The "East of Nantucket" Survey

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Purpose

Over the last year, two initiatives have focused on the absence of benthic survey data for a region east of Nantucket eastward to the Great South Channel, a portion of which is providing significant catch of Atlantic surfclams. The first is the convening of a Survey Design Working Group by the NMFS-NEFSC to redesign the federal Atlantic surfclam (*Spisula solidissima*) and ocean quahog (*Arctica islandica*) surveys. This task was a primary science recommendation from the Atlantic Surfclam Working Group as part of the 2017 benchmark assessment (NEFSC, 2017). The Survey Design Working Group identified this region east of Nantucket as the most important area supporting surfclams that fell outside of the historical survey stratum map used for the federal survey. The second was the proposal to establish an HMA, the Great South Channel Habitat Management Area, that would restrict the use of bottom tending gear, such as hydraulic dredges. The potential closure of an important surfclam fishing ground resulted in an evaluation of this HMA using historical survey data and tow-track data provided by the NEFSC and the surfclam fishery, respectively (Powell et al. 2017a). The lower half of this HMA fell within the historical survey stratum map used for the federal survey (NEFSC, 2017); however the northern half did not. As a consequence, an evaluation based on historical data could not be accomplished for the northern half (Powell et al. 2017a).

For both reasons, a survey of the region eastward of Nantucket to the Great South Channel was important and, as a consequence, a proposal was put forward to the National Science Foundation Industry/University Cooperative Research Center SCeMFiS (Science Center for Marine Fisheries) to support a survey. This proposal was funded.

Survey Location and Design

Location

The survey domain is shown in Figure 1. Three regions are demarcated. The first, located on the upper left, is a region identified by the Survey Design Working Group as a region supporting significant surfclam landings that fell outside of the historical survey stratum map (NEFSC, 2017) and, consequently, never included within the federal survey. Note that the western boundary approximates the inshore EEZ boundary and that the southern boundary abuts on the lower left the Nantucket Lightship Habitat Closure Area, an area already closed to bottom-tending gear. The larger region located in the center and to the right is that portion of the upper half of the proposed Great South Channel Habitat Management Area under consideration for a fishing exemption for the Atlantic surfclam fishery (Powell et al. 2017a). Note that the western approximately one-third of this HMA subregion overlaps the eastern approximately one-half of the region identified by the Survey Design Working Group.

Survey Design

A fixed grid design was chosen to insure that the region was evenly and densely surveyed. Fixed grids are routinely used to evaluate regions initially for later inclusion into a stratified random survey design (e.g., van der Meer, 1997; Morehead et al., 2008; HSRL, 2012; Powell et al., 2017b). A hub-and-spoke fixed grid design was implemented with spokes of 3-nm length (Fig. 1). This sampling density was chosen to approximate the densest sampling grid theoretically achievable under NEFSC survey protocol (as used for the *R/V Delaware II* surveys). Under this protocol, stations within a stratum are chosen randomly on a flexible 2’ latitude x 2.5’ longitude grid, about 2 nm x 2.5 nm (depending on latitude); that is, stations chosen randomly that fall closer than this distance are assumed to be replicates and only one is sampled.

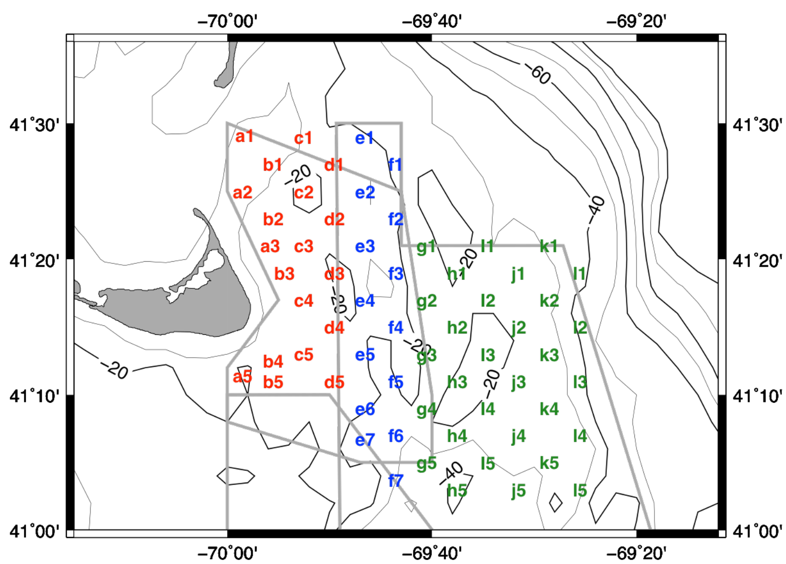

Figure 1. Survey design used for the “East of Nantucket” survey. Gray lines outline (upper left) the region recommended for survey by the Survey Design Working Group, (lower left) the northern portion of the Nantucket Lightship Habitat Closure Area, and (right) the upper half of the Great South Channel HMA under consideration for an exemption for surfclam fishing. Letters and numbers are station designations for the 63 stations in the survey. Depths are in meters.

A few stations were repositioned under a standard NEFSC protocol permitting repositioning within 1 nm of the designated position. Stations were moved for three reasons: (1) some fell just inshore of the EEZ inshore boundary and were moved offshore across the boundary line; (2) some stations fell just inside of the Nantucket Lightship Habitat Closure Area and were moved just north of that closure line; and (3) some stations fell on untowable bottom, always locations too shallow for the vessel to safely tow, and were moved laterally into deeper water. Only 6 of the 63 stations (9.5%) were repositioned.

Survey Towing and On-Deck Processing Protocol

The survey protocol followed the protocol used by NMFS-NEFSC for the 1982-2011 *R/V Delaware II* surveys in most respects. This protocol was chosen to permit comparison of "bycatch" data routinely collected during the *R/V Delaware II* surveys (see Powell et al. 2017a,c). The survey vessel was the *F/V Mariette*, homeport New Bedford, Massachusetts. This vessel fishes routinely in the area. The dredge was a 99-in hydraulic dredge of standard surfclam design. Bar spacing was 1.875″ on the top, bottom, and knife shelf and 1.75″ on the sides. Selectivity is unknown, but experience with dredges of this type suggests that the dredge will be ~100% selective for market-size surfclams (≥120 mm) with selectivity steadily declining at smaller sizes. The *F/V Mariette* uses a shaker to clean up the catch. The shaker grate was closed to 0.75″ for the survey.

Towing protocol was a 5-min tow in the direction of the next station except where large sand waves restricted towing direction. Tow speed was 3 knots. Most tows lasted for 5 min, but excessive catch or rapid shoaling decreased tow time in a few cases. Tow distance was recorded. Total swept area averaged about 1,250 m^2 (Table 1). The survey in its entirety sampled about 78,500 m^2.

	Distance (m)	Swept Area (m^2)
Mean	495.9	1,247.0
Standard deviation	52.9	133.0
Median	498.3	1,253.1
Interquartile range	70.8	178.0
Sum	31,242.0	78,561.2

Table 1. Tow track statistics. The upper 4 are given as tow^{-1}. The sum is the total for all 63 stations occupied.

The entire catch was sorted using the *R/V Delaware II* sampling protocol which included sorting all surfclams, cobbles, rocks, boulders, associated invertebrates, and shell, with two exceptions. (1) Bushel volume measurements were used for mussels rather than counts. (2) Ten haphazardly chosen each of cobbles (2-6″), rocks (6-12″), boulders (>12″), and surfclam shells were photographed, if ≥10 where present; otherwise all were photographed. Photos were biased towards particle sides with attached bionts, if present. All surfclams were measured. All other free-living invertebrates, except mussels, were counted. To limit processing time, invertebrates were tallied by higher taxon (e.g., echinoid, crab, naticid). In some cases (e.g., crabs), these categories included a number of different species. Only common taxa are included in this report. Cobbles, rocks, boulders, and shell were measured in bushels. Attached bionts were recorded as absent, present, and predominant.

All measured biota and sediment particles were standardized to per m^2 catch. Attached bionts were placed into a semiquantitative scale (viz., 0=absent, 1=present, 2=predominant). In keeping with analyses of *R/V Delaware II* bycatch data (Powell et al., 2017a). Anemones, tunicates, and sponges were combined into an attached biont category and enumerated as the sum of their individual semiquantitative scales. Surfclams were allocated to 4 size classes: <120 mm, 120-150 mm, 150-170 mm, ≥170 mm. The 120-mm division marks the size class boundary termed "fishable" in earlier NEFSC assessment reports (e.g., NEFSC, 2003). Animals smaller than 120 mm, though landed, are not targeted, and will be termed submarket-size in this report. Animals ≥150 mm are desired by companies that hand-shuck, hence the size-class boundary separating small market-size and medium market-size clams, as referred to in this report. Animals ≥170, termed large market-size clams in this report, generally exceed the von-Bertalanffy L_∞ for the remainder of the stock (Munroe et al., 2016). Photographs were analyzed in terms of percentages (e.g., percent of photographs with hydroids). The photographic analysis is biased against stations with large catches in that 10 photographs from those stations was usually a small subsample of the entire catch. However, standardizing to catch would have provided metrics dominated by a few stations and thus not be representative of the surveyed region. The photographic analysis is also biased against stations with low catches in that these stations provided fewer than 10 photographs of one or more sedimentary particle type. No standardization for under-representativeness was included.

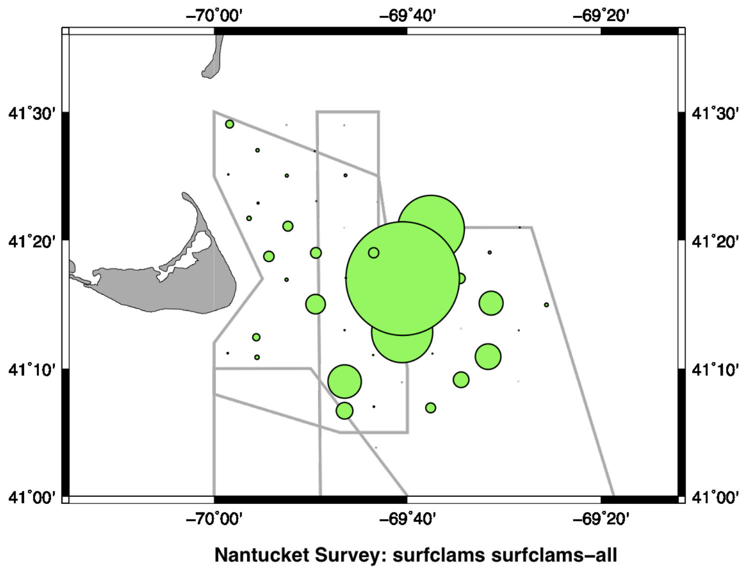

Figure 2. Catch of Atlantic surfclams. Circle diameters are linearly proportional to numbers m^{-2}. Zero catch stations are not shown (see Fig. 1 for full station complement).

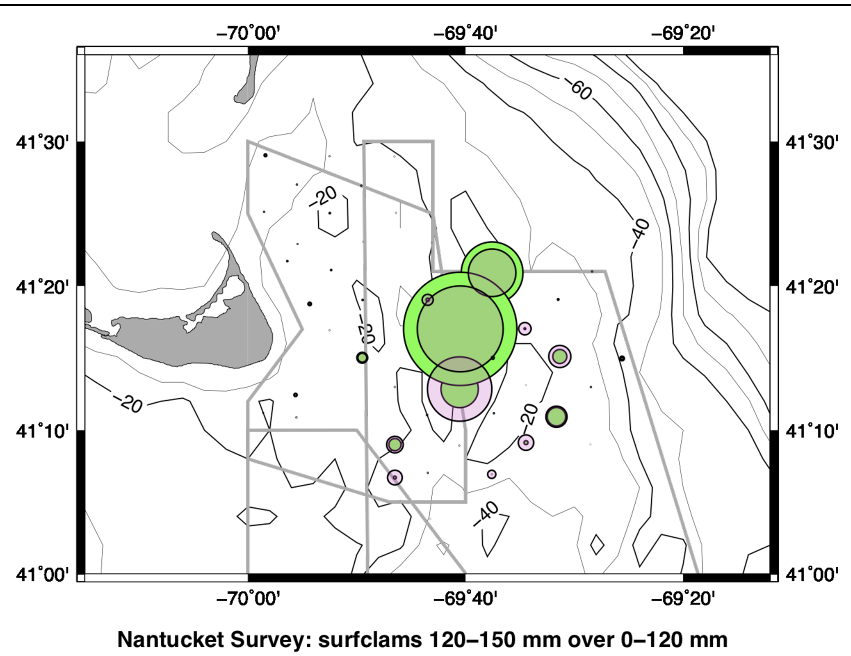

Figure 3. Catch of submarket (green) and small market (purple) Atlantic surfclams. Circle diameters are linearly proportional to numbers m^{-2}. Zero catch stations are not shown (see Fig. 1 for full station complement). Depths in m.

