Commercial Bath Sponge (*Spongia* and *Hippospongia*) and Total Sponge Community Abundance and Biomass Estimates in the Florida Middle and Upper Keys, USA

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ABSTRACT

Prior to World War II, the Caribbean bath sponge fishery was one of the most valuable fisheries in Florida. However, a major disease event in 1938 – 1939 and subsequent over-fishing almost completely eliminated the fishery. Although synthetic sponges have largely replaced natural sponges because of lower cost and reliability of supply, a world sponge trade still exists and sponges are still harvested in Florida, the Bahamas, and Cuba. Most sponges provide important habitat for a variety of organisms living within their internal canal-and-chamber systems. Sponges are able to filter large volumes of water and are very efficient in retaining small food particles to meet their nutritional requirements. Thus, their impact on the phytoplankton community could be substantial. Here, we address the need of resource managers for knowledge of the contribution of commercially valuable sponge species to the total sponge community in Florida Bay and the Gulf of Mexico side of the middle and upper Florida Keys to help them evaluate the potential ecological impacts of sponge harvesting. When the study was undertaken, the proportional contribution of .commercially harvested species to the total sponge community was not known. We assessed the numerical abundance and volumetric biomass of both commercial bath sponges and the total sponge community. Within our study area, the contribution of the two most important commercial species to total sponge community biomass was 1.3% based on numerical counts and 2.5% based on volumetric biomass. We concluded that if sponge harvesting is conducted in a sustainable manner, the ecological consequences of sponge harvesting should be relatively minor.

KEYWORDS: Florida commercial sponge fishery, commercial sponge abundance, sponge community biomass

Estimaciones de la Biomasa en los Cayos Central y Superior del Estado de Florida, EE.UU, de Esponjas Comerciales y la Comunidad Total

Antes de la segunda guerra mundial la pesqueria de espongas fue la mas valiosa pesquera en Florida. Sin embargo un evento mayor de enfermedad en 1938 – 1939 y la pesca exuberancia subsecuente casi eliminaron la pesqueria. Aunque esponjas sinteticas han reemplazaron las naturales debido a los costos inferiores y la surtimiento confiable. Un comercio de esponjas mundial aun existia y ambos esponjas estan cosechadas en Florida – Bahamas y Cuba.

El mayor numero de esponjas proven habitacion inportante para una variedad de organismos que viven dentro sus canales internos y sistemas de camaras. Esponjas pueden filtrar gran cantidades de agua y son muy eficiente en la retencion de pequenos particulas de alimento nutritivo requeridos. Su impacto en la comunidad fitoplancto podria ser considerable. El proposito del proyecto descibido aqui fue proveer los gerentes recursos con informacion para ayudarles evaluar el impacto escologico de la cosecha de esponjas y la sustenable de pesqueria. Cuando el studio fue intentado no se conocia si las especies cosechadas comerciales representaban una porcion sustentable de la totalidad de seponjas en la region cosechada. Para enderezar esta emision la abundancia de ambos comerciales y la comunidad biomasa total de esponjas fueron estudiados. Dos metodos fueron estudiados para determiner la biomasa de esponjas: contar numericamente y medicion volumetrico.

PALABRAS CLAVES: La pesqueria de esponjas commerciales in Florida, la abundancia de esponjas commerciales, la biomasa de la commuidad esponjas

Estimation de la Biomasse de la Communauté Totale et des Éponges Commerciales dans les Middle et Upper Keys de Floride, USA

Avant la Seconde Guerre mondiale la pêche des éponges était parmi les pêches les plus rentables en Floride. Cependant, une maladie majeure en 1938-1939 puis la surpêche ont fait que cette activité a presque totalement disparu. Bien que les éponges synthétiques aient largement remplacé les éponges naturelles en raison d'une baisse des coûts et de la fiabilité de l'approvisionnement, les éponges « de bain » sont encore commercialement exploitées en Floride, aux Bahamas et à Cuba. Les éponges occupent une place importante au sein de la communauté benthique. La plupart des éponges fournissent un habitat pour une grande variété d'organismes vivant dans leur système de chambres et canaux internes. Les éponges sont aussi des organismes filtreurs très efficaces et leur impact sur la communauté phytoplanctonique pourrait être considérable. L'objectif du projet décrit ici était de fournir aux gestionnaires de ces ressources suffisamment d'informations pour leur permettre d'évaluer l'impact écologique potentiel et la durabilité de cette pêche. Lorsque l'étude a été entreprise, on ne savait pas si les espèces exploitées représentaient une part importante de la communauté d'éponges se développant dans la zone où elles étaient récoltées. Pour répondre à cette question, l'abondance des éponges commerciales « de bain » et celle de la communauté totale d'éponges a été mesurée. Deux méthodes ont été utilisées pour déterminer la biomasse des éponges: comptage numérique et mesures volumétriques. Les résultats ont montré que la biomasse des éponges commerciales ne représente qu'une petite partie de la communauté totale d'éponges (1,4% selon le comptage numérique et 2,5% selon les mesures volumétriques).

