calibration survey at Crescent Beach (rock crab, lobster, sand lance, killifish, sea raven, dusky snailfish, bigeye scad) and so no adjustments to the daytime estimates in the original dataset could be made. For silversides and pollock, literature estimates of daytime and nighttime densities were used to generate calibration ratios (Table 6). For cases where species were observed only at night during the calibration surveys (eel, rock gunnel, winter flounder), this mean density was added to the generated nighttime dataset.

NEKTON DENSITY PER SITE (CALIBRATED FOR SAMPLING GEAR AND DAY-NIGHT DIFFERENCES)

Calibrated nekton densities at each site are presented in Figure 5A-5D. The affinity of many nekton species for *Z. marina* beds relative to bare soft-sediment bottom evident in the uncalibrated data remained evident for the calibrated data. High densities of green crab and sand shrimp dominate the crustacean assemblage, while lobster, rock crab, and grass shrimp occur only at low densities. Fishes found in *Z. marina* beds across the majority of sites include eel, silversides, tomcod, grubby, rock gunnel, pollock, winter flounder, pipefish, cunner, white hake, and fourspine stickleback. Of these, tomcod, grubby, pollock, and fourspine stickleback had densities >0.1 m^{-2}. The final data product of species-specific mean density pooled across sites for use in the nekton production model is shown in Table 7.

SUMMARY AND CONCLUSIONS

This report provides previously unavailable data of nekton assemblage structure and density for *Z. marina* beds and bare soft-sediment bottom on the Atlantic coast of Nova Scotia. The fish and crustacean species present were similar to those observed in *Z. marina* beds in other regions of Maritimes Canada (Joseph et al. 2006; Schmidt et al. 2011; Schein et al. 2012; Skinner 2013), although several species were unique to our sites (pollock, banded killifish, sea raven, dusky snailfish, bigeye scad). We also observed high nekton species richness, density, and juvenile/YOY presence in *Z. marina* beds relative to bare soft-sediment bottom at most sites, patterns commonly observed in many other studies (e.g., Heck et al. 1989; Connolly 1994; Edgar and Shaw 1995; Jenkins and Wheatley 1998; Guidetti 2000).

Our study was designed to provide the necessary data input for a model framework that is currently being developed to determine species-specific nekton production derived from coastal habitats (Wong and Dowd, in prep.). The required field input data for the model consists at a minimum of species-specific nekton density in one age class. Our field estimates of nekton densites were mainly for Y1, although other age classes were caught for some species. Our data were collected using different sampling methods (i.e., visual snorkel transects and trawl transects) because one sampling method could not be used across all sites. Data from the gear calibration exercise indicated that fish densities estimated from visual snorkel surveys were often much lower than from trawl data, and that the trawl did not adequately sample pelagic species. These patterns have been observed in other studies of fish assemblages in seagrass beds (Harmelin-Vivien and Francour 1992), and necessitated the use of calibration ratios to align the density estimates obtained from both sampling gears. The calibration ratios used may be applicable to other studies in the Maritimes that use similar sampling methods, and could be further strengthened by increasing the spatial resolution and replication on which they are based.

While we aimed to provide the most accurate estimates of species-specific densities through the use of calibrated data (for gear and day-night differences), we were not able to account for catch efficiency (i.e., number of fish caught divided by the number of fish present; Ferno and Olsen 1994; Fraser et al. 2007) of the trawl or detection limitations during visual surveys (Edgar et al. 2004; Buckland et al. 2005). Furthermore, our estimates may represent maximum nekton density because we sampled in the summer when density is expected to be highest (Joseph et al. 2006). Regardless, the data presented here remain useful and represent the best possible estimates of nekton densities in seagrass beds and bare soft-sediment bottom currently available for Maritimes Canada. Future work could further refine the data by including seasonal sampling, increasing replication, and accounting for limitations associated with the sampling gears.

The data generated in this study will prove useful for the application of a model to determine production of nekton derived from coastal habitats, information needed to implement policy in coastal ecosystems under the DFO Fisheries Act. Our estimates of nekton density can be used in the model based on site and habitat specific estimates, or can be used as habitat-specific means across all sites. The use of mean densities could be considered representative of seagrass beds of Atlantic NS which span a large range of environmental conditions. These data represent some of the first quantitative estimates of nekton density in seagrass and bare soft-sediment bottom for Atlantic Canada, and are important when determining nekton production derived from coastal habitats. Future work will focus on extending these data to include other coastal habitats characteristic of Atlantic Canada, such as macroalgal beds.

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TABLES AND FIGURES

Table 1. Site characteristics. T = trawl, S = snorkel, SG = seagrass (*Z. marina*), OM = organic matter in sediments, AGBM = aboveground biomass, BGBM = belowground biomass. Water depth is for mean high tide. Water temperature is from July 16 to August 12 2013 (period of sampling). Values are mean ± SE, except for water temperature which uses SD. n =5 (OM), n = 3 (particle size), n = 10 (plant metrics). For sediment particle size, percent sand = 100 – (% gravel + % silt/clay).

Site (abbreviation)	Nekton sampling method	Habitat	OM (%)	Gravel (%)	Silt/clay (%)	Shoot density (# m^{-2})	AGBM (dry g m^2)	BGBM (dry g m^2)	Canopy height (cm)	Water temp (°C)	Water depth (m)
Cable Island (Cable)	T	SG	2.42 ± 0.20	0	22.0 ± 2.14	702.4 ± 93.0	519.5 ± 41.1	622.3 ± 66.5	41.5 ± 1.5	13.7 ± 1.5	3
Crescent Beach (CresB)	T, S	SG	3.67 ± 0.86	0	27.3 ± 5.74	368.0 ± 24.9	238.4 ± 27.3	365.7 ± 79.7	39.5 ± 2.63	18.7 ± 1.83	2.5
Croucher Island (Crouch)	T	SG	2.06 ± 0.23	0	10.6 ± 0.31	1246.4 ± 105.7	260.4 ± 43.9	1317.5 ± 301.5	31.0 ± 3.14	18.0 ± 1.64	3
East Petpeswick (EPet)	S	SG	1.14 ± 0.09	0	10.1 ± 0.87	880.0 ± 76.4	320.9 ± 38.6	466.9 ± 49.6	23.6 ± 0.70	16.9 ± 3.3	1.5
Lower Three Fathom Harbour (L3Fath)	S	SG	2.57 ± 0.43	6.34 ± 5.19	26.2 ± 6.75	334.4 ± 27.9	451.9 ± 62.8	273.9 ± 42.5	63.0 ± 2.26	22.2 ± 1.56	1
Inner Sambro Island (Sambro)	T	SG	1.64 ± 0.21	0	9.14 ± 2.26	515.2 ± 40.9	143.9 ± 36.7	610.1 ± 90.9	46.0 ± 3.05	13.4 ± 2.98	4
Second Peninsula	T, S	SG	19.4 ± 1.24	0	90.2 ± 0.11	291.2 ± 21.0	316.4 ± 57.7	281.8 ± 48.6	52.5 ± 1.71	17.3 ±	2.5

(SecPen)										1.45	
Strawberry Island (Straw)	T	SG	1.43 ± 0.09	34.23 ± 8.48	2.63 ± 0.29	633.6 ± 49.2	74.7 ± 14.6	738.5 ± 124.1	22.9 ± 1.73	18.02 ± 1.64	2.5
Cable Island	T	Bare	0.93 ± 0.28	0	2.91 ± 0.62					13.7 ± 1.5	3
Crescent Beach	T, S	Bare	0.77 ± 0.02	0	0					18.7 ± 1.83	1.5
Croucher Island	T	Bare	0.94 ± 0.05	0	5.46 ± 0.13					18.0 ± 1.64	3.7
East Petpeswick	S	Bare	1.88 ± 0.30	0	30.1 ± 2.33					16.9 ± 3.3	1.5
Lower Three Fathom Harbour	S	Bare	5.73 ± 0.64	0	74.5 ± 7.71					22.2 ± 1.56	1
Inner Sambro Island	T	Bare	1.16 ± 0.24	1.22 ± 0.62	7.55 ± 4.32					13.4 ± 2.98	8
Strawberry Island	T	Bare	1.4 ± 0.15	10.51 ± 9.99	6.93 ± 1.56					18.02 ± 1.64	3.7

Table 2. Summary table of nekton length and young of the year details used to determine age classes in field samples. Length is total length (TL) unless indicated otherwise. FL = fork length, CW = carapace width, CL = carapace length, BoF = Bay of Fundy, GoL = Gulf of St. Lawrence, NH = New Hampshire, NJ = New Jersey, M = male, F = female.

Species	Habitat	Spawns	Location spawn	Lengths	References
American sand lance (*Ammodytes americanus*)	Mostly inshore but sometimes offshore, over sandy bottom, large schools, burrow in sand, sometimes between high and low tide level, may remain buried for weeks in state of aestivation	Dec-Jan	Inshore	Age (y) (length, mm) 1(90) 2(155) 3(190) 4(220) 6(260) 9(285) YOY-Y1: ≤90 mm	Scott & Scott 1988, using *A. dubius*
American eel (*Anguilla rostrata*)	Freshwater, rivers, coastal waters, estuaries, overwinter buried in mud bottom	Feb-July	Sargasso sea, then young move to fresh water and nearshore to feed and grow. Takes 1 year to reach North American coast, arrive as glass eels, become elvers when black, enter coastal rivers May-June, then become yellow eels for several years. When mature are bronze or silver.	Elvers: 127 mm after first year in freshwater Glass and elvers: 57.5-60.8 mm in June Age (y) (length, mm) Y2 (≤150) Y3 (200) Y5 (300-350) Y6 (450) Y10 (600) Y15(700-1000)	Scott & Scott 1988 Facey and van den Avyle 1987
Banded killifish (*Fundulus diaphanus*)	Euryhaline, marshy areas and brackish-water ponds, prefers submerged aquatic vegetation (SAVs), very tolerant of low O_2, considered mainly freshwater resident	Midsummer, April to August	Shallow water, no nest, eggs deposited on outer sides of SAVs, masses of algae, in sand and mud, mussel shells	From NS: Age (y) (length, mm) 1(40-50) 4(90) YOY-Y1: ≤30 mm (Schein et al. 2012)	Scott & Scott 1988 Fritz and Garside 1975 Schein et al. 2012, using *F. heteroclitus*
Sea raven (*Hemitripterus americanus*)	Rocky hard bottoms, seldom in estuaries or tidal flats, water deeper than 2m usually	Late fall to early winter	Eggs sometimes attach to finger sponges, deposited in small clusters	51-102 mm long at 6-8 months 150 mm in April at 1.5 y YOY-Y1: ≤120 mm	Scott & Scott 1988