Figures that follow generally compare two components of the catch. Circle diameters are linearly proportional to catch (in m^{-2}) or to the semiquantitative scale within each component, but are not comparable between components. Thus, for example, in a plot of surfclams and mussels, differential circle sizes for surfclams show differences in catch of surfclams between stations; ditto for mussels. However, no valid quantitative comparison can be made between the circle sizes for surfclam catch and the circle sizes for mussel catch. Correspondence analysis was used to examine the entire dataset holistically because some data were categorical (e.g., attached bionts) (Clausen, 1998). In this case, quantitative data were classified into linearly incrementing categories. A detailed rendering of catch data is provided in Appendix 1.

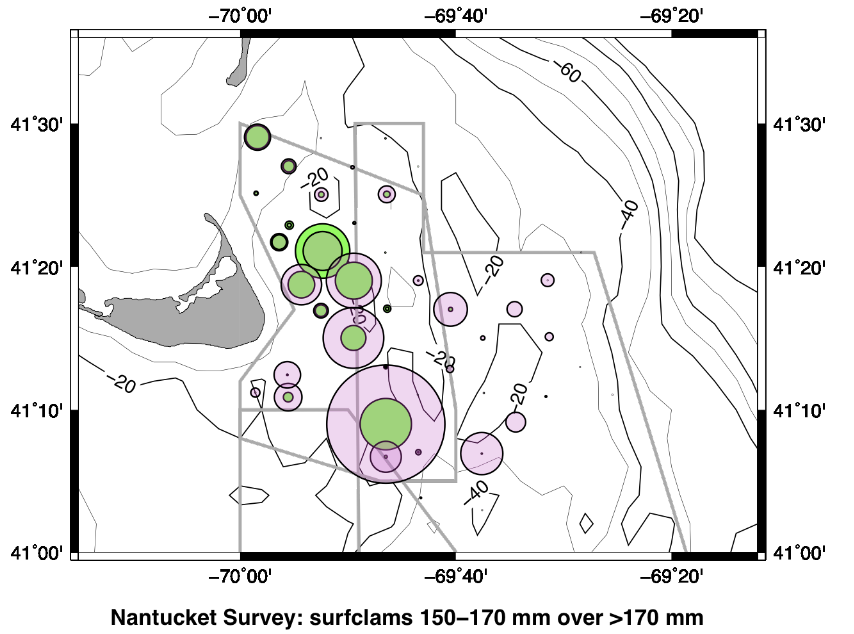

Figure 4. Catch of medium (green) and large (purple) market-size Atlantic surfclams. Circle diameters are linearly proportional to numbers m^{-2}. Zero catch stations are not shown (see Fig. 1 for full station complement). Depths in m.

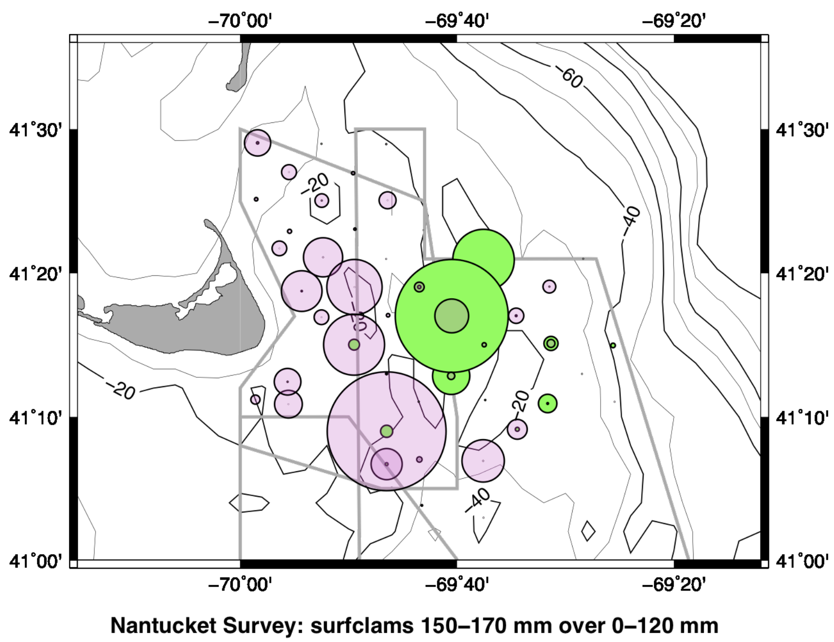

Figure 5. Catch of submarket (green) and medium market-size (purple) Atlantic surfclams. Circle diameters are linearly proportional to numbers m^{-2}. Zero catch stations are not shown (see Fig. 1 for full station complement). Depths in m.

Results

Atlantic surfclams

Atlantic surfclams were found throughout the surveyed region except for the offshore and southern portions of the HMA. Limited numbers in the south are consistent with minimal NEFSC survey catches in the strata immediately south of the surveyed area (NEFSC, 2017; Powell et al., 2017a). Highest catches were taken in the central portion of the surveyed region coincident with the north-central portion of the HMA and just outside of the region identified by the Survey Design Working Group based on reported surfclam landings (Fig. 2).

The surfclam sizes were not equivalently distributed in the survey domain. Submarket and small market –size surfclams were found in highest abundance in the central northern portion of the surveyed area coincident with the western half of the HMA and the eastern edge of the region identified by the Survey

Design Working Group from landings data. Few small surfclams were found inshore from where most landings originate. The two size classes generally overlapped wherever they occurred (Fig. 3). In contrast, medium and large market-size surfclams were found on the most extreme southwestern edge of the HMA and inshore to the EEZ boundary (Fig. 4). The two larger size classes were very similarly distributed, but the largest of the clams (≥170 mm) tended to be disproportionately relatively more common in the most inshore central portions of the survey domain. Animals 150 mm and larger were rarely encountered offshore of this region and extremely large animals (170+ mm) were very rare. Perusal of the NEFSC federal survey database for the period 2000-2015 shows that the large market-size surfclams collected on this survey represent the largest concentration of surfclams ≥170 mm in the federal stock. The differential in distribution is well depicted by a comparison of submarket and medium market-size surfclams (Fig. 5), which shows limited overlap in these two size classes. The submarket size animals dominate in water >35 m deep in comparison to the larger clams generally found at shallower depths.

Atlantic surfclam shell

Bivalve shell enters into the taphonomic process after death. Stated simply, various

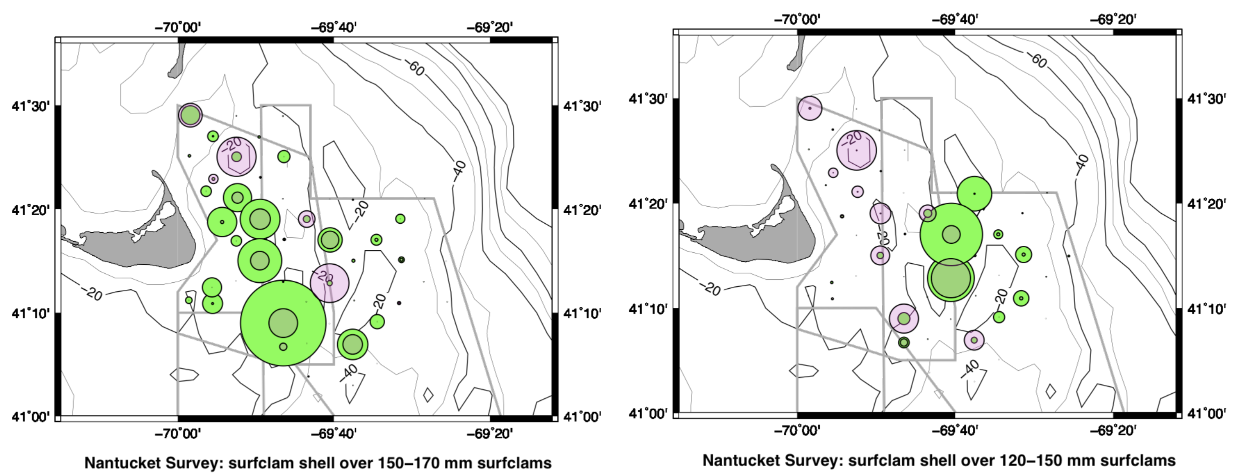

Figure 6. Left, catch of surfclam shell (purple) and medium-size market-size Atlantic surfclams (green). Right, catch of surfclam shell (purple) and small market-size Atlantic surfclams (green). Circle diameters are linearly proportional to numbers m^{-2} for surfclams and bu m^{-2} for surfclam shell. Zero catch stations are not shown (see Fig. 1 for full station complement). Depths in m.

degradational processes such as dissolution, abrasion, and bioerosion operate to destroy the shell (Staff et al., 1986; Powell et al., 1989; Davies et al., 1990) while it is at the surface or in the surficial sediments within the taphonomically-active zone (TAZ; Davies et al. 1989). Burial, on the other hand, removes shell from the TAZ, thereby preserving it for an extended period of time if not indefinitely (Powell, 1992). The robustness to taphonomic degradation of surfclam shell is unknown, but shells of similar clam species tend to be robust (Callender et al., 1994; Walker and Goldstein, 1999; Powell et al., 2011a,b). Thus, surfclam shell should remain intact for many decades after death (Powell et al., 2017c).

Over much of the stock, warming seawater temperatures are forcing surfclams to move north and offshore (Narváez et al., 2015; Powell et al., 2017c; Hofmann et al., in press). This process is well documented in the Mid-Atlantic where surfclams have moved offshore off New Jersey (Weinberg et al., 2005) and mass mortality (Kim and Powell, 2004) events have occurred inshore off Delmarva. Powell et al. (2017c) and NEFSC (2017) documented the same trends as far north as Georges Bank. NEFSC (2017) found surfclams progressing offshore off eastern Long Island. This nearly stock-wide shift in range is due to the narrow temperature window between optimal and the high lethal limit (Munroe et al., 2013; Narváez et al., 2015). Consequences of this physiology include lower condition offshore (Marzec et al. 2010), declining maximum size (L_∞: Munroe et al., 2016), and a differential distribution of surfclam shell and living surfclams (Powell et al., 2017c). In the latter case, a characteristic of recent colonization is living surfclams with little co-occurring shell whereas the opposite is indicative of a range shift, timing of which is dependent upon the degree of time averaging (Powell and Davies, 1990; Flessa and Kowalewski, 1994; Kidwell, 2002).

In the surveyed region, surfclam shell was generally encountered where large market-size surfclams were found (Fig. 6), an indication that surfclams have been a dominant benthic inhabitant at these inshore depths for an extended period of time. How long is unclear, but the maximum life span of ~30 years would suggest that inhabitation has extended over half-century time scales or longer. In contrast, smaller surfclams, found offshore of this region, rarely were found in locales where surfclam shell was abundant (Fig. 6). The inference is that this deeper-water region has been only recently inhabited by surfclams. This would be consistent with the tricennial shift in surfclams offshore. However, the absence of age data for these clams prevents unequivocal discrimination of more recent colonization from slower growth, which might also be expected offshore in deeper water (Munroe et al., 2013).