MOTS CLÉS: Pêche d'éponges commerciales, Abondance d'éponges commerciales, Abondance des communautés d'éponges

INTRODUCTION

Sponges are a major component of benthic communities in many hard-bottom coastal environments and are a particularly predominant structural feature of the hard-bottom habitat in Florida Bay and the Gulf of Mexico side of the middle and upper Florida Keys (henceforth referred to as the Gulf side of the Keys) (Figure 1; Chaippone and Sullivan 1994, Field and Butler 1994). In general, this area is recognized for its productivity, diversity, and role as a marine nursery (Holmquist *et al*. 1989, Thayer and Chester 1989). Most sponges, especially massive species such as *Spheciospongia vesparium*, provide important habitat for a variety of commensal organisms living within their internal canal-and-chamber systems (Pearse 1950, Erdman and Blake 1987). In south Florida, sponges have also been shown to provide important shelter for juveniles of Caribbean reef species such as the spiny lobster *Panulirus argus* (Field and Butler 1994, Herrnkind and Butler 1994; Herrnkind *et al*. 1997), which is an important fishery resource. Sponges are also able to filter large volumes of water and are very efficient in retaining small food particles (particularly phytoplankton < 5 microns in diameter) to meet their nutritional requirements (Reiswig 1971, Riisgard *et al*. 1993, Weisz 2006), and thus, their impact on phytoplankton communities can be substantial (Pile *et al*. 1997, Lynch and Phlips 2000, Peterson *et al*. 2006). In South Florida sponges are important ecological features and contribute significantly to the ecosystem.

Sponges have traditionally supported fisheries in the Mediterranean and Caribbean seas. However, synthetic sponges, which were introduced in the early 1950s and are lower in cost and more readily available, have largely replaced natural sponges for many uses. As a result, sponge production has remained a fraction of its former importance from the 1950s to the present, but a worldwide sponge trade still exists (Josupeit 1991). Caribbean bath sponges are still harvested in Florida, the Bahamas, and Cuba (Josupeit 1991, Alcolado 2004).

Prior to World War II (WW II), the sponge fishery was one of the most valuable fisheries in Florida. A major disease event in 1938 - 1939 (Smith 1941) and subsequent over-fishing almost completed eliminated the fishery (Storr 1964), and, as was the case worldwide, the introduction of synthetic sponges prevented natural sponges from regaining their former economic importance in Florida. Current bath sponge landings in Florida (Florida Fishery Landings Statistics) are a small fraction (approximately 10%) of

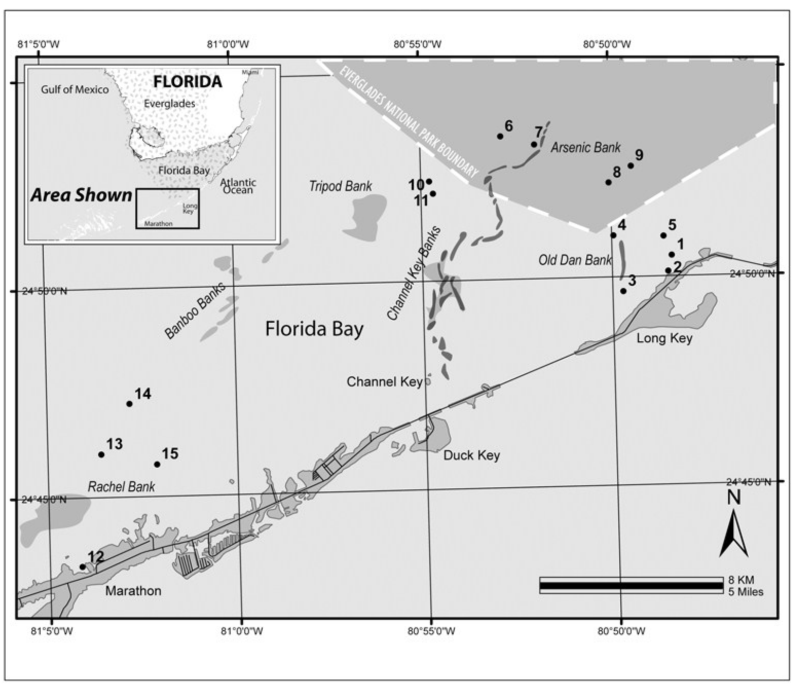

Figure 1. Sponge survey areas in the middle and upper Florida Keys.

historical sponge landings prior to WW II (Storr 1964). Nevertheless, sponge fishing effort in Florida waters increased after a sponge epizootic event in the late 1980s (DiResta *et al*. 1995, Cropper and DiResta 1999) severely reduced Mediterranean bath sponge production (Gaino and Pronzato 1989, Gaino *et al*. 1992, Vacelet *et al*. 1994). This increased fishing effort led to concerns regarding the ecological impacts of sponge harvesting and the sustainability of the sponge fishery in Florida (DiResta *et al*. 1995). In response to these concerns, the Florida Fish and Wildlife Conservation Commission (FWC; then named the Florida Marine Fisheries Commission) banned sponge harvesting within Biscayne Bay National Park (Miami, USA) in 1991.