Atlantic Silverside (*Menidia menidia*)	Schooling fish, close to shore, marshes, intertidal creeks, estuaries, sandy/gravelly shores, follows tide movements, Northern populations may be more tolerant of cold winter waters	March to August, June in PEI and NS	migrates into estuaries to spawn, adults then return to sea, young fish move to sea beginning in September	NS: 1-2yr 90 mm long YOY: 20-91 mm, (Fay et al. 1983) YOY: <80 mm (Schein et al. 2012) Based on above data, used: YOY-Y1: ≤80 mm	Fay et al. 1983, Scott & Scott 1988, Schein et al. 2012
Atlantic Tomcod (*Microgadus tomcod*)	Inshore, shallow water; saltmarsh, eelgrass, mud flats, max depth of 6m in bays, rarely strays from shore	Dec/Jan	Estuaries, salt water, gravel, boulders, sand bottoms; remain in estuary where hatch for summer, enters brackish and fresh water during spawning migrations in late fall or early winter	60-90 mm first summer in Canada, larger juveniles 100 mm by early fall YOY-Y1: ≤100 mm	Scott & Scott 1988; Stewart & Auster 1987
Grubby sculpin (*Myoxocephalus aenaeus*)	Coastal waters, estuaries, NS coast, sand, mud, gravel bottom in protected areas, rocky off exposed shores, abundant in eelgrass when plants plentiful, tolerant of winter water temperatures	Winter-Spring	Coastal waters	Max length 127-152 mm, 180 mm (Scott & Scott) YOY: 40-69 mm SL 1+: 66-98 mm SL (Lazzari et al. 1989) Based on above data, used: YOY-Y1: ≤65 mm Y1-Y2: 65-90 mm	Scott & Scott 1988, Lazzari et al. 1989
Rock gunnel (*Pholis gunnellus*)	Tide pools, intertidal areas, hides under stones, crevices, seaweed, avoids mud bottom, intertidal to deep depths, migrates offshore in winter to spawn then returns inshore in March	Winter, leaves intertidal areas in Nov and returns in March	Deep offshore waters	Age (y) (length mm, BoF, NH) 1(68, 73) 2(96, 109) 3(118, 131) 4(139,155) 5(155, 170) Based on above data, used: YOY-Y1: ≤70 mm Y1-Y2: 70-100 Y2-Y3: 100-120	Scott & Scott 1988

				Y3-Y4: 120-140 Y4-Y5: >140	
Pollock (*Pollachius virens*)	Water column, young move inshore in summer and offshore in winter (0-1 year old up to 20 cm long); At 2 years, deeper nearshore water or offshore	March-Sept NS	Offshore	Age (y) (length mm FL) 0(200) 1(210) 2(380) 3(440) 4(540) 5(610) 6(690) Based on above data, used: YOY-Y1: ≤200mm	Scott & Scott 1988
Winter flounder (*Pseudopleuronectes americanus*)	Inshore, shallow-water, soft muddy to moderately hard, young fish shallower than older, shows seasonal movement, move offshore in winter onshore in summer, young spend first 2 years in shallow inshore waters, use all inshore available habitats, often most abundant in eelgrass and macroalgae	Late winter, early spring	Shallow water over sand or mud	Age (y) (length mm) 2(178) 5(377) 7(411) 8(424) (St. Mary's Bay NS) YOY<30 mm (Schein et al. 2012) Based on above data, used: YOY-Y1: ≤30 mm Y1-Y2: 30-178 mm Y2-Y3: 190-250 mm Y7: 400 mm Y8: 500 mm	Scott & Scott 1988, Buckley 1989, Lazzari 2008, Goldberg et al. 2002, Schein et al. 2012
Northern Pipefish (*Syngnathus fuscus*)	Seaweed and eelgrass, salt marshes, estuaries, sometimes brackish, only rarely travels to open sea, have seasonal inshore-offshore migrations	March-August	Brooded by male	YOY in June in NJ 10-80 mm By August: 20-175 mm Second YOY cohort in August:	Scott & Scott 1988 Campbell & Able 1998 Lazzari & Able 1990

				<55 mm Sept-Nov: YOY 10-200 mm Based on above data, used: YOY-Y1: ≤175mm Y1-Y2: 175-200 Y2-Y3: 200-300	
Cunner (*Tautogolabrus adspersus*)	Shallow, inshore waters, on or near bottom, submerged seaweed and *Z. marina*, avoid brackish water, migration offshore is rare, in winter become torpid and remain inshore under rocks in shallow waters	June-mid August GoL, bit later in NS	Coastal habitats	Age (y) (length, mm) GoL: 4(165) 6-7 y(240) NFLD: 3-10(140 - 270) YOY (Able et al. 2005) 24-71 mm Based on above data, used: YOY-Y1: ≤80 mm	Scott & Scott 1988 Auster 1989 Able et al. 2005 Serchuk and Cole 1974
Whitehake (*Urophysis tenuis*)	YOY in nearshore 1m depths, move into deeper water as they grow, demersal continental-shelf and upper continental-slope species 200-1000m	Not regular, depends on location	Scotia shelf, GoL	YOY-Y1: ≤150 mm long Age (y) (length, mm) 3(410) 4(460) 5(530)	Scott & Scott 1988
Dusky snailfish (*Liparis gibbus*)	Benthic, lives mainly on rock, sand and mud bottom most common 100-200m depth	June – summer	St. Lawrence estuary, suggests coastal areas/estuaries	Size avg in Atlantic Canada 110-120 mm long(adult) (assume small size caught is YOY-Y1)	Scott & Scott 1988

				YOY-Y1: ≤50 mm	
Bigeye scad (*Selar crumenophthalmus*)	Common off NS in late summer and fall, Usually 2-10m, circumpolar			140 -170 mm avg size (assume small size caught is YOY-Y1) YOY-Y1: ≤70 mm	Scott & Scott 1988
Fourspine stickleback (*Apeltes quadracus*)	Coastal waters, marine or brackish, stickleback with highest salinity tolerance, the only marine stickleback species	May-July	SAVs in intertidal areas, nests, favors *Zostera marina*, red pelvic fins during mating	Use as for 3-spine below Mature at 52 mm YOY-Y1: ≤15 mm (Schein et al. 2012)	Scott & Scott 1988 Schein et al. 2012
Threespine stickleback (*Gasterosteus aculeatus*)	Marine, brackish, fresh waters, mainly shallow-water areas, SAVs, pools, creeks, estuaries	June-July	Fresh water, for those in the sea, migrates to fresh or brackish water and then returns to saltwater in autumn.	YOY-Y1 : (15-33 mm long) 2 y (20-55) 3y (35-55) Max size=100 mm, but most 76 mm YOY-Y1: ≤15 mm (Schein et al. 2012) Y1-Y2: >30<60 mm	Scott & Scott 1988 Schein et al. 2012
Rock crab (*Cancer irroratus*)	Shallow water, intertidal to 575m, prefer shallow water and sandy bottom, but found on all types of substrate			Age (y) (length mm CW; M,F) 1(13.7,13.7) 2(39.9, 39.9) 3(65.9, 50.8) 4(80.4, 61.1) 5(97.3, 70.9) 6(116.9, 80.1) 7(139.6, 88.9)	Reilly and Saila 1978 DFO 2013/030
Green crab (*Carcinus maenas*)	Hard and soft bottom, subtidal and intertidal shallow inshore habitats, adults tidally migrate	Recruits Aug-Sept		Age (y) (length mm CW; M,F) 0(10, 10) 0+(18, 20) 1(31,35) 2(45,45) 3(55,55) 4(61, 60)	Baeta et al 2005 Berrill 1982

				Based on above data, used: YOY-Y1: ≤30 mm CW) Y1-Y2: 31-45 Y2-Y3: 45-60 Y3-Y4: 60-70 Y4-Y5: 71-80 Y5-Y6: 81+	
Sand shrimp (*Crangon septimsinosa*)	Some populations have offshore migration of adults in summer to reduce exposure to high temperatures, although Gulf of St. Lawrence populations may only see this in some proportion of the population, tolerant to low salinity, intolerance to anoxia			Age (y) (length mm CL) 1(1-10) 2(11-14) 3(15-17) YOY-Y1: ≤10 mm CL	Oh et al. 1999 Locke et al. 2005
Lobster (*Homarus americanus*)	Coastal waters but deeper to 750m in Gulf of Maine, newly settled and juvenile lobsters prefer cobble or gravel bottoms, or eelgrass, burrow into sediments, as grow to adults found on varied bottoms including rocky and open mud/sand bottoms, adults seasonally migrate to shallow waters in summer and deeper waters in winter			Age (y) (length mm CL) 0.8(7) 1(12) 2(32) 3(52) 3.9(67) 4.9(82) 6(96) 7(107) 8(117) 9(126) 10(133) 11(140) 12(145) 13(150) 14(155) Based on above data, used: Y4-Y5: 65-80 mm CL Y5-Y6: 80-100 Y6-Y7: 100-110 Y7-Y8: 110-120	French McCay et al 2003 Tremblay et al. 2013

				Y8-Y9: 120-128	
Grass shrimp (*Palaemonetes vulgaris*)	Prefer dense SAVs			Assume 80% of catch is YOY, due to short life span of 1.5 y	Hoffman 1980 Anderson 1985

Table 3. Fish and large decapods captured in seagrass (*Z. marina*) beds and on bare soft-sediment bottom. Species with commercial fisheries status in Maritimes Canada (NB, PEI, NS) are indicated by an asterisk. Species that are mainly inshore, move offshore as adults, and/or migrate seasonally are indicated by an "X". SG = seagrass beds, MA = macroalgal beds, FW = freshwater, SW = saltwater, YOY = young of the year.