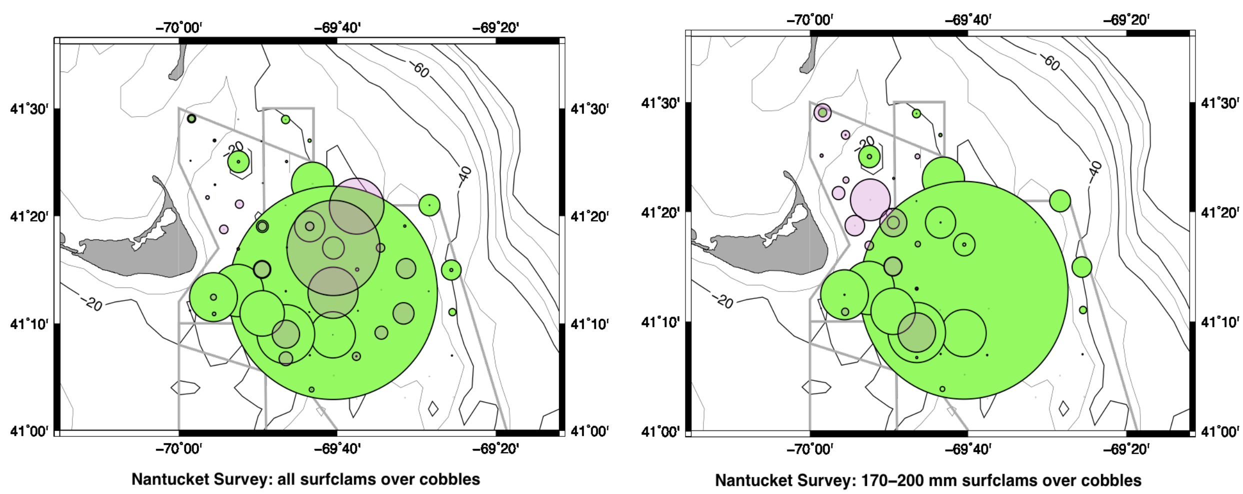

Figure 7. Left, catch of all, mostly submarket and small market-size, Atlantic surfclams (purple) and cobbles (green). Right, catch of large market-size Atlantic surfclams (purple) and cobbles (green). Circle diameters are linearly proportional to numbers m^{-2} for surfclams and bu m^{-2} for cobbles. Zero catch stations are not shown (see Fig. 1 for full station complement). Depths in m.

Distribution of cobbles, rocks, and boulders

Cobbles, rocks and boulders are routinely encountered on Georges Bank in regions occupied by surfclams (Powell et al. 2017c). Surfclams, however, are sand denizens and, presumably, do not require or benefit from the presence of such sedimentary components in their habitat. Cobbles, defined following *R/V Delaware II* survey protocol as particles 2-6″ in diameter, were commonly encountered at many sites in the surveyed region (Fig. 7). Cobbles were most common at intermediate depths in the west-central portion of the HMA and southeast of Nantucket. Medium and large market-size surfclams are generally found inshore and north of the cobble-rich region. In contrast, submarket and small market-size surfclams are most common within the depth range where cobbles are also frequently encountered (Fig. 7). Assuming that the distribution of smaller surfclams indicates a range extension into deeper water, surfclams are becoming increasingly abundant at depths where cobbles are also common. However, closer inspection suggests that submarket and small market-size surfclams tend to be more common in locales within this depth range where cobbles are less abundant, though overlap is clearly increased relative to the distributional dichotomy between cobbles and medium and large market-size surfclams.

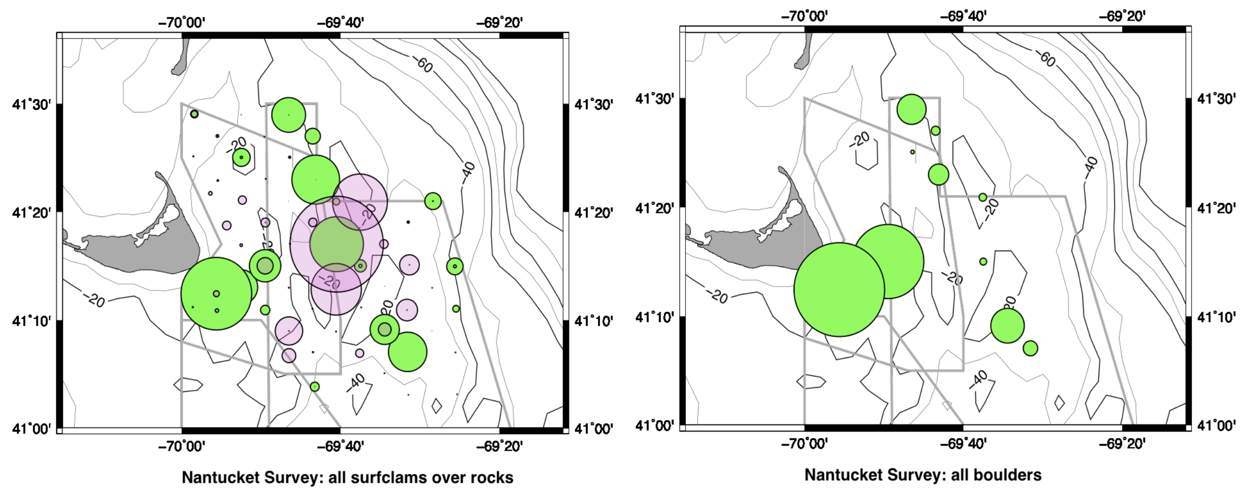

Figure 8. Left, catch of all, mostly submarket and small market-size, Atlantic surfclams (purple) and rocks (green). Right, catch of boulders. Circle diameters are linearly proportional to numbers m^{-2} for surfclams and bu m^{-2} for rocks and boulders. Zero catch stations are not shown (see Fig. 1 for full station complement). Depths in m.

Rocks, sediment particles 2-12″ in diameter following *R/V Delaware II* survey protocol, are much less common than cobbles; however, the distribution of rocks is similar to cobbles, as might be anticipated by the glacial origin of both (Trumbull, 1972). Rocks were most common in the north and central portions of the HMA and southeast of Nantucket (Fig.8). As with cobbles,

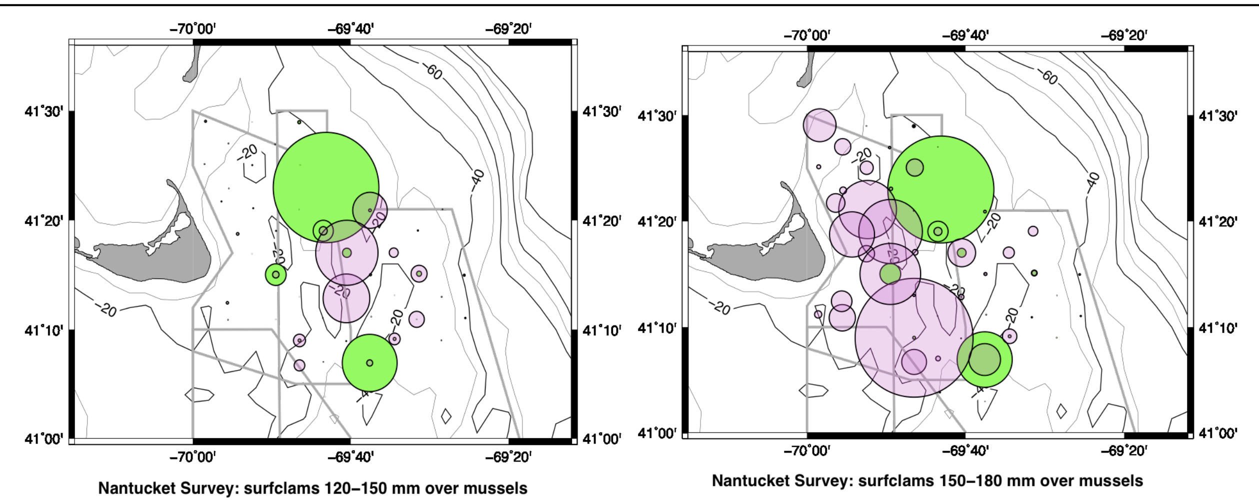

Figure 9. Left, catch of small market-size Atlantic surfclams (purple) and mussels (green). Right, catch of medium to large market-size Atlantic surfclams (purple) and mussels (green). Circle diameters are linearly proportional to numbers m^{-2} for surfclams and bu m^{-2} for mussels. Zero catch stations are not shown (see Fig. 1 for full station complement). Depths in m.

the distribution of medium and large market-size surfclams clearly diverged from that of rocks. The smaller surfclam sizes were most abundant at depths where rocks were often encountered, but closer inspection suggests that surfclams tend to be more common in locales within this depth range where rocks are less abundant (Fig. 8). An equivalent conclusion is reached for boulders, sediment particles >12″ in diameter. Boulders were sporadically and uncommonly encountered on the survey, but were more likely to be encountered at sites where rocks were common (Fig. 8).

Distribution of mussels

Mussels were abundant in a few tows. When abundant, they occurred in dense mats

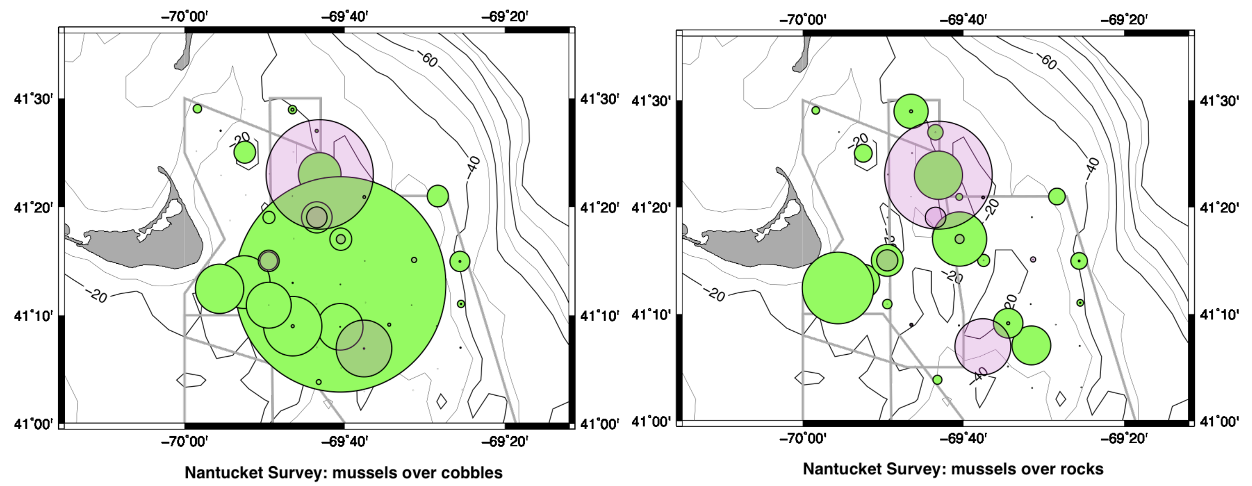

Figure 10. Left, catch of cobbles (green) and mussels (purple). Right, catch of rocks (green) and mussels (purple). Circle diameters are linearly proportional to bu m^{-2}. Zero catch stations are not shown (see Fig. 1 for full station complement). Depths in m.

attached to pebbles and sand grains, which counterweighed their tendency towards saltation. Mats normally were a mixture of *Modiolus modiolus* and a *Mytilus* species or just *Mytilus*. Two species of *Mytilus* are found along the northeast coast, *Mytilus edulis* and *Mytilus trossulus,* with the latter extending farther north and the former farther south. Considerable overlap in their ranges exists north of Cape Cod (Rawson and Harper, 2009. According to Hilbish et al. (2000), mussels collected south of central Maine on the East coast were likely *Mytilus edulis* as *M. edulis* is the predominant species from central Maine south (Rawson et al., 2001) to Cape Hatteras (Wells and Gray, 1960). Regardless, no attempt was made to determine the species composition of the mytilids on this survey. Large mussel catches were characterized by a wide range of size classes including new recruits and adults; as a

Figure 11. Underside of a piece of mussel mat showing the interwoven byssal threads securing the mussels to pebbles and sand grains to achieve a cohesive mass with added weight to resist saltation under low current velocities.

consequence, numbers caught were too large to permit tallying the catch numerically. Bushel volumes were used. Limited time on site prevented individual measurements from being taken.