The Gulf side of the Keys constitutes a major portion of the commercial bath-sponge fishing grounds that support a small artisanal fishery (principally for *Spongia* spp. and *Hippospongia* spp.) in the Florida Keys. Prior to our study, the proportional contribution of commercially harvested species to the total sponge community in the habitat where they were harvested was not known and the FWC was concerned that the Florida Keys sponge fishery might be impacting the ecosystem. To provide resource managers with information to help them evaluate the potential ecological impacts of sponge harvesting and the sustainability of the fishery, we assessed the abundance (number per m^2) and biomass (volume per m^2) of commercial bath sponges and of the total sponge community in this area. Following completion of this study, cyanobacterial plankton blooms have repeatedly resulted in extensive sponge mortalities in the area (Butler *et al*. 1994, Donahue 2008a). Hence, this report also represents the only quantified information on sponge community composition and biomass in this region prior to what may have become a persistent condition.

METHODOLOGY

Our sampling sites were determined based on discussions with sponge harvesters and with staff and researchers at the Keys Marine Laboratory (Marathon, Florida), as well as on general field reconnaissance. The objective was to survey sponge abundance and biomass in habitats where commercial bath sponge species are typically harvested and in a region where sponge harvesting is prohibited. During the course of this study sponge harvesting activity was sometimes observed in the vicinity of our sampling areas, but no sponge harvesting was ever observed in Everglades National Park (ENP), where sponge harvesting has long been prohibited. The habitat sampled was hard-bottom substrate interspersed with seagrass meadows. This hard-bottom habitat consisted of low-relief limestone bedrock overlain by a thin veneer of sediment and was populated by a complex assemblage of sponges, octocorals, small hard corals, seagrasses, and macroalgae (calcareous green algae, including *Halimeda* spp. and *Penicillus* spp., and red drift algae, including *Laurencia* spp.). Commercial bath sponge species are not present in the coral reef habitats found on the Atlantic Ocean side of the Florida Keys.

Sponge Numerical Abundances

A total of 45 dive stations at 15 areas (three dive stations per area) within four general regions were surveyed during summer 1991 (Figure 1). A general description of the four regions sampled is as follows: Long Key (Areas 1–5), a part of Florida Bay north of Long Key and south of the southern boundary of Everglades National Park (ENP); ENP (Areas 6–9), where sponge harvesting is prohibited; West of ENP (Areas 10–11), sponge fishing grounds west of the western boundary of ENP; Marathon (Areas 12–15), sponge fishing grounds north of Marathon.

Sponge abundance was determined in each area by counting all sponges within twelve, 100-m by-2 m transects (200 m^2), (three dive stations per area, four transects per dive station). In total, 2,400 m^2 was surveyed per area. After each dive, the boat was repositioned at a new station approximately 50 m from the previous station and the station location was recorded using LORAN C. Upon occasion, transects may have overlapped or crossed, but the maximum area of overlap was estimated to be 1% and considered to be negligible. The 100 -m transect lines commonly traversed the spectrum of hard bottom and seagrass patches characteristic of the areas surveyed. On some occasions, equipment failure or deteriorating weather conditions prevented the completion of the full set of 12 transects.

At each dive station, a 100-m measuring tape was fixed to the boat anchor and initially deployed directly into the water current direction (transect 1). One diver deployed the tape while the second diver counted the number of sponges found within 1 m of each side of the tape. Large callipers (used to measure human body thickness by radiologists) were used to measure the maximum height and broadest diameter of all commercial sponges found. Transect 2 was conducted while rewinding the tape and returning to the anchor, as follows. At the end of the initial 100-m transect, and again at the 50-m mark (to minimize transect overlap), the tape was moved until it followed a compass bearing offset by approximately 45^o from transect 1. Both divers lifted the measuring tape off the bottom while moving it, to prevent the tape from snagging on large bottom features (e.g., sponges, soft corals). Within 10 m of the anchor, the tape was moved a third time, to minimize overlap near the anchor. The anchor was then moved approximately 10 m so that no overlap would occur while conducting transects 3 and 4, which were conducted following the same procedure as used for transects 1 and 2.