Species	Mainly inshore	Habitat preferences	YOY/juveniles inshore, offshore as adults	Winter offshore migration
American sand lance (*Ammodytes americanus*)*	X	Sandy bottom		
American eel (*Anguilla rostrata*)*	X	SG and MA, FW or SW		
Banded killifish (*Fundulus diaphanus*)	X	SG and MA, mainly FW		
Sea raven (*Hemitripterus americanus*)		Rocky hard bottoms		
Atlantic Silverside (*Menidia menidia*)*		Marshes, creeks, estuaries, sand/gravel shores	X	X
Atlantic Tomcod (*Microgadus tomcod*)*	X	SG and MA		
Grubby sculpin (*Myoxocephalus aenaeus*)	X	SG and MA, sand, mud, gravel bottom		
Rock gunnel (*Pholis gunnellus*)	X	Tide pools, crevices, SG and MA		X
Pollock (*Pollachius virens*)*		Water column, little benthic association	X	X
Winter flounder (*Pseudopleuronectes americanus*)*	X	Soft-bottom to somewhat hard, prefers SG and MA		X
Northern Pipefish (*Syngnathus fuscus*)	X	SG and MA		X
Cunner (*Tautogolabrus adspersus*)	X	SG and MA		
Whitehake (*Urophysis tenuis*)*		1m depths, often in SG and MA	X	
Dusky snailfish (*Liparis gibbus*)		100-200m, rock or sand bottom		
Bigeye scad (*Selar crumenophthalmus*)		2-10m		
Fourspine stickleback (*Apeltes quadracus*)	X	Brackish and SW, SG and MA		
Threespine stickleback (*Gasterosteus aculeatus*)	X	FW in summer, SW in fall and winter, SG and MA		
Rock crab (*Cancer irroratus*)*	X	Sandy bottom, but found on all substrates		
Green crab (*Carcinus maenas*)	X	Hard and soft-bottom, intertidal to shallow subtidal		
Sand shrimp (*Crangon septimsinosa*)	X	Sandy sediments		X
Lobster (*Homarus americanus*)*	X	YOY and juveniles in SG and MA, cobble or gravel; adults rocky to open mud/sand flats		X (adults)
Grass shrimp (*Palaemonetes vulgaris*)	X	SG and MA		

Table 4. Proportion of nekton captured that were Y1 (YOY to Y1). Values are from pooling data across all sites. * indicates that the American eels captured were in Y2 but their first year in the inshore.

Species	Proportion Y1
Rock crab (*Cancer irroratus*)	0.063
Green crab (*Carcinus maenas*)	0.19
Sand shrimp (*Crangon septimsinosa*)	0.62
American lobster (*Homarus americanus*)	0.20
Grass shrimp (*Palaemonetes vulgaris*)	0.80
Sand lance (*Ammodytes americanus*)	1
American eel (*Anguilla rostrata*)	0.88*
Banded killifish (*Fundulus diaphanus*)	0
Sea raven (*Hemitripterus americanus*)	1
Atlantic Silverside (*Menidia menidia*)	1
Tomcod (*Microgadus tomcod*)	0.98
Grubby Sculpin (*Myoxocephalus aenaeus*)	0.89
Rock gunnel (*Pholis gunnellus*)	0.13
Pollock (*Pollachius virens*)	1
Winter flounder (*Pseudopleuronectes americanus*)	0.47
Northern Pipefish (*Syngnathus fuscus*)	0.904
Cunner (*Tautogolabrus adspersus*)	1
White hake (*Urophysis tenuis*)	1
Dusky snailfish (*Liparis gibbus*)	1
Bigeye scad (*Selar crumenophthalmus*)	1
Fourspine stickleback (*Apeltes quadracus*)	0
Threespine stickleback (*Gasterosteus aculeatus*)	0.66

Table 5. Calibrations used to adjust snorkel and trawl data to account for sampling gear differences. S = snorkel, T = trawl, SG = seagrass (*Z. marina*).

Species	Observations at calibration sites	Adjustment for data	Justification
Rock crab	- Mostly observed during snorkel transects at calibration sites, although some observed in trawl at other sites (Sambro)	- No adjustments for trawl or snorkel data	- Green crab density was similar when compared between snorkel and trawl - This suggests rock crabs also likely caught by trawl if present
Green crab	- Green crab density 2.2 times higher when compared between snorkel and trawls in SG at calibration sites (S/T = 2.2) - In bare, green crab density was 20 times higher in snorkel data relative to trawl at calibration sites (S/T = 19.8).	- For trawl data on SG, multiply by 2.2 - For trawl data on bare, multiply by 20	- Green crabs move easily on bare relative to SG and likely escaped trawl (Wong pers. obs).
Sand shrimp	- Sand shrimp density is 1-2 orders of magnitude higher in trawl data relative to snorkel data at calibration sites	- No adjustments for trawl data - SG snorkel: multiply snorkel data by 1/0.143 (mean S/T from calibration sites) - Bare snorkel: multiply snorkel data by 1/0.0111 (mean S/T from bare calibration sites)	- Shrimp hard to see while snorkelling in SG. On bare, shrimp escape by swimming or digging, or remain in burrows
Lobster	- None at calibration sites	- No adjustments to data	
Grass shrimp	- Grass shrimp density is an order of magnitude higher in trawl data than in snorkel data at calibration sites	- No adjustments for trawl data - SG snorkel data: multiply by 1/0.239 (mean of S/T from calibration sites)	- Shrimp hard to see while snorkelling due to transparent colouration - No grass shrimp in bare
Sand lance	- None found at calibration sites - Low densities found at a few other sites during trawls on bare sediment	- No adjustments to data	- Sand lance leave the sediments when disturbed, so are likely well sampled by trawls
Eel	- Eel density is ~3 times lower in trawl data relative to snorkel data in SG and bare at calibration sites	- Multiple trawl data in SG by 2.93 (mean of S/T from calibration sites) - No adjustments for snorkel data - If trawl data is zero: determine if habitat is similar to that of calibration sites (shallow, muddy, low water exchange). If so, add $0.285 m^{-2}$ (average from calibration sites). If habitat dissimilar (i.e., rocky, deep, sandy), no adjustments made.	- Mesh on trawl nets too big to capture elvers. - Elvers observed in very shallow waters where trawl cannot access.

Killifish	- None observed in trawl or snorkel data at calibration sites - Killifish were present in fyke nets at one sampling site (L3F).	- Add killifish at sites of low salinity and where caught in fyke nets (i.e., L3F). - Average density from fyke nets is 0.263 m^{-2} (SG) and 0.139 m^{-2} (bare)	- Killifish are a brackish water species which do not frequent full salinity. L3F is the only brackish water site sampled. - Killifish home range is 36-38 m, 375 m max (Abraham 1985) - Assume fyke net fishes 40 m^2 area for killifish
Sea raven	- None in snorkel or trawls at calibration sites - Were observed at one sampling site in bare (Cable Island)	- No adjustments to data	- Assume only in habitats where had to use trawl (deep, well flushed, some rocks)
Silverside	- Only in snorkel transects at calibration sites, mainly in SG	- Add 0.182 silversides m^{-2} to trawl data in SG (mean density from all sites where observed).	- Trawl does not sample pelagic fishes - Silversides are common on the coast in the summer. - Most silversides were observed in SG, so additions made only to trawl data in SG
Tomcod	- In both trawl and snorkel data in SG and bare for one calibration site (CB)	- No adjustments for trawl data - For snorkel data in SG multiply by 1/0.061 (mean S/T from calibration sites) - For L3F, Tomcod observed in fyke nets in SG but not in snorkel transects. Tomcod added using mean (0.0146 m^{-2}) from SP snorkel data.	- Tomcod are hard to see within *Z. marina* while snorkelling given their colouration and skittish nature.
Grubby sculpin	- Grubby density was 2 orders of magnitude lower in snorkel transects relative to trawls in SG at calibration sites	- Use trawl data unadjusted - For snorkel data in SG: multiply by 1/0.0141 (mean S/T from calibration sites)	- Grubby often rest on the bottom, making them difficult to see among the *Z. marina* leaves while snorkelling.
Rock gunnel	- None observed at calibration sites. Rock gunnels were observed at other more rocky, deeper sites.	- Use trawl data unadjusted	- Would not expect rock gunnels at snorkel sites, which tended to be shallow with few rocks and more muddy sediments
Pollock	- Pollock observed during snorkel transects in mainly SG at calibration sites.	- Adjust trawl data in SG by adding 0.0396 m^{-2} (mean from snorkel sites)	- Trawl does not sample pelagics
Winter flounder	- Sparse at calibration sites, but observed in both snorkel transects and trawls at sampling sites	- No adjustments to either trawl or snorkel data	- Flounder are observed using both snorkel transects and trawls
Pipefish	- In both snorkel transects and trawls at calibration sites	- For snorkel data in SG: multiply by 1/0.0756 m^{-2} (mean S/T from calibration sites)	- The shape, colouration, and position of pipefish within SG make them difficult to see while

	- 1 to 2 orders of magnitude lower in snorkel transects than in trawls		snorkelling - Pipefish are highly associated with SG and so no additions made to bare
Cunner	- In trawls at the calibration sites, but not in snorkel transects	- Use trawl data unadjusted	- Individuals sampled were very small YOY, would not have been visible during snorkelling - However, small sample size makes it difficult to meaningfully adjust the data
White hake	- Observed in some trawls at calibration sites - Also observed in trawls at other sites and in fyke nets	- Use trawl data unadjusted - For sites where observed in fyke nets in SG but not in trawls (only Sec Pen): add average density from the other sites (0.0147 m^{-2})	- White hake are skittish and fast swimmers, and are not easily observed while snorkelling
Dusky snailfish	- None observed at the calibration sites - Observed in trawls at one sampling site (Sambro)	- Use trawl data unadjusted	- The snailfish was only rarely observed at a deeper site (Sambro), and is not likely common at the other sites
Big eye scad	- None observed at the calibration sites - Observed in trawls at one sampling site (Strawberry Island)	- Use trawl data unadjusted	- The scad was only rarely observed at a deeper site (Strawberry Island), and is not likely common at the other sites
Sticklebacks	- In both snorkel and trawl data at the calibration sites - Snorkel data is ~2 orders of magnitude lower than trawl data (only observed in SG)	- Adjust snorkel data for total sticklebacks (when species could not be differentiated) by multiplying by 1/0.047 m^{-2} (mean of S/T at calibration sites) - For Fourspine sticklebacks: adjust snorkel data by multiplying by 1/0.048 (mean of S/T at calibration sites) - For Threespine sticklebacks: adjust snorkel data by multiplying by 1/0.0259 (mean of S/T at calibration sites)	- Total sticklebacks were further divided by assuming 75% were 4 spine and 25% 3 spine. For L3F, 50% were assumed to be 4 spine and 50% 3 spine - These divisions are based on the fact that most Threespines go to freshwater in the summer, although some remain in salt water. At L3F, the more brackish water meant that more Threespines were present in the summer relative to other sites.