Mussels did not occur at sites where medium and large market-size surfclams were found (Fig. 9). Large mussel catches occurred primarily offshore of the region where these larger surfclams were common, with highest catches in the northwestern portion of the HMA, with a single exception of one site in the south-central portion of the HMA (Fig. 9). On the other hand, sites where submarket and small market-size surfclams abounded fell within the same depth range as sites yielding quantities of mussels. Nonetheless, although the two taxa overlapped in their offshore depth range, at no site were both caught in large quantities. The two distributions were clearly locally disjunct (Fig. 9).

The distribution of mussels along the northeast coast of the U.S. in the intertidal is

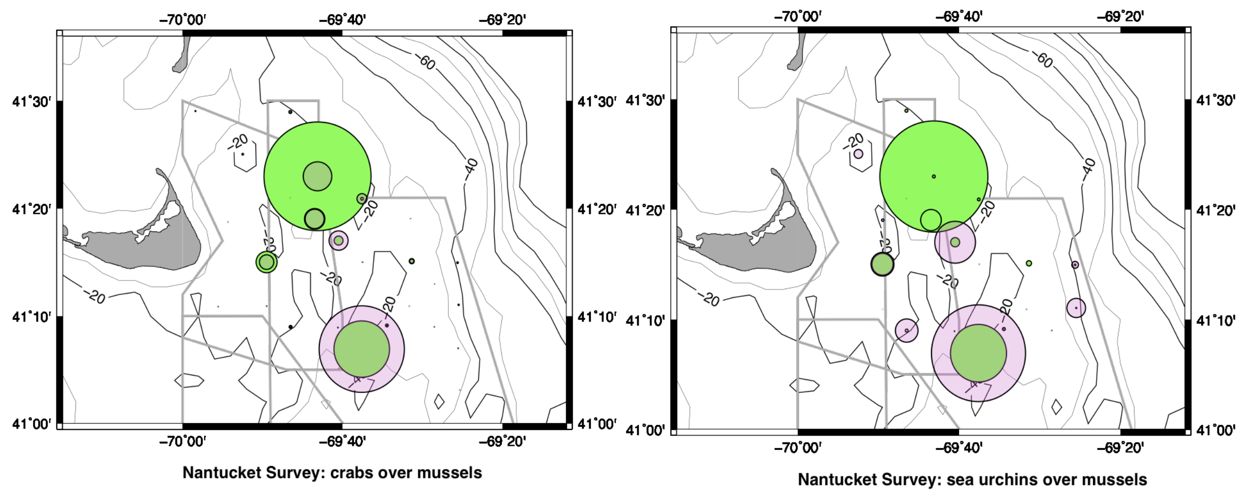

Figure 12. Left, catch of crabs (purple) and mussels (green). Right, catch of regular echinoids (purple) and mussels (green). Circle diameters are linearly proportional to numbers m^{-2} for crabs and echinoids and bu m^{-2} for mussels. Zero catch stations are not shown (see Fig. 1 for full station complement). Depths in m.

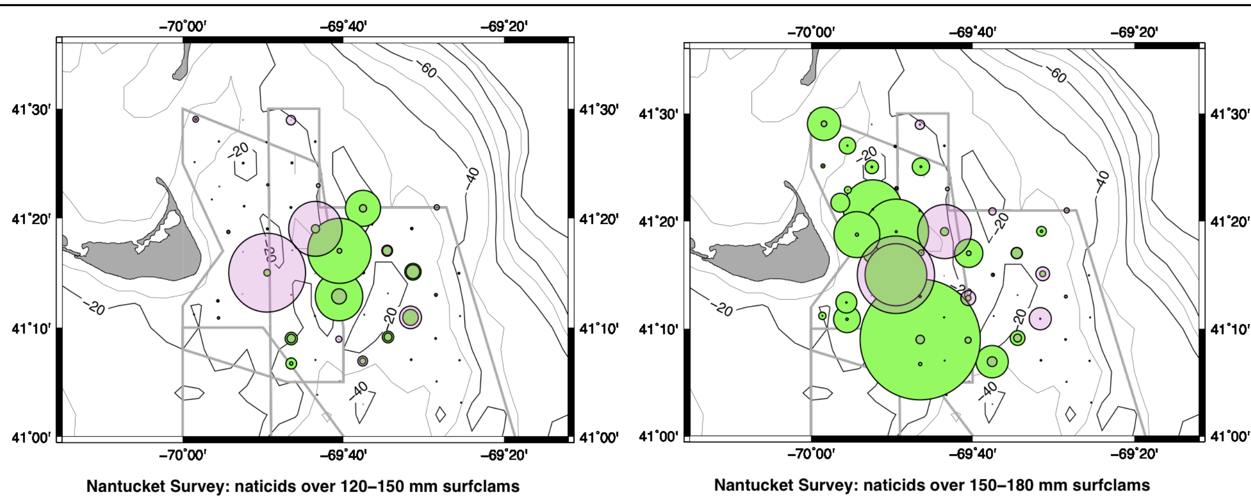

Figure 13. Left, catch of naticid gastropods (purple) and small market-size Atlantic surfclams (green). Right, catch of naticid gastropods (purple) and medium to large market-size Atlantic surfclams (green). Circle diameters are linearly proportional to numbers m^{-2} for naticids and surfclams. Zero catch stations are not shown (see Fig. 1 for full station complement). Depths in m.

noteworthy for being associated with rocky shores or manmade structures (Lauenstein et al., 1997; Cockrell et al., 2015), although they commonly occur in intertidal mats along the western European coast (Beukema and Cadée, 1996; Diederich, 2006). The abundance of cobbles and rocks at some survey sites suggests ideal substrate exists for mussels and sites yielding mussels or cobbles and rocks in abundance were often located in a similar depth range along a southeast trending line from the northwestern corner of the HMA south to the central region of the HMA (Fig. 10). Surprisingly, the mussels were rarely abundant at sites where cobbles, rocks, or boulders were common (Fig. 10), even though all four were frequently encountered in the same depth range. Thus, mussel beds did not depend on large sedimentary particles for their presence or integrity; rather, their cohesion was based on interwoven byssal threads, pebbles, and sand grains (Fig. 11), as is typical of mussel beds on soft sediments (Salas et al., 2016; wa Kangeri et al., 2014, 2016).

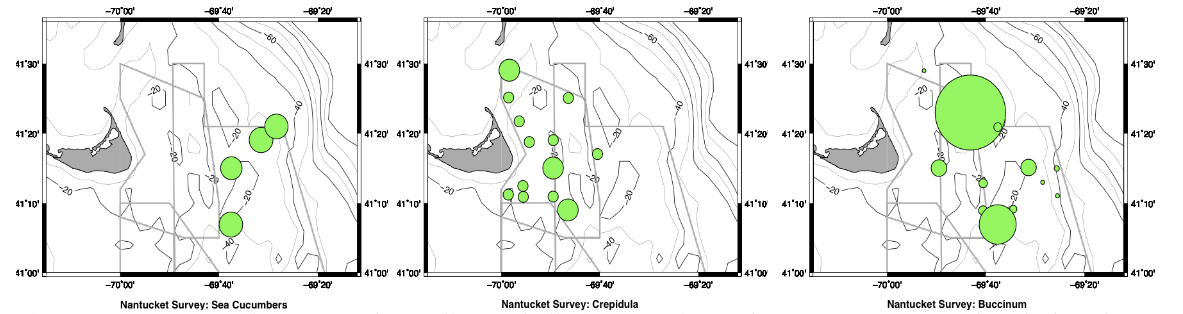

Figure 14. Presence of sea cucumbers, slipper shells (*Crepidula*), and *Buccinum* gastropods. Circle values for slipper shells and sea cucumbers are 1=present and 2=abundant. Circle diameters for *Buccinum* are linearly proportional to numbers m^{-2}. Zero catch stations are not shown (see Fig. 1 for full station complement). Depths in m.

Distribution of miscellaneous megabenthos – mostly mobile

Crabs and regular sea urchins occurred commonly at a few sites (Fig. 12), typically coincident with mussels. Naticid snails were also commonly encountered at most, except the deepest, depths. Naticids are bivalve predators (Stanton et al., 2981; Boggs et al., 1984; Powell et al., 2001). The expectation based on known predation proclivities (Dietl and Alexander, 1997; Quijón et al., 2007) that they should co-vary with surfclams is not supported, however, as their distribution did not obviously coincide with the distribution of large or small surfclams (Fig. 13). Nor did it obviously coincide with the distribution of mussels. The survey encountered a number of small clams (e.g., *Astarte, Pitar*), which are poorly caught by the survey gear and thus not reported here. Likely these clams

Figure 15. Example surfclam shell (upper left), cobble (upper right), rock (lower left), and boulder (lower right) free of attached epibionts.

are the primary prey of the naticids. Sea cucumbers were caught at a few sites (Fig. 14). All of these were in deeper water, distinctly deeper than the depth range of mussels, surfclams, and

	Photographs Examined	Fraction Encrusted Barnacles or Scars	Fraction Encrusted Barnacles	Fraction Encrusted Barnacle Scars
Shells	290	56.9%	30.0%	51.4%
Cobbles	445	61.8%	22.7%	59.6%
Rocks	140	74.3%	28.6%	73.6%
Boulders	26	80.8%	26.9%	76.9%
Total	901			

Table 2. Frequency of occurrence of barnacles and barnacle scars on shells, cobbles, rocks, and boulders. Note that photographic analyses are not normalized to substrate catch volume or by station: numbers are raw estimates based on the number of photographs taken. Note that substrate photographs emphasize the side with the most attached epibionts