Within each transect, specific abundance data were recorded for three commercial sponge species; *Hippospongia lachne* (sheepswool or wool sponge), *Spongia barbara* (yellow sponge), and *Spongia graminea* (glove sponge). *Spongia graminea* is considered to be of inferior quality and is not usually harvested for commercial purposes (Storr 1964). A third species of *Spongia*, *S. barbara dura* (hardhead sponge) was found throughout the study area. However, this smaller subspecies is not harvested in Florida because it has a lower commercial quality, and it rarely exceeds the Florida minimum legal size (12.5 cm diameter). Therefore, specific abundance data for *S. barbara dura* was not collected and it was grouped with the Unidentified-Sponge category, which included all sponges other than those targeted for species identification. Another species of *Spongia*, *S. tubulifera* (grass sponge), is harvested in Florida, but was not found within our sampling regions.

It is important to note here that differentiation of *Spongia* species can be difficult in the field (Cook and Bergquist 2002). Wiedenmayer (1977) concluded that the vernacular names and identifications used by sponge fishers are often more reliable than the scientific names; and indeed, this seems to be the case with *S. barbara dura* (hardhead sponge) and *S. barbara* (yellow sponge). *Spongia dura* of Hyatt (1877), or *Spongia dura typica* Hyatt, 1877, as it is more correctly known, is, the original name for the hardhead sponge. Although *Spongia dura typica* is presently considered to be a synonym of *S. barbara* (see Van Soest 1978), de Laubenfels and Storr (1958) considered these two species to be different; they formally recognised *S. dura typica* as a subspecies of *S. barbara*, i.e., *S. barbara dura*. We (and local fishermen) concur with this move and continue to differentiate the two varieties in the field in the following ways: The ecotosome of *S. barbara dura* is black, while that of *S. barbara* is yellowish brown, and the oscules of *S. barbara dura* are generally smaller in diameter than that those of *S.* b*arbara*, and situated at the apex of columnar mounds on the apex. The skeleton of *S. barbara dura* is tougher than that of *S. barbara*, which is easier to tear. *S. barbara dura* has a vaguely pedunculate morphology, with a restricted base and expanded apex, the surface of which is mounded, and the sides of which have a columnar pattern. This species can be quite variable under certain field conditions, while *S. barbara* is almost always a uniformly-shaped egg-shaped column.

Specific abundance data was collected for four other large, conspicuous species; *Spheciospongia vesparium* (loggerhead sponge), *Ircinia campana* (vase sponge), *S. barbara dura* (stinker sponge), and *Ircinia felix* (branching stinker sponge). *Spheciospongia vesparium* and *I. campana* were chosen because they are the two most numerous and widely distributed large sponges in the nearshore hard-bottom areas of the Florida Keys (Donahue 2008b). *Ircinia strobilina* and *I. felix* were also chosen because field reconnaissance prior to initiating the study indicated that these easily distinguishable species were relatively abundant and found throughout the study area. Thus, specific abundance data was collected for a total of seven species. All other sponges were lumped into a single "Unidentified-Sponge" category.

Because the purpose of our study was to assess the abundance of commercial species and their contribution to total sponge community abundance, we attempted to survey the relatively rare commercial sponges while simultaneously surveying all other common species. In order to sample adequate numbers of commercial sponges in transects, priority had to be given to covering large areas. Therefore, complete data for some small, inconspicuous, or otherwise confounding sponge species were sometimes minimized. Specific abundance data for *Chondrilla nucula*, a sometimes relatively abundant small sponge species often found growing in clusters among seagrass blades, was not recorded because there was insufficient time to stop and count each specimen. Because of its small size, it was judged to be a minor contributor to sponge community biomass. Nevertheless, its presence or absence in transects was recorded. There was also insufficient time to count the sometimes many small, encrusting, sponges growing on the surfaces of large unidentifed sponges (e.g. *Geodia gibberosa* and *Stelleta kalitetilla*). This aggregation of one large sponge with small sponges growing on it was counted as one Unidentified-Sponge. Thus, our numerical counts of total number of sponges were conservative. Our quantitative counts of sponge abundances were minimum estimates of the actual numbers of sponges per m^2 and the proportional contributions of commercial sponge abundances to total sponge community abundances were maximum estimates.

Volumetric Measurement of Sponge Biomass

The commercial sponges in the study area were relatively large compared with many of the other sponge species encountered. Consequently, volumetric measurements combined with numerical abundance measurements provide a more accurate quantitative estimate of the contribution of commercial sponges to the total sponge community.

We used three methods of measuring sponge volumes. For all measurements, no sponges were collected within the area covered by transects. Sponges of each species were collected from at least four areas adjacent to the transect areas. Each specimen was carefully handled and not allowed to drain for more than five seconds. Our intent was to prevent spilling of excess water into the container used to measure volume while not draining water from the sponge's canal system. After measuring, every effort was made to return the sponges alive to the water.