Table 6. Calibrations used to determine density of nekton at night by adjusting data collected in the day. SG = seagrass (*Z. marina*), D = day, N = night.

Species	Observation at calibration site	Adjustment to day densities to estimate night densities	Justification/notes
Rock crab	- None on bare or SG		
Green crab	- Density an order of magnitude higher at night than day in both SG and bare	Bare: multiply day data by 1/0.189 to obtain night estimate (D/N calibration) SG: multiply day data by 1/0.520 to obtain night estimate (D/N calibration)	
Sand shrimp	- Density higher at night than day in both SG and bare	Bare: multiply day data by 1/0.154 to obtain night estimate (D/N calibration) SG: multiply day data by 1/0.314 to obtain night estimate (D/N calibration)	
Lobster	- None on bare or SG		
Grass shrimp	- None on bare - Density in SG higher in day than at night	SG: multiply day data by 1/1.833 to obtain night estimate (D/N calibration)	
Sand lance	- None on bare or SG		
Eel	- None on bare - In SG, only present at night	SG: Add 0.126 m^{-2} to night dataset (mean of night data from calibration site)	
Killifish	- None on bare or SG		
Sea raven	- None on bare or SG		
Silverside	- None on bare or SG - Pelagic species not sampled by trawl	SG: multiply day data by 1/3.98 to obtain night estimate (D/N calibration)	- D/N calibration from Matilla et al. 1999, sampled using snorkel transects. - Silversides only observed in SG during sampling, so no additions made to bare.
Tomcod	- None on bare - Density higher at night than in day in SG	SG: multiply day data by 1/0.593 to obtain night estimate (D/N calibration)	
Grubby sculpin	- None on bare - Density higher at night than in day in SG	SG: multiply day data by 1/0.283 to obtain night estimate (D/N calibration)	
Rock gunnel	- None on bare - Only observed at night in SG	SG: Add 0.0036 m^{-2} to night dataset (mean of night data from calibration site)	
Pollock	- None on bare or SG	SG: Multiply day data by 1/0.202 to obtain night estimate (D/N	- D/N calibration from Rangely and

	- Pelagic species not sampled by trawl	calibration)	Kramer 1995, sampled using snorkel transects.
Winter flounder	- None on bare - Only observed at night in SG	SG: Add 0.0519 m^{-2} to night dataset (mean of night data from calibration site)	
Pipefish	- None on bare - Slightly higher density at night than in day in SG	SG: multiply day data by 1/2.94 to obtain night estimate (D/N calibration)	
Cunner	- None on bare - No difference in density between day and night in SG		
White hake	- None on bare - No difference in density between day and night in SG		
Dusky snailfish	- None on bare or SG		
Scad	- None on bare or SG		
Sticklebacks	- Fourspine on bare higher in night than day, but very low density. Threespine on bare higher in day than night, but very low density. - Density of Fourspine and Threespine in SG higher in day than in night.	4 spine SG: multiply day data by 1/3.0625 to obtain night estimate (D/N calibration) 3 spine SG: multiply day data by 1/3.47 to obtain night estimate (D/N calibration)	- Very low density on bare excludes meaningful calibrations.

Table 7. Mean (± 1 SE) species-specific nekton density (number per m^{-2}) pooled across sites. Data are calibrated for differences in sampling gear and day-night. These data are now ready for use as data inputs for the production model. Note these estimates do not include catch efficiency or detection limitations of the sampling methods employed.

Species	Bare soft-sediment bottom	Seagrass (*Z. marina*)
Rock crab	0	0.078 ± 0.035
Green crab	6.839 ± 6.002	1.996 ± 0.862
Sand shrimp	12.60 ± 3.008	1.189 ± 0.343
Lobster	0.084 ± 0.019	0.018 ± 0.070
Grass shrimp	0.016 ± 0.035	0.082 ± 0.023
Sand lance	0.002 ± 0.003	0
Eel	0.0010 ± 0.0005	0.198 ± 0.082
Killifish	0.0245	0.044
Sea raven	0.001 ± 0.002	0
Silverside	0.313 ± 0.235	0.095 ± 0.007
Tomcod	0.00014 ± 0.00011	0.141 ± 0.035
Grubby sculpin	0.0205 ± 0.0197	0.628 ± 0.275
Rock gunnel	0.0112 ± 0.0103	0.010 ± 0.074
Pollock	0.0004 ± 0.0005	0.086 ± 0.053
Winter flounder	0.0317 ± 0.036	0.074 ± 0.049
Pipefish	0.0005 ± 0.0012	0.044 ± 0.018
Cunner	0.0122 ± 0.0194	0.004 ± 0.004
White hake	0.0005 ± 0.0012	0.0051 ± 0.0026
Snailfish	0	0.0002 ± 0.0011
Scad	0	0.0002 ± 0.0007
Fourspine stickleback	0.00029 ± 0.00023	2.587 ± 0.466
Threespine stickleback	0	2.699 ± 0.236

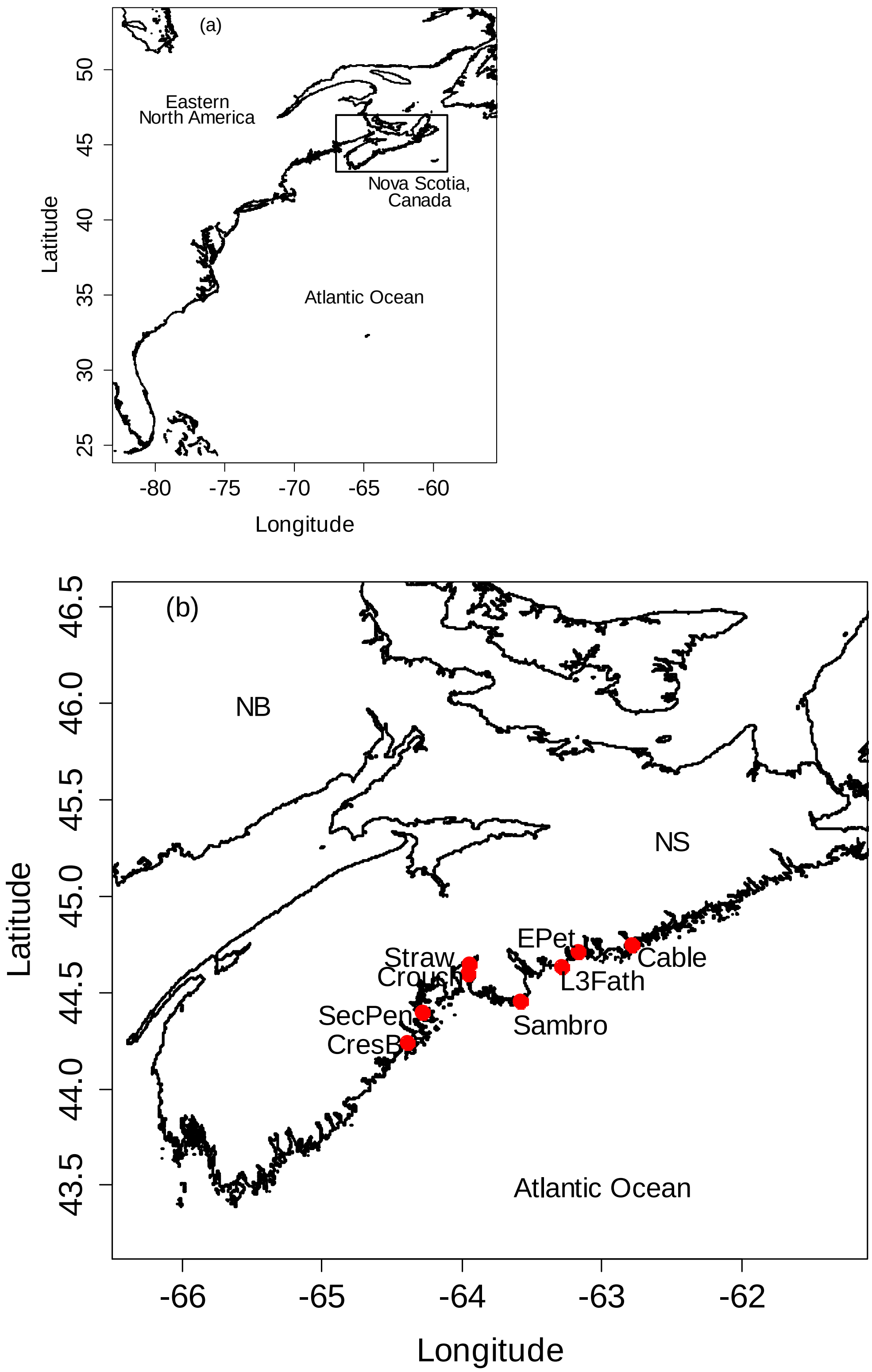

Figure 1. (a) East coast of North America. Nova Scotia (NS) is indicated by the box. (b) Field sites on the Atlantic coast of NS. NB = New Brunswick. See Table 1 for site abbreviations.