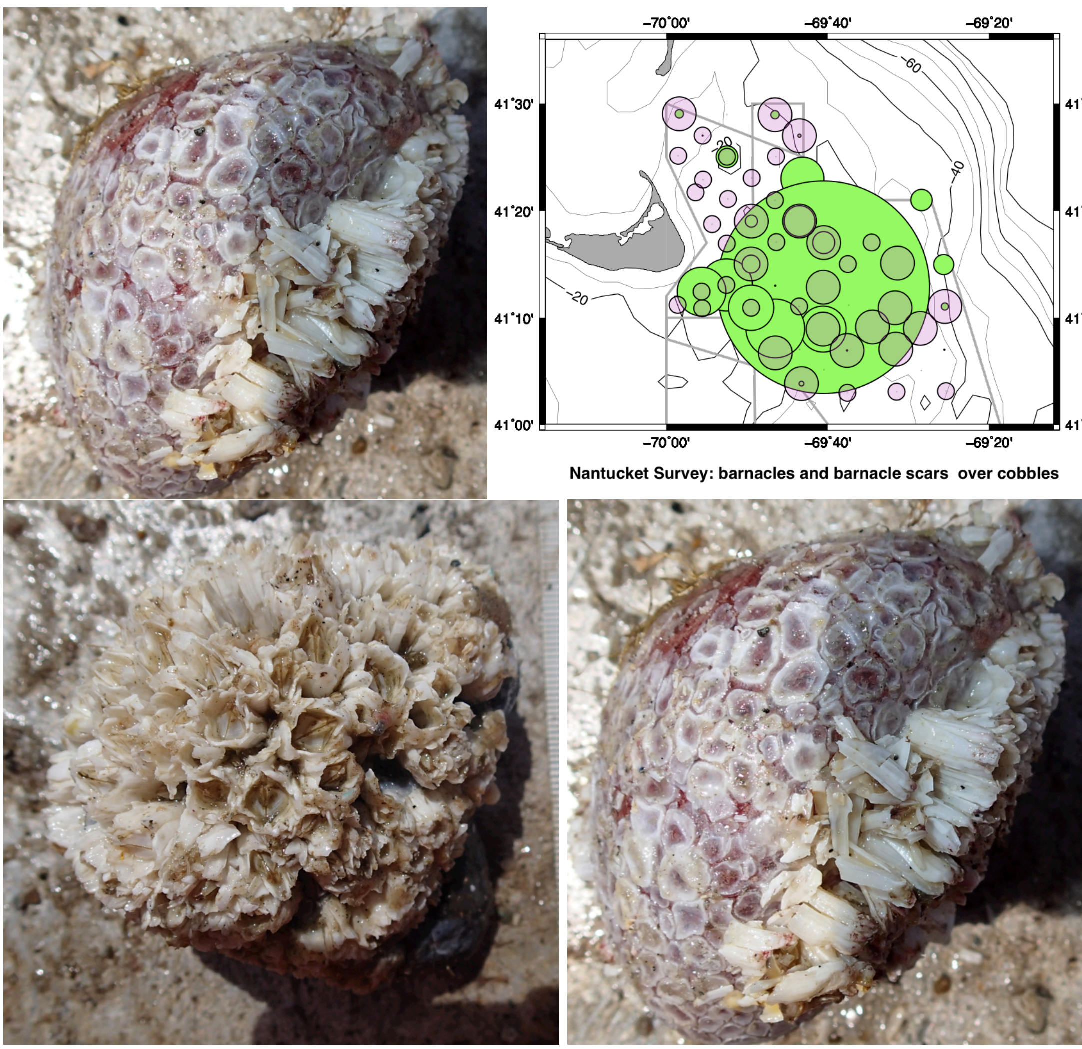

Figure 16. Upper right, occurrence of barnacles and barnacle scars (purple) and cobbles (green). Circle diameters are linearly proportional to bushels m^{-2} for cobbles. Circle values for barnacles are 1=present and 2=abundant. Zero catch stations are not shown (see Fig. 1 for full station complement). Depths in m. Upper left and lower, photographs of representative cobbles and rocks with barnacles and barnacle scars.

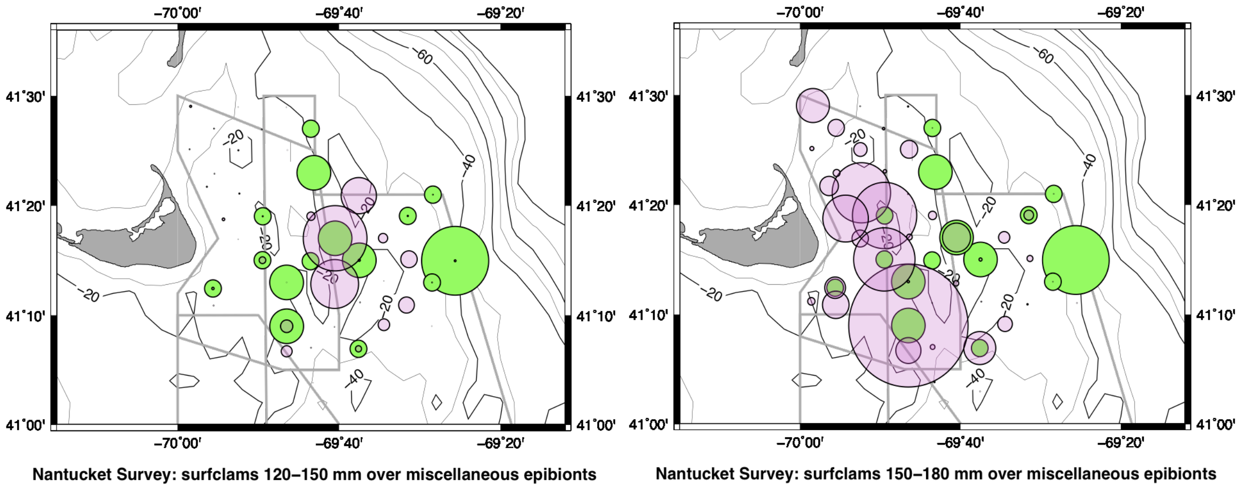

Figure 17. Left, occurrence of anemones, tunicates, and sponges (green) and small market-size Atlantic surfclams (purple). Right, occurrence of anemones, tunicates, and sponges (green) and medium to large Atlantic surfclams (purple). Circle diameters are linearly proportional to numbers m^{-2} for surfclams. Circle values for epibionts are the summary designations of 1=present and 2=abundant for each taxon. Values range from 1 to 6; largest value obtained was 4. Zero catch stations are not shown (see Fig. 1 for full station complement). Depths in m.

their associated biota. *Buccinum* gastropods were often caught in the central and northeast portion of the HMA (Fig. 14). Slipper shells were commonly caught inshore at sites where large surfclams and surfclam shells were abundant (Fig. 14).

	Photographs Examined	Fraction Encrusted Tunicates, Anemones, Sponges	Fraction Encrusted Tunicates	Fraction Encrusted Anemones, Sponges
Shells	290	4.8%	4.8%	0.0%
Cobbles	445	11.2%	10.1%	1.3%
Rocks	140	8.6%	7.9%	1.4%
Boulders	26	7.7%	3.8%	3.8%
Total	901			

Table 3. Frequency of occurrence of tunicates, anemones, and sponges on shells, cobbles, rocks, and boulders. Note that photographic analyses are not normalized to substrate catch volume or by station: numbers are raw estimates based on the number of photographs taken. Note that substrate photographs emphasize the side with the most attached epibionts.

	Photographs Examined	Fraction Encrusted Hydroids
Shells	290	50.0%
Cobbles	445	29.9%
Rocks	140	39.3%
Boulders	26	19.2%
Total	901	

Table 4. Frequency of occurrence of hydroids on shells, cobbles, rocks, and boulders. Note that photographic analyses are not normalized to substrate catch volume or by station: numbers are raw estimates based on the number of photographs taken. Note that substrate photographs emphasize the side with the most attached epibionts.

Distribution of attached epibenthos

Evaluation was made of large attached epibenthos on cobbles, rocks, boulders, and surfclam shell. Accordingly, the survey did not record the occurrences of small encrusting organisms such as spirorbids, serpulids, and foraminifera. Cobbles, rocks, boulders, and surfclam shell were most commonly free of the recorded suite of attached epibionts (Fig. 15), with the exception of barnacle scars (Table 2). For surfclams, death occurs at the sediment-water interface, as the species is infaunal. Thus, the shell initially is mostly or completely buried. SSETI (Shelf and Slope Experimental

Taphonomy Initiative) has shown that even a dusting of sediment will prevent attachment of most encrusters, the small calcareous polychaetes and certain encrusting foraminifera being exceptions (Parsons-Hubbard et al., 1997, 2001; Powell et al. 2008). Thus, encrustation on surfclam shell was anticipated to be relatively rare due to their infaunal tier (Rodland et al., 2004). Surprisingly, perhaps, encrustation was also rare on cobbles rocks and boulders, with the exception of barnacle scars, suggesting that these sedimentary constituents are also persistently or frequently buried.

The most common and ubiquitous large epibiont was the barnacle. Barnacles were

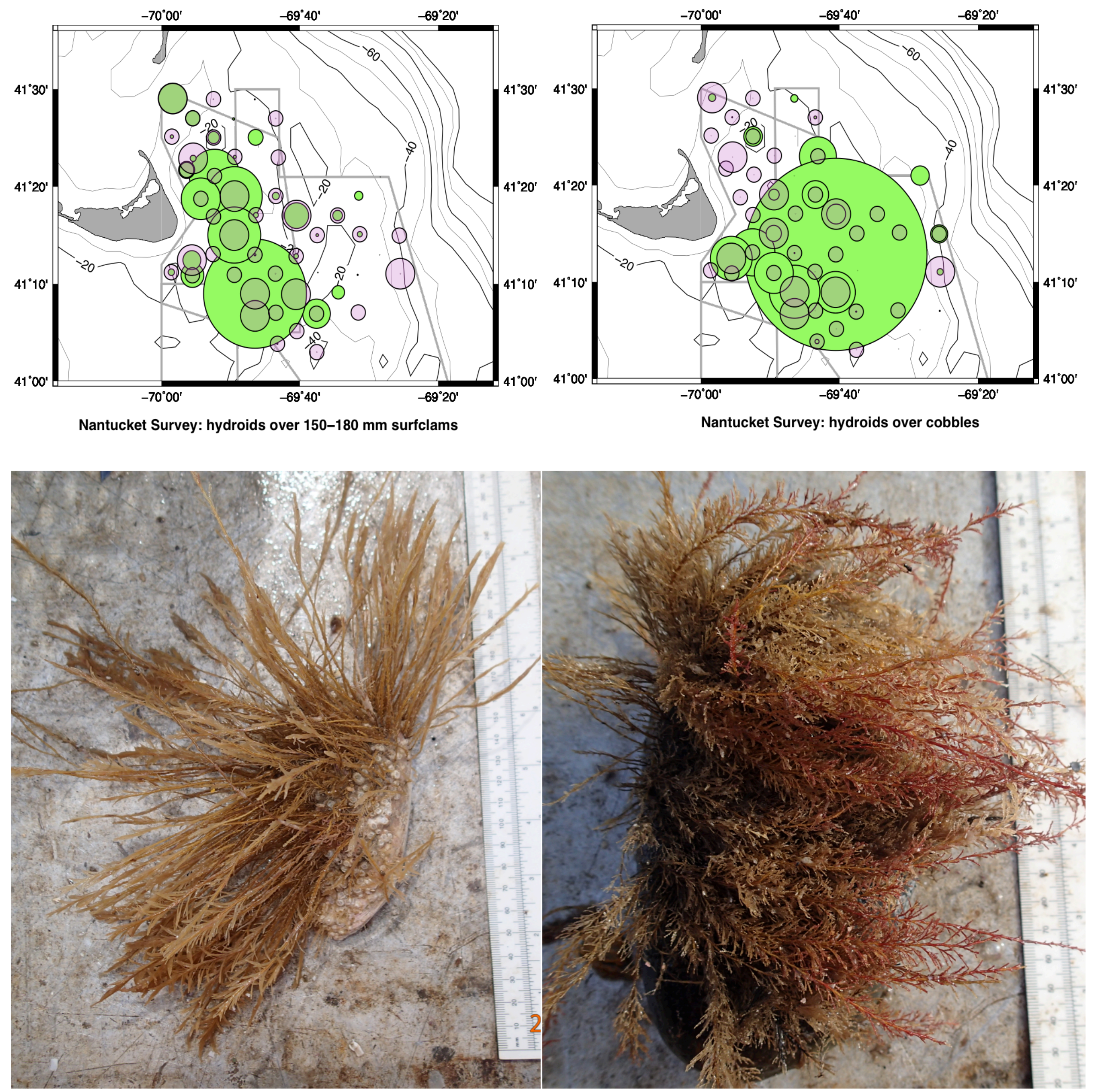

Figure 18. Upper left, occurrence of hydroids (purple) and medium to large market-size Atlantic surfclams (green). Upper right, occurrence of hydroids (purple) and cobbles (green). Circle diameters are linearly proportional to numbers m^{-2} for surfclams and bu m^{-2} for cobbles. Circle values for hydroids are 1=present and 2=abundant. Zero catch stations are not shown (see Fig. 1 for full station complement). Depths in m. Lower panels, representative hydroids attached to a surfclam shell and a cobble. Note that hydroids and erect bryozoans were not discriminated; thus reference here and elsewhere to 'hydroid' should not be interpreted as a definitive identification.

observed encrusting cobbles, rocks, boulders, and surfclam shells at almost every site where these particles were present (Fig. 16, Table 2). Barnacles and barnacle scars were least common on surfclam shells and most common on boulders, with frequency incrementing with particle size, consistent with an anticipated increasing likelihood of exposure of the particle above the sediment-water interface and immobility of the particle while exposed. Barnacles are common fouling organisms, widely reported present-day and in the fossil record (e.g., Scanland, 1979; Zuschin and Pervesler, 1996; Parras and Casdío, 2005; Nielson and Funder, 2007; Schneider et al., 2008). The overwhelming majority of barnacle occurrences in this survey were in the form of barnacle scars (the basal plate or the attachment mark made by the basal plate) rather than intact barnacles. Barnacle fragments and scars are very likely commonplace on hard substrate, but are very rarely reported (Brett et al., 2011; see Aguirre et al., 2008 for a fossil example). Attached barnacles occurred with about equal frequency among the particle types (Table 2) whereas barnacle scars occurred with increasing frequency with increasing particle size.