Volume estimates for the two common commercial bath sponges, *H. lachne* and *S. barbara*, involved calculating and verifying species-specific regression equations for size/shape vs. volume. Because these species have more uniform shapes compared to many other sponge species, we could generate regression relationships between size/shape and volume for each species and then apply the regression to the measurements of each individual recorded during the transect surveys. We calculated volumes based on predictors that approximated the shapes of the sponges; sphere, cube, cylinder, and cone. Each predictor was regressed against the known measurements and the volumes for each species, which were determined by placing each measured specimen in a 20-L or 115-L (for large specimens) container fitted with an overflow spout, and measuring the volume of water displaced in a graduated cylinder to the nearest 10 ml (see Donahue 2008b for a similar technique). The predictor for the equation with a slope closest to 1.0 and highest r^2 value was chosen. The geometric shape that proved to be the most accurate was a cone shape . The equations describing these regressions were:

Hippospongia lachne **volume = 1.13 (cone) + 87.6**
($n = 34$, $r^2 = 0.85$)
Spongia barbara **volume = 1.25 (cone) + 215.0**
($n = 27$, $r^2 = 0.91$)

The volume of each sponge was estimated by using the sponge's measurements (diameter and height) in the appropriate equation. Note that because of geographic variation in their growth forms, these equations would need to be verified or modified before they can be used to estimate the volumetric biomass of these species from other areas. The biomass of each species within each transect was estimated by totalling the calculated volumes of the sponges measured in the transect.

We estimated volumes of each of four more irregularly shaped species (*S. vesparium*, n=59; *I. campana*, n = 75; *I. strobilina*, n = 16; and *S. graminea*, n = 25) by measuring the volume of water displaced by each specimen, as described above, and averaging the species-specific volumes. To estimate the volumes of these species in our transects, we multiplied the mean volume for each species by the number of individuals of that species in each transect.

Because of time limitations and the highly irregular branching shape of *I. felix*, this species was grouped with the sponges for volume measurement. This group of sponges consisted principally of small, delicate specimens. The volume of these sponges was determined by collecting a sample of 50 sponges in a mesh bag and measuring the water displacement, as described above, of the pooled sample in the bag. Then the displacement of the mesh bag was measured and subtracted from the pooled-sample measurement. A total of 20 samples from four areas were measured in this manner. An overall mean volume for the sponges was then calculated.

To gauge the accuracy of the water displacement method for measuring sponge volumes, an initial trial was conducted in which three replicate measurements were made for each of several individuals of the seven major identified species and for the pooled Unidentified-Sponge samples. In general, the method was accurate. Except for *I. campana* (a vase shaped sponge), the difference between the smallest and largest measurement ranged from 3% to 7%. The variation in replicate measurements for *I. campana* ranged from 5% to 27%. Variation among measurements for the pooled Unidentified-Sponge samples was approximately 11%. Later efforts to refine estimates of the *I. felix* and Unidentified-Sponge volumetric biomass were thwarted by a mass sponge mortality (Butler *et al*. 1995) that eliminated *I. felix* from the entire study area and affected sponge species in the Unidentified-Sponge category differentially. Thus, the remaining sponges could not be considered representative of the sponge community prior to the mortality.

The methods we used to determine volumetric biomass can be considered to be minimally destructive as the sponges were quickly returned alive to the water. Donahue (2008b) used a similar technique to repeatedly measure growth of three sponge species (*S. vesparium*, *I. campana*, and *S. barbara*) over approximately two years. Most of the sponges we returned to the water will probably not reattach to the seabed. It is not uncommon to find unattached sponges on the seabed in our study area. During our survey work, we occasionally found each of the commercial species, as well as *S. vesparium*, *I. strobilina* and *I. felix*, unattached to the substrate and in apparently healthy condition (these sponges are called "rollers" by commercial harvesters). Although some species are sensitive to cutting and moving, cut sponge pieces have survived and even reattached to the substratum (Wilkinson and Thompson 1997).

RESULTS

Because we did not quantify the percentage of the hard -bottom habitat required by most sponges that we surveyed versus the percentage of seagrass meadow in our transects, comparative statistical analysis among species or regions is not valid. Differences among species or among regions in sponge numerical abundance or volumetric biomass may be due to differences among regions in habitat availability and environmental conditions. Therefore, we report our findings as factual information only.

Sponge Numerical Abundances

A total of 33,600 m^2 (3.36 hectares) was quantitatively surveyed. The total number of sponges counted was 24,494. The mean abundance of all sponges was 0.72/m^2; the lowest abundance was 0.32/m^2 (Area 8) and highest was 1.52 m^2 (Area 14) (Figure 2A). As noted earlier, these estimates are conservative.