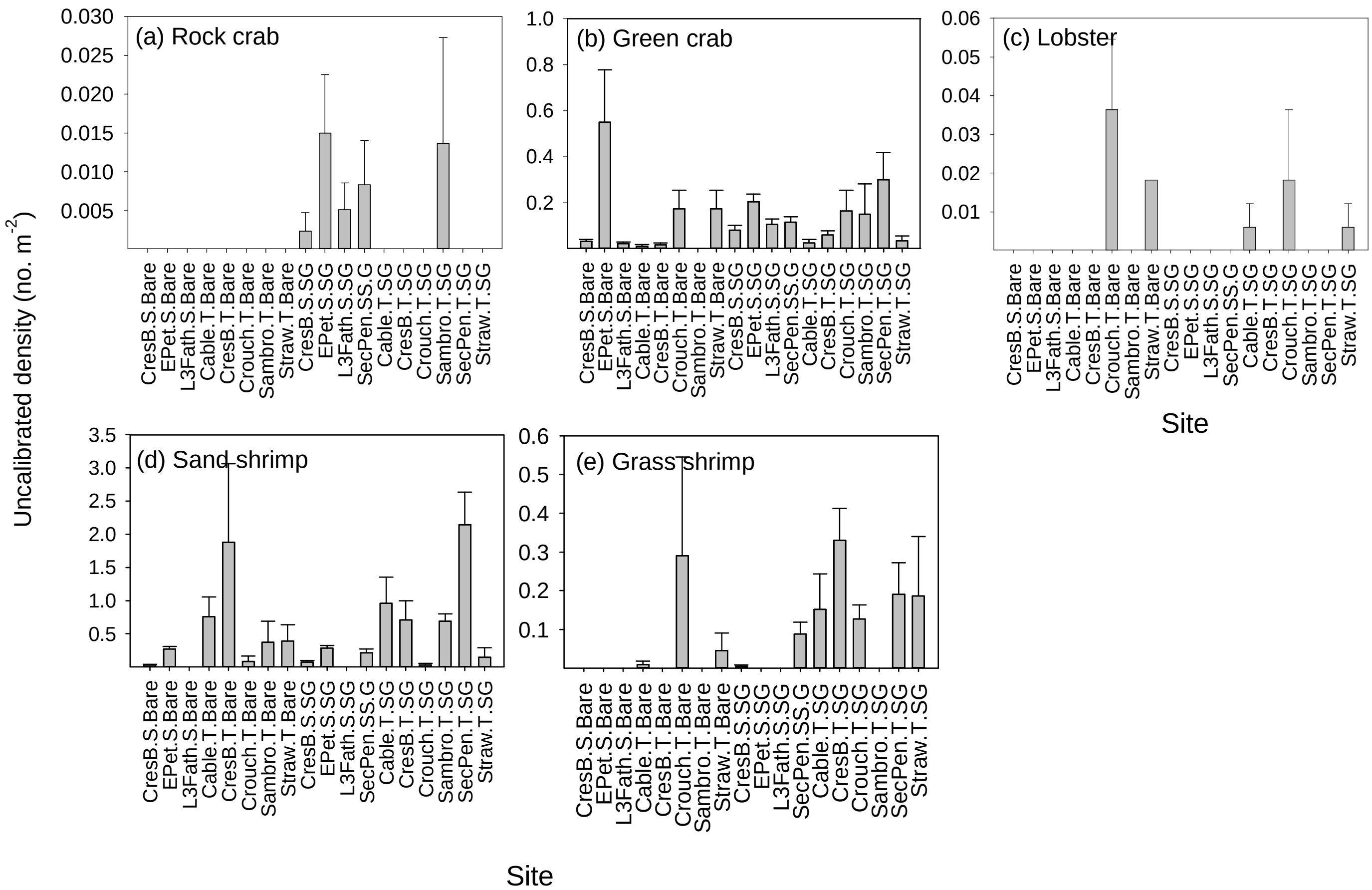

Figure 2A. Mean uncalibrated decapod density (+ 1SE) in seagrass (SG; *Z. marina*) and bare soft-sediment bottom at various field sites. Sampling gear included snorkel (S) and trawl (T) transects. Labels on the x-axes indicate site, gear and habitat. See Table 1 for site abbreviations.

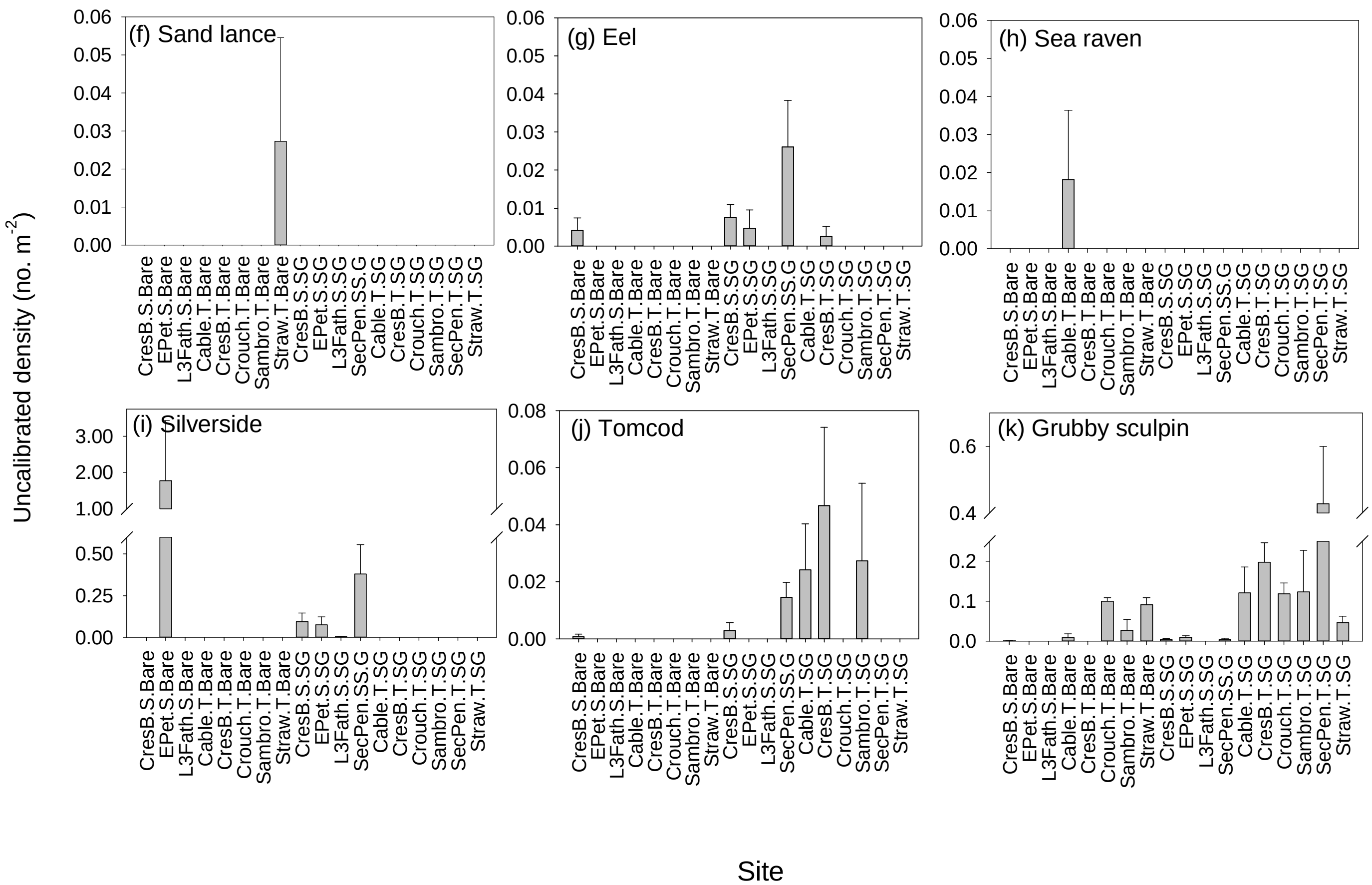

Figure 2B. Mean uncalibrated fish density (+ 1SE) in seagrass (SG; *Z. marina*) and bare soft-sediment bottom at various field sites. Sampling gear included snorkel (S) and trawl (T) transects. Labels on the x-axes indicate site, gear and habitat. See Table 1 for site abbreviations.