Sponges, anemones, and tunicates were rarely encountered (Fig. 17). These attached epibionts were most often encountered in the north and north-eastern sectors of the HMA. Overlap with medium and large market-size surfclams was very limited. Overlap increased with the smaller surfclams due to their predominance in deeper water than their larger brethren, but at only one site were these epibionts caught coincident with a large number of small surfclams (Fig. 17). In part, this tendency accrued from the differential distribution of surfclams, rocks and boulders, upon which most large epibionts were attached. Frequency of encounter was low. Attachment to surfclam shells occurred less frequently than attachment to sedimentary particles (Table 3), but these epibionts were exceedingly rare in comparison to barnacles and barnacle scars. Importantly, these epibionts do not leave long-lasting scars when detached or eroded off. The occurrence rate of whole barnacles was higher, but only about three times as high in comparison to the factor of 10 difference for barnacle scars. Thus, the impact of taphonomy was recorded for the barnacles, but not for the other epibionts.

Nearly all occurrences of anemones, tunicates, and sponges were provided by the tunicates (Table 3). Sponges and anemones were exceedingly rare. This is consistent with an analysis for a region on Georges Bank and also the southern part of the Great South Channel HMA (Powell et al. 2017a). Tunicates were least often encountered on boulders and surfclam shells and most often encountered on rocks and cobbles. Sponges and anemones were never encountered on surfclam shells and were distinctly more frequent, though still very rare, on boulders, suggesting that the larger sediment particles provided some degree of temporal stability above the sediment-water interface allowing these slower growing epibionts to populate.

In contrast to the tunicates, sponges, and anemones, the attached hydroids[1] were considerably differentially distributed (Fig. 18). Hydroids were commonly encountered at many sites. Many such sites were locations yielding medium and large market-size surfclams and surfclam shell (Fig. 18). Hydroids, though found attached to cobbles, rocks, and boulders, were distinctly differentially distributed from these sedimentary particles, emphasizing the importance of surfclam shell (Fig. 18). Photographic analysis confirmed the ubiquity of hydroids as attached epibionts (Table 4), though less common than barnacles and barnacle scars (Table 2), and the importance of surfclam shells as points of attachment (Table 4).

[1]Erect bryozoans and hydroids could not be differentiated during the survey. Most organisms encountered were likely hydroids, but conformation is lacking; nonetheless, for brevity, this type of epibiont will be referred to as "hydroid" throughout this report.

Correspondence analysis

The first two axes explained most of the variation in the dataset. Dimension 1 (x axis) was specified by the relative abundance of the various survey constituents, with lower abundance sites on the left (negative values) and higher abundance sites on the right (positive values).

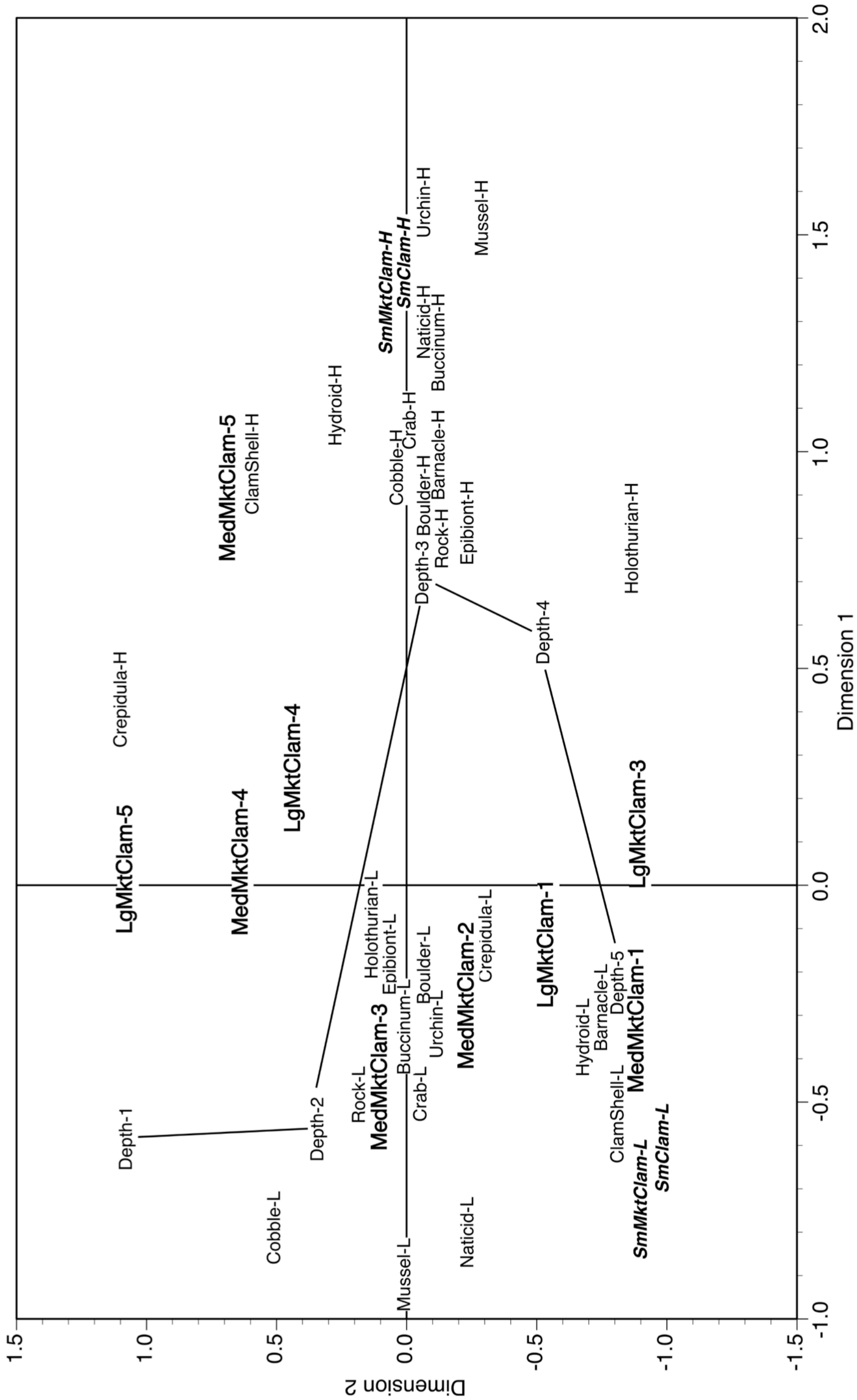

Figure 19. Correspondence analysis for the “East of Nantucket” survey dataset. Categorical values for biota were constructed by classifying catch values into quintiles (surfclams, mussels, cobbles), quartiles (rocks, naticids, crabs, surfclam shells), terciles (hydroids, barnacles/scars), and halves (boulders, anemones+sponges+tunicates, echinoids, slipper shells, sea cucumbers,). Depth divisions were 36, 55, 75, and 90 m. Values by surfclam names, Lg and Med, and depths represent positions in the quintile/quartile/tercile/half. For the remaining constituents, L refers to the lowest and H to the highest quintile/quartile/tercile/half. Sm, small; Mkt, market;, Med, medium; Lg, large.

Dimension 2 (y axis) was specified by depth, with shallower sites having positive values and deeper sites having negative values. Accordingly, the upper left quadrant was occupied by sites with rare constituents in shallow water; the upper right, by abundant constituents in shallow water; the lower left quadrant, by rare constituents in deeper water; and the lower right quadrant, by abundant constituents in deeper water.

The host of low-abundance constituents in deeper water (lower left quadrant) identifies the limited biota present at the deepest sites. Surfclam shell and surfclams, hydroids, barnacles, naticids, and slipper shells, for example were rarely collected at deeper water sites. In the lower right-hand quadrant are the sea cucumbers; these were the only large animals collected solely at the deepest depths.

In the upper right quadrant are the larger size classes of surfclams, surfclam shell, slipper shells which were found in greatest abundance on surfclam shells, and to some extent hydroids which are distributed more broadly across the depth range of the survey than the slipper shells. The medium and large market-size surfclams and the remaining afore-mentioned taxa represent the characteristic community elements at the shallow water sites. Mussels and smaller surfclams fall near zero on the y axis and at distinctly positive values on the x axis. These taxa were abundant at moderate depths, along with *Buccinum* gastropods, naticids, sea urchins, crabs, and the attached epibiota (anemones, tunicates, sponges). Depth is not a discriminator for these taxa, although the distributions of surfclams, mussels, and attached epibiota rarely overlap substantively within this depth range. Cobbles, rocks, and boulders are also abundant at intermediate depths. Note in Figure 19 the translation of depth along the x axis (abundance) from depth=2 (35-55 m) to depth=3 (55-75 m) and the translation back from depth=4 (75-90 m) to depth=5 (>90 m). Biota are scarce below 90 m. Mussels and the submarket and small market-size surfclams are most abundant at 55-75 m. The larger surfclams are most abundant at <35 m.

Discussion

Hydrodynamics and burial

The first noteworthy observation is the commonplace encounter with sedimentary particles potentially providing good attachment substrate for erect sessile epibiota. Surfclam shells are abundant at many locations. Cobbles were nearly ubiquitous. Though very common at a smaller proportion of stations, rocks were routinely encountered, and boulders were encountered occasionally. In contrast, slow growing attached epibionts such as sponges were exceedingly rare and most soft-bodied attached epibionts were rare. Two exceptions to the rarity of attached epibionts exist: barnacles and barnacle scars and hydroids.

The frequency of barnacle scars relative to intact barnacles is suggestive of sediment scour under a high-flow regime, which is a characteristic of the region between Nantucket and the Great South Channel. The absence of a well-developed attached epibiont community strongly suggests that cobbles, rocks, and boulders are often buried, and are scoured when exposed. The commonplace occurrence of barnacles, given the hydrodynamic conditions, can be explained by their rapid growth rates in high current velocities (Goren, 1979; Bertness et al., 1991; Sanford et al., 1994; Nishizaki et al., 2015), permitting successful colonization during relatively short periods of substrate exposure and limited scour. The oddity of hydroids also may be explained by their rapid growth rates (Gili and Hughes, 1995). That is, only this type of epibiont could reach a large size in the short time that these sedimentary constituents are exposed and remain unscoured. The relatively high proportion of cobbles, rocks, and boulders without attached biota or with only barnacle scars is particularly instructive in supporting the hypothesis that these sedimentary constituents remain buried much of the time or are repeatedly scoured (Wilson, 1987). As a consequence, cobbles, rocks, and boulders contribute little to the community composition in the surveyed region, which is composed almost exclusively of infaunal clams and gastropods and mobile and mat-forming epifauna.

Community types

The survey region supports four primary community types. The deepest depths yield few mega-epifauna or mega-infauna: the characteristic taxon is the sea cucumber, which is essentially the sole representative at these depths (Fig. 19). At the other end of the depth spectrum, the shallowest sites are occupied by a distinct surfclam-dominated community, comprising an abundance of medium and large (≥150 mm) market-size surfclams, and a few common attached epibiota, the hydroids and slipper shells, that are primarily found attached to exposed surfclam shell. The abundance of surfclam shell indicates that surfclams have inhabited these depths for an extended period of time.