From a fisheries perspective, the two most important species in the study area were *H. lachne* and *S. barbara*. The mean abundance of *H. lachne* was 71/ha; the range was 29/ha (Area 8) to 134/ha (Area 12; Table 1). The mean abundance of *S. barbara*, which was found in all regions except Marathon (Areas 12-–15), was 35/ha and the range was 0/ha (Area 2) to 88/ha (Areas 6 and 8). The mean abundance of *S. graminea*, which was found only in the Marathon region, was 175/ha and the range was 71/ha to 250/ha (Table 1). The highest abundances of the commercially harvested sponges, particularly *H. lachne*, were found in the Marathon region (Areas 12–15), where sponge harvesting occurs (Table 1). Overall, 42% of all *H. lachne* and *S.* b*arbara* were of legal harvestable size (12.5 cm in diameter). The percentage of legal size sponges was essentially identical between harvested and protected areas.

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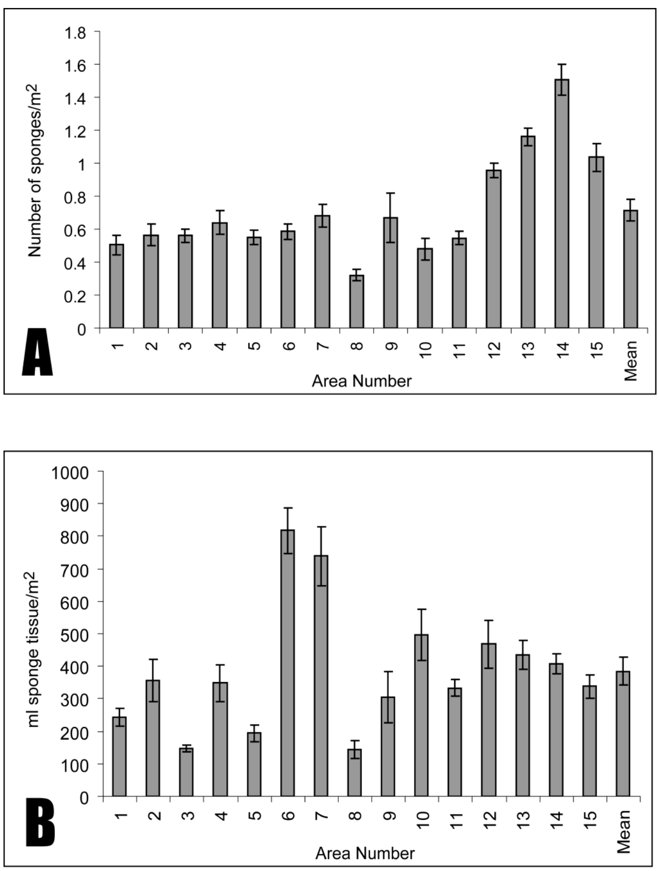

Figure 2. Total sponge community abundance (± S. D.) in the middle and upper Florida Keys. A. Count. B. Volumetric biomass

Sponge Volumetric Biomass

The mean volume determined for the six individual species ranged from 621 ml for *I. stobilina* to 4,846 ml for *S. vesparium* (Table 2). The mean volume for the Unidentified-Species group was 154 ml per individual, based on the mean volume from the pooled samples. The mean volumetric biomass for all sponges over the entire study area was 389 ml/m^2 and the range was 143 ml/m^2 (Area 8) to 818 ml/m^2 (Area 6) (Figure 2B). Those areas with the highest volumetric biomass were areas where *S. vesparium* was particularly abundant.

Contribution of Commercial Sponges to the Total Sponge Community

Overall, the commonly harvested commercial sponges *H. lachne* and *S.* b*arbara* comprised 1.3% of the sponges counted and 2.5% of the volumetric biomass (Figure 3). Although *S. graminea* is considered to be a commercial sponge, it is infrequently harvested because its spongin fiber skeleton is weak and tears easily. If S. *graminea* is grouped with the other commercial species, then commercial sponges constitute 2.0% of the sponge community numerical abundance and 5.1% of the volumetric biomass. In some areas, the contribution of *S. graminea* to the total sponge community was much larger than that of *H. lachne* and *S.* b*arbara*; in Area 12 of the Marathon region, *S. graminea* represented 11% of the total sponge community volumetric biomass.

Table 1. Mean number of *Hippospongia lachne, Spongia barbara, Spongia graminea* (sponges/hectare). Areas are shown in Figure 1.