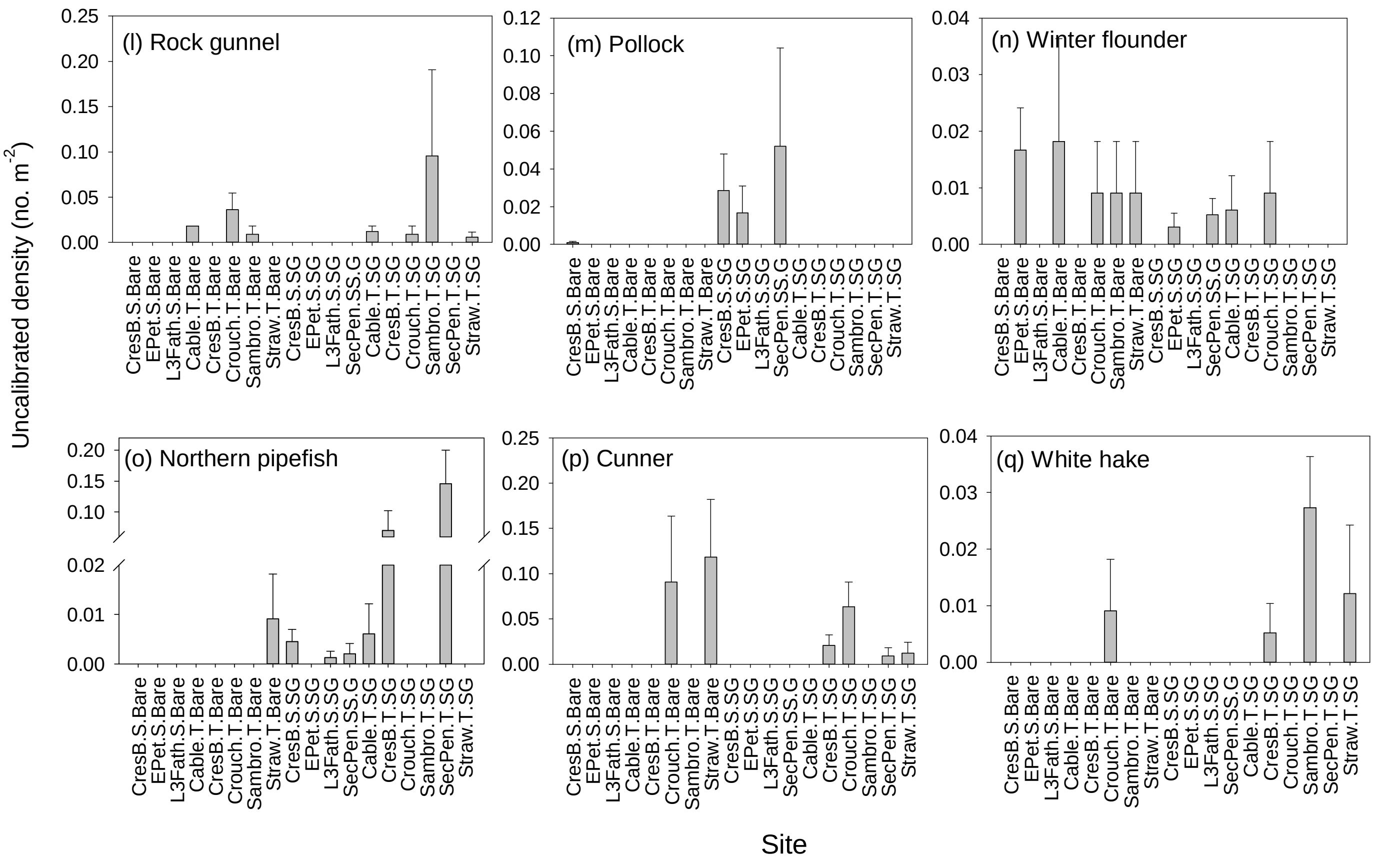

Figure 2C. Mean uncalibrated fish density (+ 1SE) in seagrass (SG; *Z. marina*) and bare soft-sediment bottom at various field sites. Sampling gear included snorkel (S) and trawl (T) transects. Labels on the x-axes indicate site, gear and habitat. See Table 1 for site abbreviations.

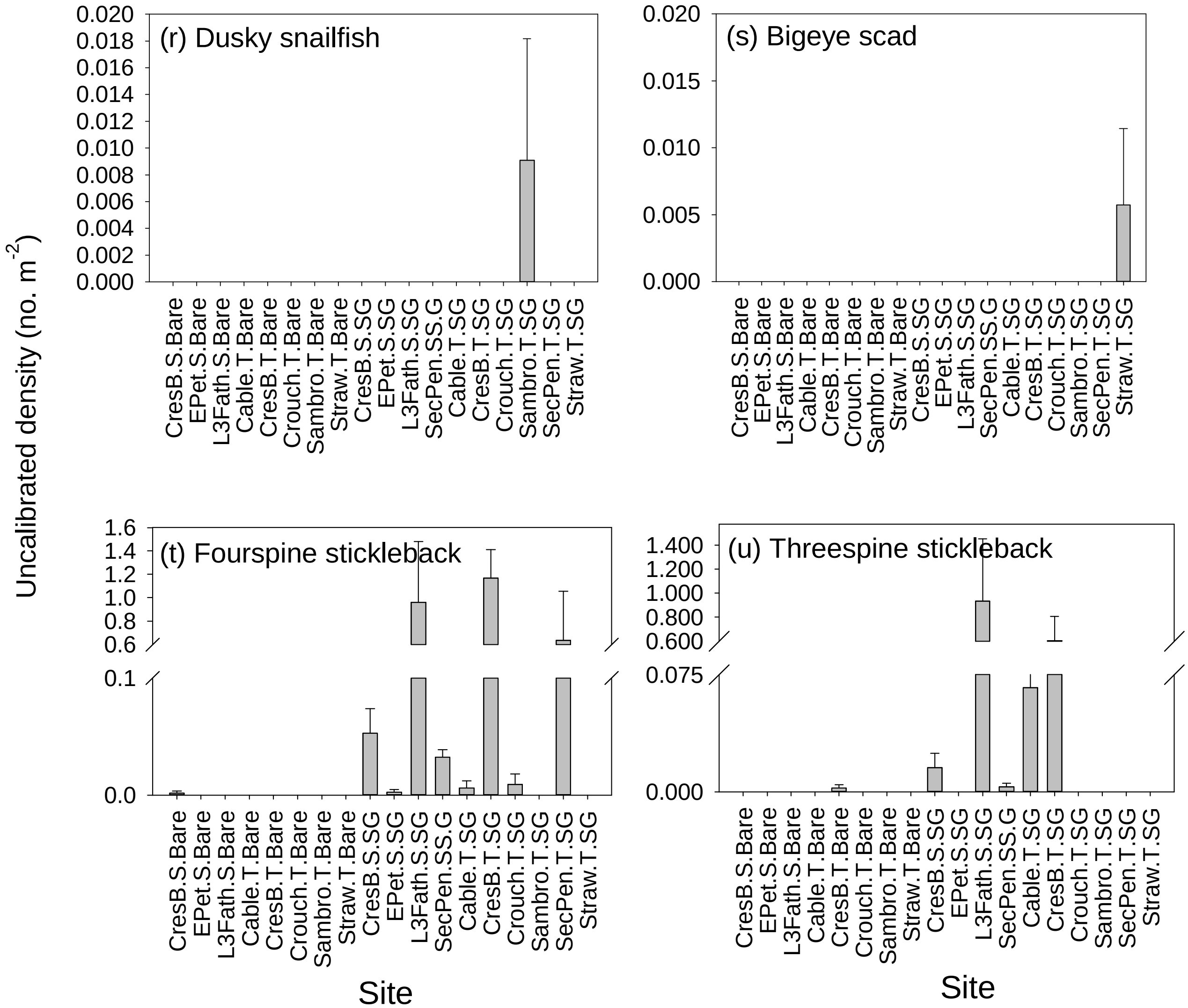

Figure 2D. Mean uncalibrated fish density (+ 1SE) in seagrass (SG; *Z. marina*) and bare soft-sediment bottom at various field sites. Sampling gear included snorkel (S) and trawl (T) transects. Labels on the x-axes indicate site, gear and habitat. See Table 1 for site abbreviations.

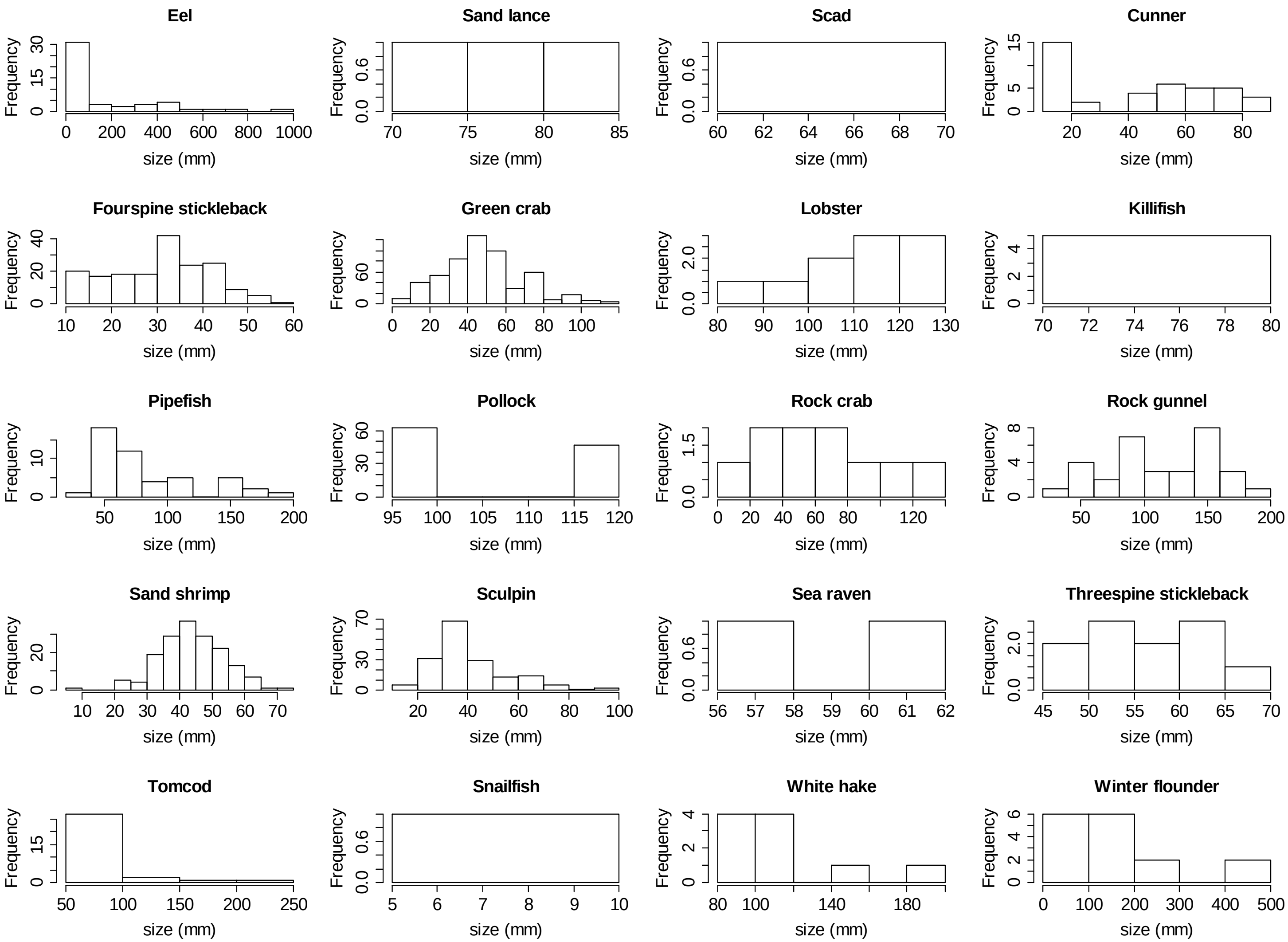

Figure 3. Size frequency histograms of nekton pooled across all sites and habitats. Fish and shrimp are total length, and lobster and crabs are carapace width.