The presence of common attached organisms on surfclam shell, despite the hydrodynamic regime facilitating resuspension and burial, suggests that a mechanism exists maintaining exposure of some fraction of the shell resource. Shell left to natural bottom conditions will essentially always be buried, normally rapidly, in soft-sediment environments (van Straaten, 1952; Clifton and Hunter, 1973; Conover, 1975; Parsons-Hubbard et al., 1997; Powell et al., 2008), unless transiently uncovered by the passage of sand waves (Diaz et al., 2003), as may well be the case in the surveyed region. Regardless, shell routinely will have few or no epibionts due to its limited exposure time (e.g., Rodland et al., 2006; Powell et al., 2008; Brett et al., 2011: compare to exposed scallops, oysters, epifaunal clams, and hermatized gastropods, Walker, 1988; Lescinsky, 1993; Smyth and Roberts, 2010; Souto et al., 2012; Vicentuan-Cabaitan et al., 2014). Possibly, the activities of the fishery are responsible. Hydraulic dredges resuspend the bottom, but some shell is retained while the remaining smaller sedimentary constituents settle back out. The retained shell is subsequently discarded overboard and can be expected to remain for a time on the sediment surface providing potential habitat for fast growing epibionts such as slipper shells and hydroids. The consistent association of hydroids and surfclam shell provides support for this possibility.

Two communities exist at intermediate depths. One is dominated by submarket and small market-size surfclams (<150 mm). Hydroids are present, but surfclam shell is not abundant, and slipper shells and mobile epifauna are rare. Although no other taxa characteristically co-occur, naticids are frequently collected, as they are at most shallow and moderately deep sites. The other community is created by the presence of mussel mats. Crabs, sea urchins, and other mobile epifauna abound. Mussels are a foundational species, establishing through their presence living or the production of shell a hard-bottom terrain in a soft-bottom milieu conducive to these other denizens (see Goddard and Love, 2010; Manoukian et al., 2010; van der Zee et al., 2015). Neither of these community types is dependent upon rocks, cobbles, or boulders; in fact, the distribution of these sedimentary particles, though common at the same depths, does not track the distribution of concentrations of surfclams or mussels.

Correspondence analysis does not identify the origin of the dichotomous nature of these two community types. Possibly, these are multiple stable points (see Gray, 1977; Peterson, 1984; Knowlton, 1992) within the same thermal, depth, and hydrodynamic range. While speculative, it might be anticipated that a mussel mat would prevent settlement of surfclams, thereby excluding them (see a case for razor clams: van der Heide et al., 2014). Certainly, once established, mussel beds can maintain themselves by facilitating recruitment (Commito et al. 2014). Thus, once established, mussel beds would tend to be self-perpetuating. What controls the absence of mussel mats is less clear. Salas et al. (2016) and wa Kangeri et al. (2014, 2016) note that mussel beds on soft sediments are constructed to resist erosion and this is a product of byssal thread interweaving and the incorporation of shell fragments, pebbles, and other small sedimentary constituents. High current velocities can resuspend and move mussel beds (wa Kangeri et al., 2016): current velocities in the surveyed region reach such velocities (Harris et al., 2012; Dalyander et al., 2013) and, so, one might anticipate that mussel beds are more or less mobile over time. The dynamics of this process are not studied in the surveyed region; however, *Mytilus* can survive shallow burial and return to the sediment surface (Hutchison et al., 2016), thus providing two mechanisms (mat transport and exhumation) to recover from hydrodynamic events. On the other hand, active filtration and sediment disturbance by surfclams might limit initial mussel settlement, thereby establishing the competing multiple stable point.

Surfclam range shift dynamics

Mid-Atlantic water temperatures have been warming for at least the last 200 years, with a distinct increase in rate since 1970 (Nixon et al., 2004; Fulweiler et al., 2015; Steinman et al., 2015; Pace et al., in press). That warming bottom water temperatures are forcing surfclams to move offshore is well described (see review in Hofmann et al., in press). This process has been ongoing since the 1970s. Evidence exists over nearly the entirety of the stock, from Delmarva to Georges Bank. Throughout much of this region, the offshore movement has initiated recruitment within the area occupied by ocean quahogs. This co-habited ecotone is now well described. Powell et al. (2017c) recently documented this phenomenon on Georges Bank. The finding of smaller surfclams offshore in the survey east of Nantucket is consistent with the expectation of recruitment into deeper water. Presently, the alternative that surfclams are simply growing slower along the deeper portion of their onshore-offshore range cannot be excluded, and differential growth rates might be anticipated as temperature plays a major role determining maximum size (Munroe et al. 2016). However, evidence for new occupation can be found in the distribution of surfclam shell, which, as on Georges Bank (Powell et al., 2017c), is found in limited quantities in regions where recent colonization is inferred and in greater quantities in water shallower than this. The signal provided by surfclam shell is clear in the case of the region east of Nantucket where surfclam shell is found predominately in regions where larger surfclams are present. The observation of species present living, but not in the death assemblage is unusual and normally explained by rarity of occurrence or poor preservability (e.g., Albano, 2014; Martinelli et al., 2016), neither of which is true for Atlantic surfclams in the surveyed region. Long post-mortem shell half-lives impose taphonomic inertia into the system which permits the death assemblage to track the history of occupation (Kidwell, 2008; Poirier et al., 2010), but which also imposes a time delay between initial colonization and representation in the death assemblage (Olszewski, 2012) and a variable signal of range relinquishment depending on the degree of time averaging (e.g., Perry, 1986; García-Ramos et al., 2016). Thus range expansion, as inferred from this survey, provides a stronger and less ambiguous signal than range relinquishment.

The boundaries of the biogeographic range of a species are typically delineated by the thermal tolerance of the organism with range contraction and range shifts being the common response to evade regions where temperatures have reached or exceeded the upper bounds of tolerance (Hutchins, 1947; Lucey and Nye, 2010; Weinert et al., 2016). Interestingly, another species that has shown a contraction and poleward shift in range over the past several decades is *Mytilus edulis* (Hutchins, 1947). In 1943, *M. edulis* was found as far south as Beaufort, NC (McDougall, 1943). By 1960, the southern boundary of the range had contracted polewards to Cape Hatteras, NC, due to increasing water temperature with increasing abundances and sizes to the north and mortality to the south of Cape Hatteras (Wells and Gray, 1960). Moving forward to 2005, the *M. edulis* population along the entire North Carolina coast no longer persists year-round owing to increasing water temperatures (Jones et al., 2009). In total, the southern boundary of *M. edulis* has contracted roughly 350 km polewards (Jones et al., 2010).

The temperature tolerances of the two species (Atlantic surfclam and blue mussel) are relatively similar; both would be identified as cool temperate species. Both extend into the Gulf of Maine, with *M. edulis* being the better established, most likely due to an abundance of hard substrate. The differentials of the southern and inshore range boundary for the two species are unclear, however, one might consider that if the smaller surfclams offshore do indeed represent a relatively recent range extension, then this may presage a future withdrawal of mussels from the region. As of this writing, no evidence exists that the ocean quahog is withdrawing from its inshore boundary as a consequence of the Mid-Atlantic warming that has produced the surfclam invasive front, but ocean quahogs have the ability to estivate during the warmer months, something not available to the mussel. Certainly evidence from this survey suggests that community dynamics in the 35-75 m depth range are in flux off Nantucket, west of the Great South Channel.

Acknowledgments

This research was supported by the NSF Industry/University Cooperative Research Center SCeMFiS (Science Center for Marine Fisheries) (grant number 1266057) under the direction of the SCeMFiS Industry Advisory Board (IAB). Conclusions and opinions expressed herein are solely those of the authors.

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Appendix 1: Catch data for the 'East of Nantucket' survey

			Surfclams number per m^2				
Site	Latitude	Longitude	<120	121-150	151-170	171-200+	Total
A1	41.48550	69.97083	0.02729	0.04945	0.06310	0.05628	0.19611
A2	41.41667	69.97500	0.00144	0.01155	0.00794	0.00939	0.03033
A3	41.35000	69.93000	0.00251	0.02089	0.03843	0.04512	0.10694
A5	41.19000	69.97500	0.00200	0.00601	0.02205	0.00200	0.03207
B1	41.45000	69.92500	0.00162	0.01298	0.03812	0.02920	0.08192
B2	41.38334	69.92500	0.00089	0.01073	0.01073	0.02236	0.04472
B3	41.31667	69.90667	0.01733	0.06775	0.10557	0.06933	0.25998
B4	41.20833	69.92500	0.01556	0.07301	0.08259	0.00479	0.17595
B5	41.18333	69.92500	0.00268	0.00936	0.06823	0.02408	0.10435
C1	41.48333	69.87500	0.00360	0.00432	0.00144	0.00000	0.00935
C2	41.41667	69.87500	0.00975	0.02039	0.03103	0.01330	0.07446
C3	41.35000	69.87500	0.00550	0.02017	0.09167	0.12834	0.24568
C4	41.28333	69.87500	0.00360	0.00450	0.03784	0.03063	0.07658
C5	41.21667	69.87500	0.00000	0.00000	0.00000	0.00000	0.00000
D1	41.45000	69.82500	0.00086	0.01370	0.00771	0.00000	0.02227
D2	41.38334	69.82500	0.00205	0.00205	0.00716	0.00819	0.01944
D3	41.31667	69.82500	0.00199	0.02193	0.14553	0.09768	0.26713
D4	41.25000	69.82500	0.12684	0.15738	0.14329	0.05872	0.48623
D5	41.18333	69.82500	0.00113	0.00113	0.00000	0.00000	0.00226
E1	41.48333	69.77500	0.00182	0.00363	0.00182	0.00182	0.00908
E2	41.41667	69.77500	0.00248	0.00413	0.04047	0.01569	0.06278
E3	41.35000	69.77500	0.00106	0.00106	0.00106	0.00212	0.00531
E4	41.28333	69.77500	0.00000	0.00000	0.00936	0.01990	0.02927
E5	41.21667	69.77500	0.00504	0.00504	0.00504	0.01007	0.02518
E6	41.15000	69.77500	0.14173	0.29179	0.27928	0.12088	0.83368
E7	41.11167	69.77500	0.03653	0.28859	0.08219	0.00731	0.41461
F1	41.45000	69.72500	0.00000	0.00000	0.00000	0.00149	0.00149
F2	41.38334	69.72500	0.00173	0.00086	0.00000	0.00000	0.00259
F3	41.31667	69.72500	0.03792	0.18958	0.02212	0.00316	0.25277
F4	41.25000	69.72500	0.00000	0.00000	0.00000	0.00000	0.00000
F5	41.18333	69.72500	0.01306	0.01132	0.00087	0.00000	0.02525
F6	41.11666	69.72500	0.00529	0.01058	0.01235	0.00353	0.03175
F7	41.06167	69.72500	0.00000	0.00555	0.00417	0.00000	0.00972
G1	41.35000	69.67500	0.00000	0.00165	0.00000	0.00000	0.00165
G2	41.28333	69.67500	1.28780	1.46079	0.07688	0.00961	2.83508
G3	41.21667	69.67500	0.42367	1.09177	0.01630	0.00000	1.53174
G4	41.15000	69.67500	0.00000	0.00863	0.00000	0.00000	0.00863
G5	41.08333	69.67500	0.00000	0.00088	0.00000	0.00000	0.00088
H1	41.31667	69.62500	0.00000	0.00000	0.00000	0.00000	0.00000