Area	*H. lachne*		*S. barbara*		*S. graminea*	
	Mean	SE	Mean	SE	Mean	SE
1	37.5	12.5	37.5	8.1	0.0	0.0
2	68.5	18.7	0.0	0	0.0	0.0
3	46.0	15.6	54.0	14.3	0.0	0.0
4	75.0	22.6	67.0	22.5	0.0	0.0
5	42.0	10.4	33.5	11.3	0.0	0.0
6	29.2	9.7	87.5	18.6	0.0	0.0
7	42.0	12.1	67.0	14.3	0.0	0.0
8	29.0	9.7	87.5	25.5	0.0	0.0
9	45.0	20.4	55.0	21.7	0.0	0.0
10	80.0	13.3	10.0	6.7	0.0	0.0
11	50.0	10.7	16.5	7.1	0.0	0.0
12	133.5	24.1	0.0	0.0	250.0	80.8
13	125.0	23.4	0.0	0.0	158.5	38.2
14	125.0	25.7	0.0	0.0	71.0	15.6
15	79.2	15.9	0.0	0.0	233.5	66.7

Table 2. Mean volume of selected sponges in mid and upper Florida Keys.

Species	Sample Size	Mean Volume (ml)	Standard Deviation
S. vesparium	n = 58	4,846	3,658
S. graminea	n = 25	1,963	1,836
S. barbara	n = 28	1,004	953
H. lachne	n = 48	999	715
I. campana	n = 75	766	707
Ircinia strobilina	n = 16	621	302
Unidentified (including *I. felix)*	n = 20	154	Pooled sample

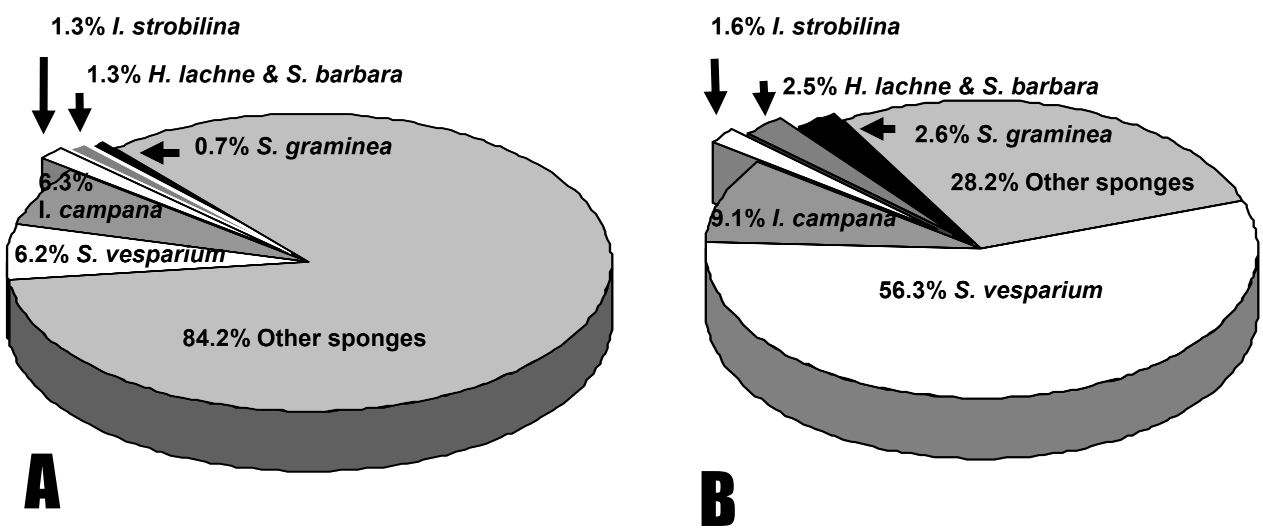

Figure 3. Percentage contribution of *Speciospongia vesparium*, *Ircinia campana*, *Ircinia strobilina*, *Spongia graminea*, *Hippospongia lachne* and *Spongia barbara* (combined) and other unidentified sponges to total sponge community biomass. A. Count. B. Volumetric biomass.

DISCUSSION

The data reported here provide estimates of both the contribution of commercially valuable bath sponges to the total sponge community in a geographical region that supports commercial sponge production, and the abundance and biomass of the entire sponge community in a geographic region where sponges are a particularly dominant structural feature. Immediately subsequent to completion of this work, widespread sponge mortalities coincidental with cyanobacterial plankton blooms decimated sponge populations throughout our study area (Butler *et al.* 1995). Thus, the estimates presented here are historical because they constitute the only quantified information available on the abundance and biomass of sponges in the study areas prior to devastating phytoplankton blooms. Recovery of sponge populations from the fall 1992 bloom proceeded slowly during the following 15 years (Stevely *et al*. In prep), and was hampered by additional sponge mortalities, again in association with a cyanobacterial plankton bloom, in 1994 – 1995 and 2007 (Donahue 2008a). These plankton blooms may have become a persistent, episodic condition. It is not yet known if these blooms are due to anthropogenic impacts.