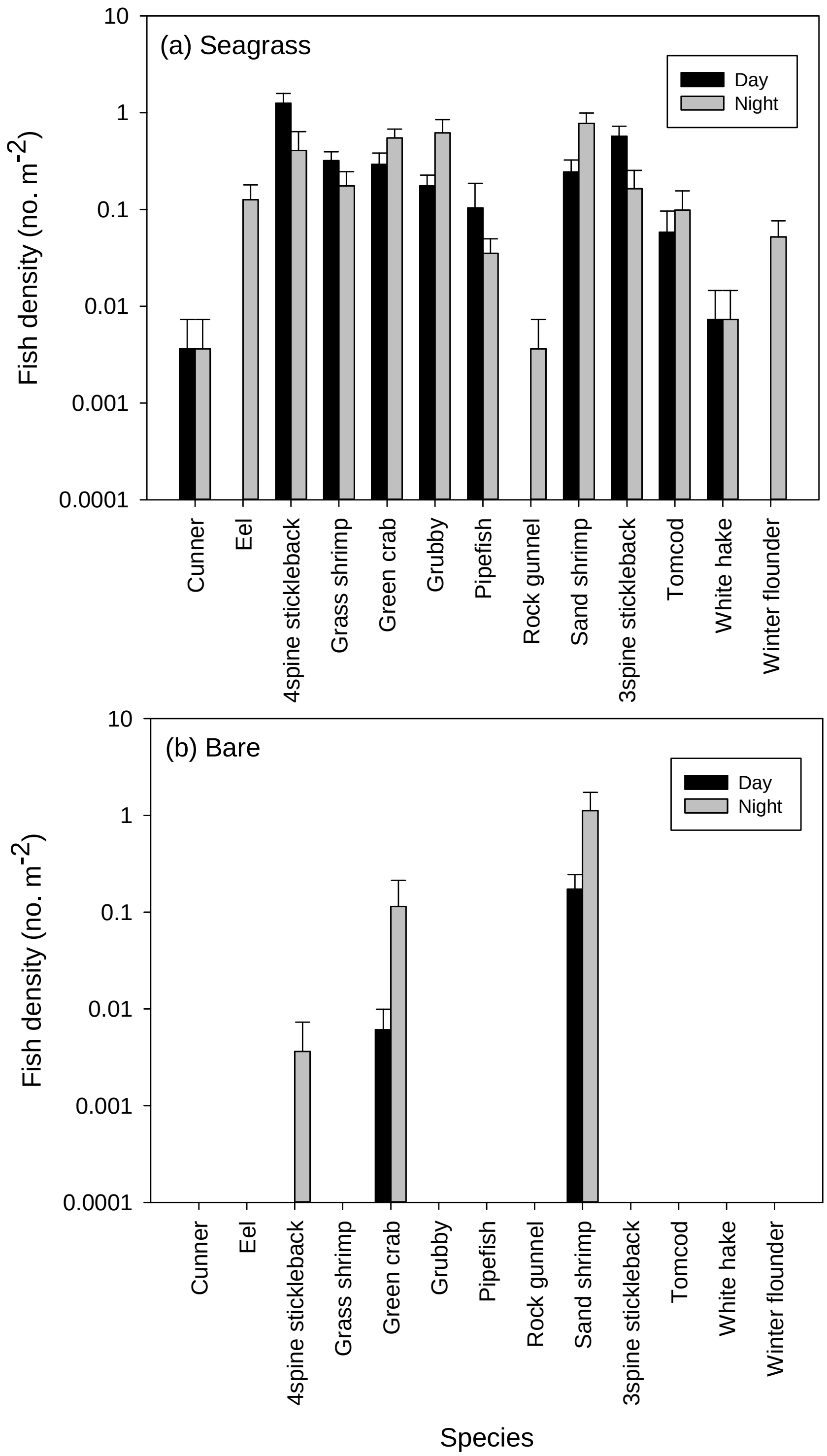

Figure 4. Nekton density in the day and night used to determine appropriate day/night data calibrations. Data were collected by trawling at Crescent Beach in July 2014.

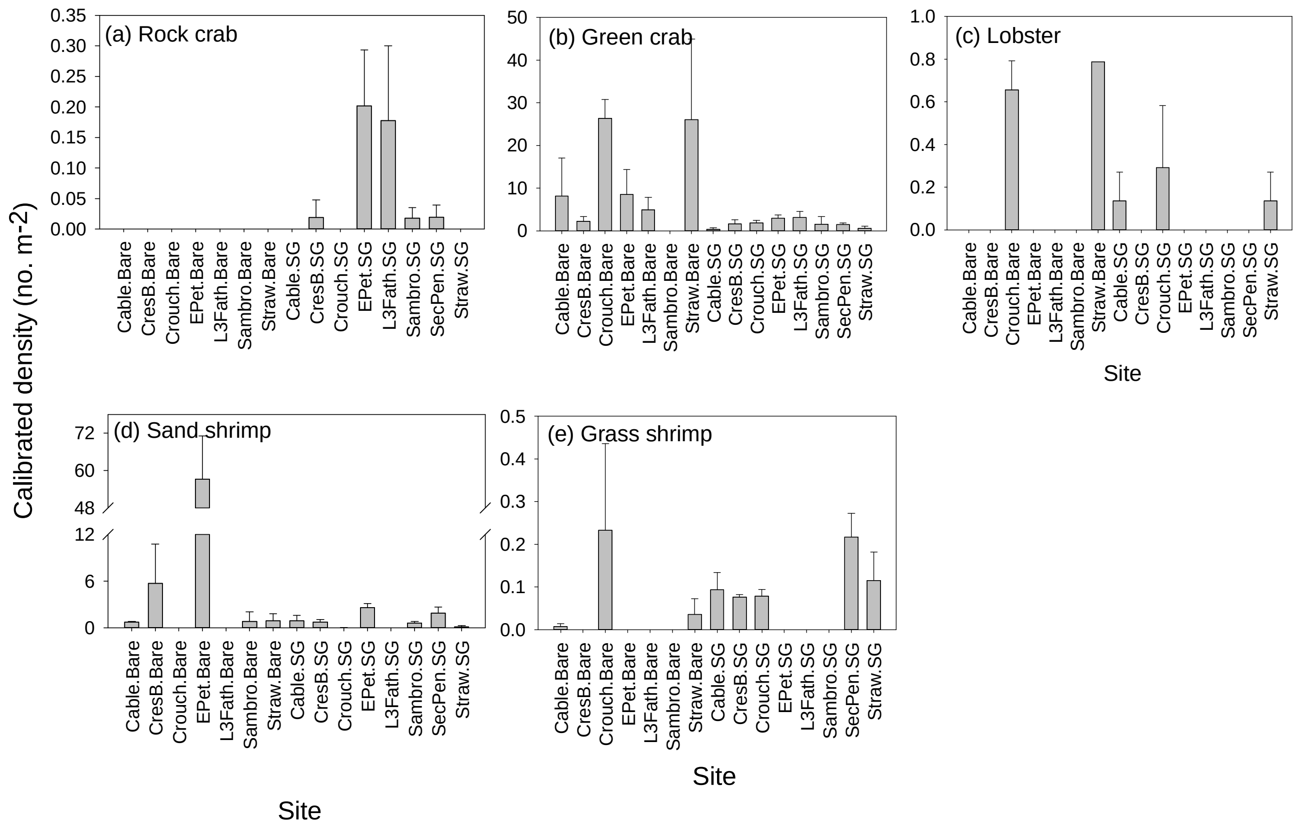

Figure 5A. Mean calibrated decapod density (+ 1SE) in seagrass (SG; *Z. marina*) and bare soft-sediment bottom at various field sites. Data are calibrated to account for differences in sampling gear (snorkel or trawl) and time of day (day or night), and represent Y1 equivalents. Error bars incorporate error associated with sampling replication and calibration ratios. Labels on the x-axes indicate site and habitat. See Table 1 for site abbreviations.