H2	41.25000	69.62500	0.03188	0.05453	0.01091	0.00000	0.09732
H3	41.18333	69.62500	0.00915	0.01118	0.00203	0.00000	0.02237
H4	41.11666	69.62500	0.00501	0.14142	0.09762	0.00250	0.24654
H5	41.05000	69.62500	0.00000	0.00000	0.00089	0.00000	0.00089
I1	41.35000	69.57500	0.77387	0.89687	0.00000	0.00000	1.67073
I2	41.28333	69.57500	0.01870	0.20574	0.03390	0.00000	0.25835
I3	41.21667	69.57500	0.00000	0.00328	0.00000	0.00000	0.00328
I4	41.15000	69.57500	0.04946	0.28880	0.04946	0.00000	0.38772
I5	41.08333	69.57500	0.00000	0.00083	0.00000	0.00000	0.00083
J1	41.31667	69.52500	0.00776	0.02759	0.03018	0.00086	0.06639
J2	41.25000	69.52500	0.17110	0.40500	0.01949	0.00000	0.59559
J3	41.18333	69.52500	0.23426	0.39926	0.00407	0.00000	0.63760
J4	41.11666	69.52500	0.00094	0.00000	0.00000	0.00000	0.00094
J5	41.05000	69.52500	0.00077	0.00077	0.00000	0.00000	0.00154
K1	41.35000	69.47500	0.00420	0.01471	0.00105	0.00000	0.01996
K2	41.28333	69.47500	0.00000	0.00000	0.00000	0.00000	0.00000
K3	41.21667	69.47500	0.00232	0.01236	0.00077	0.00000	0.01544
K4	41.15000	69.47500	0.00072	0.00216	0.00000	0.00000	0.00287
K5	41.08333	69.47500	0.00000	0.00000	0.00000	0.00000	0.00000
L1	41.31667	69.42500	0.00000	0.00000	0.00000	0.00000	0.00000
L2	41.25000	69.42500	0.05004	0.04003	0.00000	0.00000	0.09007
L3	41.18333	69.42500	0.00000	0.00160	0.00080	0.00000	0.00239
L4	41.11666	69.42500	0.00000	0.00000	0.00000	0.00000	0.00079
L5	41.05000	69.42500	0.00073	0.00000	0.00000	0.00000	0.00073

	S.s. shell	Cobbles	Rocks	Boulders	Mussels
Site	bu per m^2				
A1	0.0014610	0.0006392	0.0000913	0.000000	0.0000073
A2	0.0000071	0.0000071	0.0000000	0.000000	0.0000000
A3	0.0000071	0.0000000	0.0000000	0.000000	0.0000000
A5	0.0000092	0.0000092	0.0000000	0.000000	0.0000092
B1	0.0000875	0.0000875	0.0000070	0.000000	0.0000070
B2	0.0005770	0.0000072	0.0000000	0.000000	0.0000000
B3	0.0001953	0.0000078	0.0000000	0.000000	0.0000000
B4	0.0000086	0.0036477	0.0008583	0.001931	0.0000086
B5	0.0001213	0.0000121	0.0000000	0.000000	0.0000000
C1	0.0000072	0.0000072	0.0000000	0.000000	0.0000072
C2	0.0024222	0.0016262	0.0002140	0.000000	0.0000171
C3	0.0006970	0.0000070	0.0000000	0.000000	0.0000139
C4	0.0000077	0.0000000	0.0000000	0.000000	0.0000000
C5	0.0000082	0.0039069	0.0004113	0.000206	0.0000082
D1	0.0000000	0.0000080	0.0000000	0.000000	0.0000080
D2	0.0000720	0.0000072	0.0000072	0.000000	0.0000072
D3	0.0012680	0.0009057	0.0000072	0.000000	0.0000145
D4	0.0011471	0.0013382	0.0003824	0.001529	0.0126943
D5	0.0000000	0.0033897	0.0001130	0.000000	0.0001130
E1	0.0000000	0.0006192	0.0004128	0.000619	0.0018164
E2	0.0000077	0.0000077	0.0000077	0.000077	0.0000077
E3	0.0000076	0.0000076	0.0000000	0.000000	0.0000758
E4	0.0000944	0.0000094	0.0000000	0.000000	0.0000000
E5	0.0000087	0.0000868	0.0000000	0.000000	0.0000087
E6	0.0017780	0.0044027	0.0000085	0.000000	0.0017780
E7	0.0004463	0.0006694	0.0000000	0.000000	0.0000089
F1	0.0000000	0.0002451	0.0001857	0.000186	0.0001857
F2	0.0000086	0.0032368	0.0005783	0.000432	0.0647368
F3	0.0010275	0.0023016	0.0000000	0.000000	0.0123301
F4	0.0000000	0.0000000	0.0000000	0.000000	0.0000000
F5	0.0000000	0.0000077	0.0000000	0.000000	0.0000077
F6	0.0000084	0.0000084	0.0000000	0.000000	0.0000000
F7	0.0000000	0.0003564	0.0001080	0.000000	0.0000108
G1	0.0000083	0.0024825	0.0000828	0.000000	0.0000000
G2	0.0010868	0.0016519	0.0006521	0.000000	0.0053905
G3	0.0023937	0.0159308	0.0000000	0.000000	0.0003302
G4	0.0000086	0.0034508	0.0000086	0.000000	0.0004313
G5	0.0000000	0.0000088	0.0000000	0.000000	0.0000088
H1	0.0000000	0.0000000	0.0000000	0.000000	0.0000000
H2	0.0000073	0.0005854	0.0001463	0.000146	0.0001829

H3	0.0000000	0.0000083	0.0000000	0.000000	0.0000000
H4	0.0012085	0.0001007	0.0000000	0.000000	0.0336778
H5	0.0000089	0.0000089	0.0000000	0.000000	0.0000089
I1	0.0000803	0.0024101	0.0000080	0.000161	0.0016067
I2	0.0001846	0.0000000	0.0000000	0.000000	0.0000074
I3	0.0000000	0.0000082	0.0000000	0.000000	0.0000082
I4	0.0000071	0.0017818	0.0003564	0.000713	0.0017818
I5	0.0000083	0.0000083	0.0000083	0.000000	0.0000000
J1	0.0000081	0.0007286	0.0000081	0.000000	0.0000081
J2	0.0001896	0.0005689	0.0000076	0.000000	0.0030341
J3	0.0001919	0.0003838	0.0000077	0.000000	0.0001535
J4	0.0000000	0.0014071	0.0004690	0.000310	0.0000094
J5	0.0000000	0.0000077	0.0000077	0.000000	0.0000000
K1	0.0000000	0.0015968	0.0001996	0.000000	0.0000080
K2	0.0000000	0.0000000	0.0000000	0.000000	0.0000000
K3	0.0000077	0.0000077	0.0000000	0.000000	0.0000077
K4	0.0000000	0.0000072	0.0000000	0.000000	0.0002371
K5	0.0000000	0.0000077	0.0000000	0.000000	0.0000000
L1	0.0000000	0.0000000	0.0000000	0.000000	0.0000000
L2	0.0000100	0.0015012	0.0002002	0.000000	0.0010008
L3	0.0000000	0.0005349	0.0000798	0.000000	0.0007984
L4	0.0000000	0.0000790	0.0000079	0.000000	0.0000079
L5	0.0000000	0.0000073	0.0000073	0.000000	0.0000073

	Naticids	Sea Urchins	Sea Cucumber	Crabs	Barnacles and Scars	Hydroids or Bryozoans	Sponge	Anemone	Tunicate
Site	Number per m^2				Rank				
A1	0.01680	0.00000	0.00000	0.00292	2	2	0	0	0
A2	0.00212	0.00000	0.00000	0.00000	1	1	0	0	0
A3	0.00000	0.00000	0.00000	0.00000	1	1	0	0	0
A5	0.00275	0.00000	0.00000	0.00000	1	1	0	0	0
B1	0.00350	0.00000	0.00000	0.00000	1	1	0	0	0
B2	0.00144	0.00000	0.00000	0.00000	1	2	0	0	0
B3	0.00937	0.00000	0.00000	0.00078	1	1	0	0	0
B4	0.00429	0.00000	0.00000	0.00000	1	2	1	0	0
B5	0.00728	0.00000	0.00000	0.00121	1	1	0	0	0
C1	0.00072	0.00000	0.00000	0.00000	0	1	0	0	0
C2	0.00514	0.00257	0.00000	0.00514	1	1	0	0	0
C3	0.00418	0.00000	0.00000	0.00000	1	1	0	0	0
C4	0.00077	0.00000	0.00000	0.00000	1	1	0	0	0
C5	0.00082	0.00000	0.00000	0.00000	1	1	0	0	0
D1	0.00239	0.00000	0.00000	0.00000	0	0	0	0	0
D2	0.00648	0.00000	0.00000	0.00000	1	1	0	0	0
D3	0.00580	0.00072	0.00000	0.00000	2	2	1	0	0
D4	0.23094	0.00688	0.00000	0.04359	2	2	1	0	0
D5	0.00000	0.00000	0.00000	0.00113	1	1	0	0	0
E1	0.02807	0.00000	0.00000	0.00165	2	0	0	0	0
E2	0.00536	0.00000	0.00000	0.00000	1	0	0	0	0
E3	0.00531	0.00000	0.00000	0.00000	1	0	0	0	0
E4	0.00189	0.00000	0.00000	0.00000	1	1	0	0	0
E5	0.00174	0.00000	0.00000	0.00000	0	1	2	0	0
E6	0.02540	0.00677	0.00000	0.00508	0	2	1	1	0
E7	0.00982	0.00000	0.00000	0.00000	2	2	0	0	0
F1	0.00446	0.00000	0.00000	0.00000	2	1	0	1	0
F2	0.01122	0.00086	0.00000	0.08632	0	1	1	0	1
F3	0.16111	0.00000	0.00000	0.05754	2	1	0	0	0
F4	0.00076	0.00000	0.00000	0.00000	0	0	1	0	0
F5	0.00306	0.00000	0.00000	0.00000	1	1	0	0	0
F6	0.00251	0.00000	0.00000	0.00000	0	1	0	0	0
F7	0.00216	0.00000	0.00000	0.00000	2	1	0	0	0
G1	0.00000	0.00000	0.00000	0.00000	0	0	0	0	0
G2	0.01391	0.01217	0.00000	0.05738	2	2	1	0	1
G3	0.04457	0.00000	0.00000	0.00000	2	1	0	0	0
G4	0.01812	0.00000	0.00000	0.00086	2	2	0	0	0
G5	0.00088	0.00000	0.00000	0.00088	0	1	0	0	0
H1	0.00000	0.00000	0.00000	0.00000	0	0	0	0	0

H2	0.00220	0.00000	0.00073	0.00073	1	1	0	0	2
H3	0.00166	0.00000	0.00000	0.00000	0	0	0	0	0
H4	0.02900	0.02820	0.00081	0.25782	2	1	1	0	0
H5	0.00089	0.00000	0.00000	0.00000	1	1	0	0	0
I1	0.02169	0.00000	0.00000	0.03053	0	0	0	0	0
I2	0.03249	0.00000	0.00000	0.00000	1	1	0	0	0
I3	0.00164	0.00000	0.00000	0.00000	0	0	0	0	0
I4	0.02352	0.00071	0.00000	0.00285	2	0	0	0	0
I5	0.00000	0.00000	0.00000	0.00000	0	0	0	0	0
J1	0.00729	0.00000	0.00081	0.00081	0	0	0	0	1
J2	0.04096	0.00000	0.00000	0.01289	2	1	0	0	0
J3	0.06601	0.00000	0.00000	0.00000	2	0	0	0	0
J4	0.00469	0.00000	0.00000	0.00000	2	1	0	0	0
J5	0.00000	0.00000	0.00000	0.00000	1	0	0	0	0
K1	0.01517	0.00000	0.00080	0.00000	0	0	0	0	1
K2	0.00000	0.00000	0.00000	0.00000	0	0	0	0	0
K3	0.00849	0.00000	0.00000	0.00077	0	0	1	0	0
K4	0.00503	0.00000	0.00000	0.00000	2	0	0	0	0
K5	0.00309	0.00000	0.00000	0.00000	0	0	0	0	0
L1	0.00000	0.00000	0.00000	0.00000	0	0	0	0	0
L2	0.00300	0.00200	0.00801	0.00000	0	1	2	0	2
L3	0.00240	0.00559	0.00798	0.00000	2	2	0	0	0
L4	0.00316	0.00000	0.00000	0.00158	0	0	0	0	0
L5	0.00293	0.00000	0.00000	0.00073	1	0	0	0	0