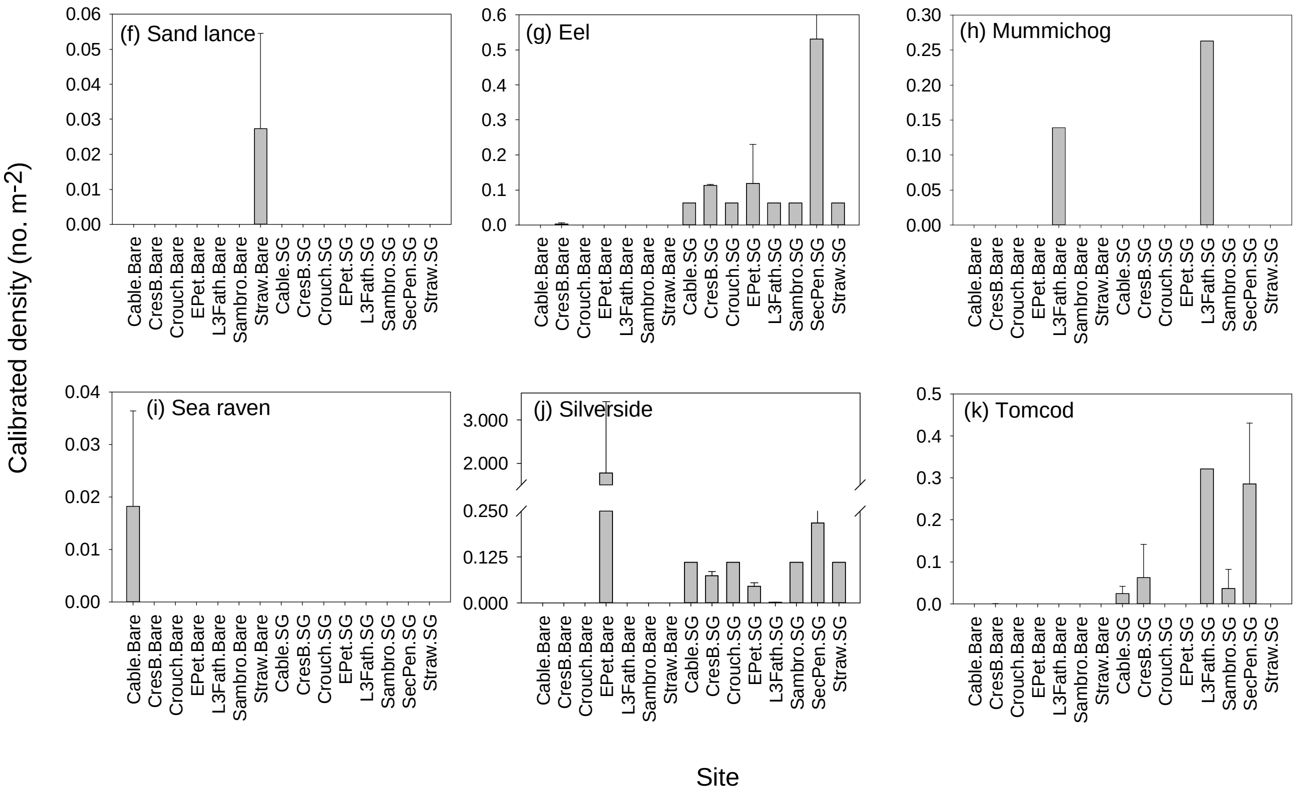

Figure 5B. Mean calibrated fish density (+ 1SE) in seagrass (SG; *Z. marina*) and bare soft-sediment bottom at various field sites. Data are calibrated to account for differences in sampling gear (snorkel or trawl) and time of day (day or night), and represent Y1 equivalents. Error bars incorporate error associated with sampling replication and calibration ratios. Labels on the x-axes indicate site and habitat. See Table 1 for site abbreviations.

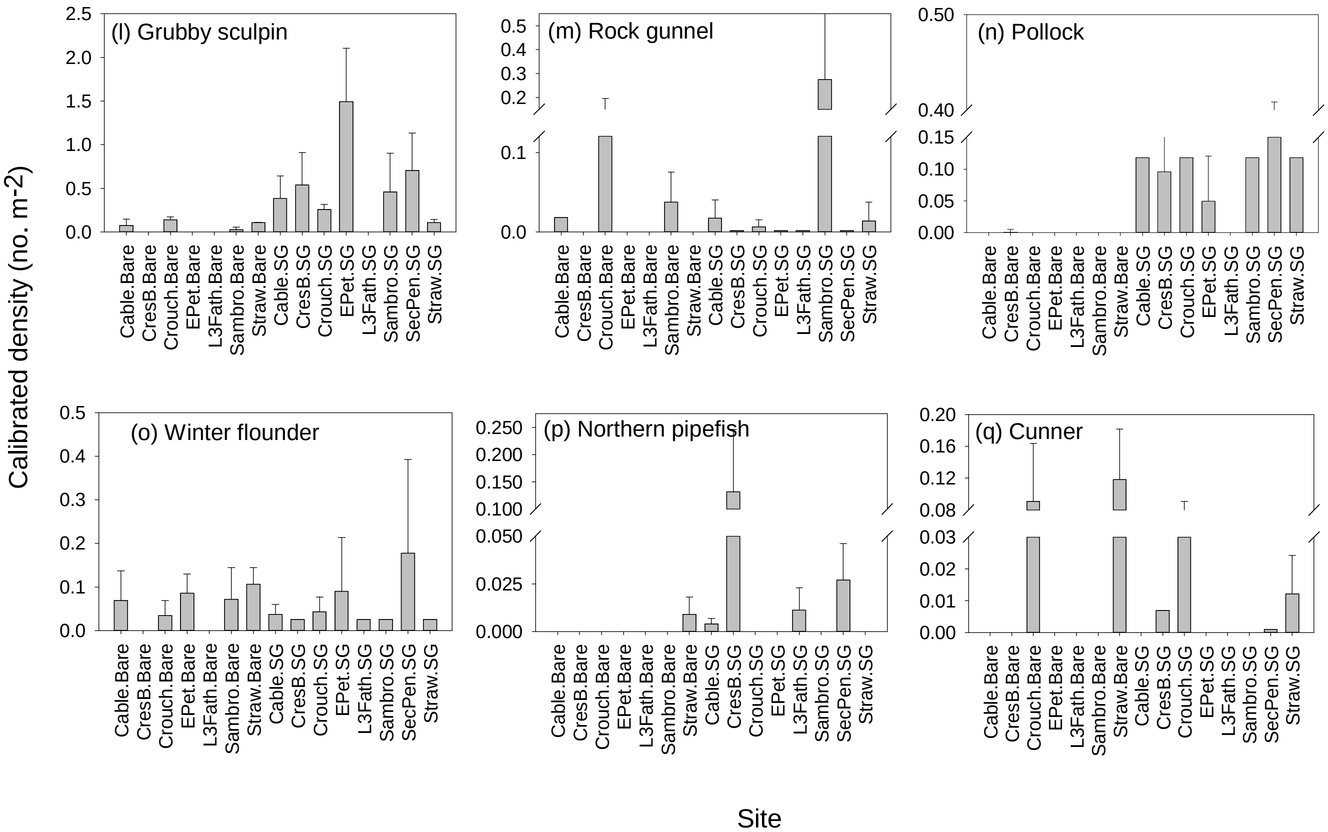

Figure 5C. Mean calibrated fish density (+ 1SE) in seagrass (SG; *Z. marina*) and bare soft-sediment bottom at various field sites. Data are calibrated to account for differences in sampling gear (snorkel or trawl) and time of day (day or night), and represent Y1 equivalents. Error bars incorporate error associated with sampling replication and calibration ratios. Labels on the x-axes indicate site and habitat. See Table 1 for site abbreviations.

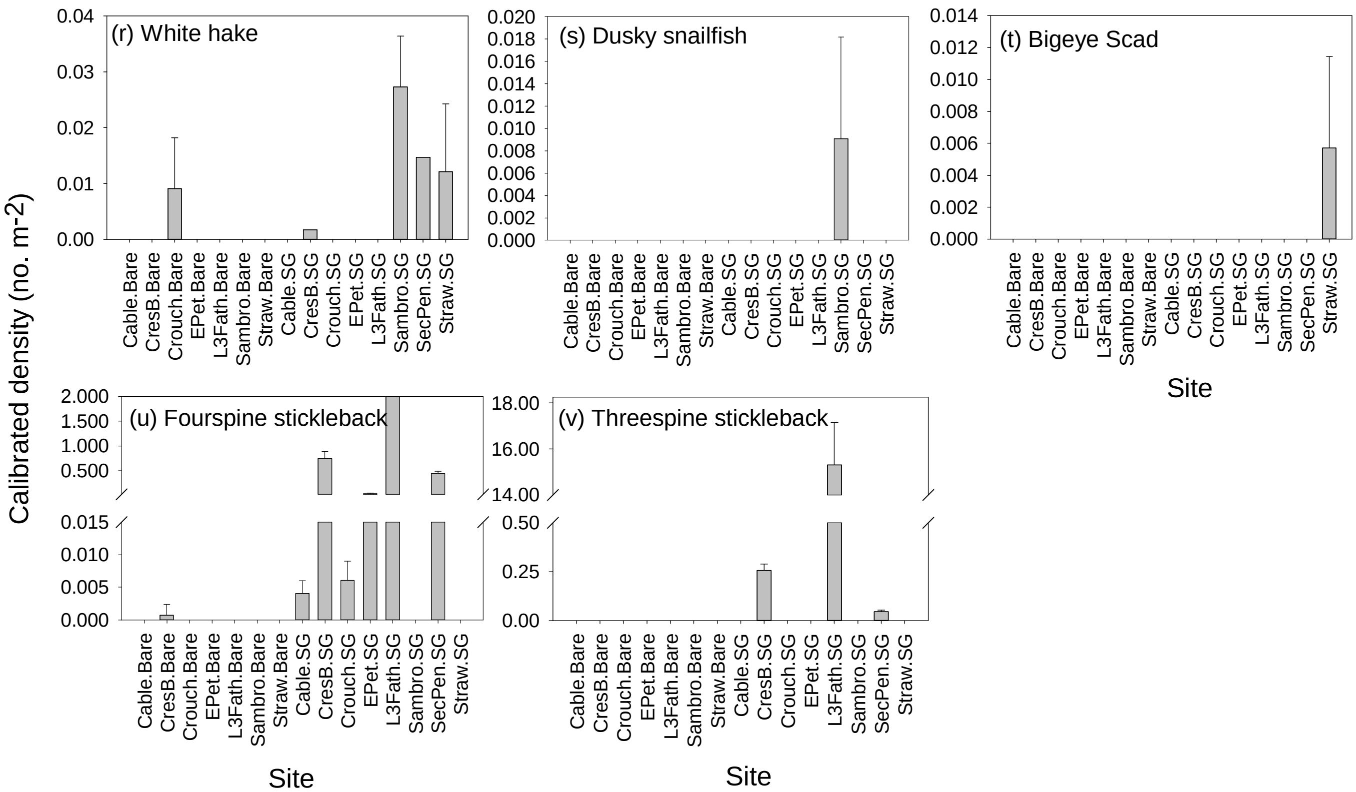

Figure 5D. Mean calibrated fish density (+ 1SE) in seagrass (SG; *Z. marina*) and bare soft-sediment bottom at various field sites. Data are calibrated to account for differences in sampling gear (snorkel or trawl) and time of day (day or night), and represent Y1 equivalents. Error bars incorporate error associated with sampling replication and calibration ratios. Labels on the x-axes indicate site and habitat. See Table 1 for site abbreviations. For panel (u), Fourspine stickleback at L3Fath.SG is 13.27 ± 3.52 m^{-2}.