Because of the ecological importance of sponge filter feeding and the role of sponges in providing structural habitat, we judged that the measurement of volumetric biomass was more important than numerical counts, because biomass more accurately reflects filter feeding capacity and ability to provide structural habitat. The percentage contribution of commercial sponges to the total sponge community based on numerical counts was slightly lower than the percentage based on volumetric biomass because commercial sponges are relatively larger compared with many other sponge species. Also, our numerical counts of all species were underestimates because we did not count *C. nucula* or unidentified encrusting sponges present on other Unidentified-Sponges. The comparatively large volume of commercial sponges belies the accuracy of simple numerical counts in proportional estimates of their contribution to sponge communities. Diaz and Ruetzler (2001) noted that volume or weight estimates are the most realistic measure of sponge abundance. Alvarez *et al*. (1990) also reported that the relative contribution of each species to sponge community biomass changed considerably depending on whether the contribution was based on numerical abundance or percentage of area covered by sponges.

The two most economically important sponge species harvested in our study area, *H. lachne* and *S. barbara*, represent only a very small fraction of the total sponge community (1.3% of the numerical abundance and 2.4% of the volumetric biomass). Two non-commercial species, *S. vesparium* and *I. campana*, predominated in the sponge community, accounting for approximately 65% of the total sponge community volumetric biomass. Sponge communities predominated by a small number of species have been reported in other areas. Wulff (1994) found that four sponge species (including an *Ircinia* species) accounted for 80% of the total sponge community volume in a Caribbean hard-bottom community. Similarly, Alvarez *et al*. (1990) noted that in a Venezuelan fringing coral reef habitat, three species accounted for more than 50% of the total area covered by sponges in a Venezuelan fringing coral reef habitat.

Surprisingly, the overall percentages of legal sized commercial bath sponges were essentially the same in both harvested and protected areas, and notably, the highest abundance of commercially harvested sponges was found in the Marathon region, which is subjected to harvesting, Commercial sponge abundance would be dependent on hard-substrate availability and other environmental factors, as well as on the effects of harvesting effort. Differences in relative abundance of the different sponge species among areas could be due to environmental or ecological differences rather than harvesting effort. A more rigorous experimental design and statistical analysis to measure the effects of hard substrate availability and sponge harvesting on commercial sponge abundance is needed to distinguish the effects of habitat structure vs. sponge fishing on the abundance of commercial sponges.

Although the glove sponge (*S. graminea*) was not found throughout the study area and is infrequently harvested, it can be a substantial component of the total sponge community biomass in some areas. At Marathon Area 12, where it was the most abundant, *S. graminea* represented 11% of the total sponge community biomass. If marketing conditions change and the glove sponge is harvested more intensely, its harvest could have a larger impact on total sponge community biomass where it is especially abundant.

DiResta *et al*. (1995) reported an average density of commercial sponges (*H. lachne*, *S. barbara*, *S. graminea,* and *S. tubulifera*) of 300/ha on the hard bottom portion of Biscayne Bay where commercial sponges were found in their highest density. The overall density reported here was 154/ha (*H. lachne*, *S. barbara,* and *S. graminea*). However, in the areas where we found *S. graminea*, the combined abundance of *H. lachne* and *S. graminea* averaged 268/ha (range: 195 – 310/ha). In the habitat DiResta *et al*. (1995) surveyed, the commercial sponge fauna was numerically dominated by *S. tubulifera* which was not found in our study area. Furthermore, the distribution of *S. graminea* was limited in our study area, suggesting that the habitat we surveyed differed from that surveyed by Diresta *et al*. (1995) in Biscayne Bay.

We conclude that, in the sponge habitat we surveyed, commercial sponge biomass is a relatively small component of total sponge community biomass. Therefore, if sponges are harvested in a sustainable manner, the ecological consequences of sponge harvesting should be relatively minor. Furthermore, the similar numerical abundance and proportion of legal size commercial bath sponges found within the Everglades National Park protected region and the three regions within the sponge fishing grounds suggests that sponge fishing has not resulted in a large depletion of these sponges in the Gulf side of the Keys. Current sponge fishery regulations in Florida (Florida Administrative Code: 68-28) include the following (the first three are applicable to the Florida Keys area):

i) Establishment of a minimum size of 12.5 cm diameter,

ii) Establishment of protected areas (Everglades National Park, Biscayne Bay National Park),
iii) Closure of harvesting sponges by diving (sponge harvesting in the Florida Keys must be accomplished by hooking from a boat, using a hook attached to a long pole to retrieve sponges); and
iv) Where harvesting sponges by diving is permitted (northern Gulf of Mexico), requirement that sponge divers harvest sponges by cutting rather than tearing the sponge free from the bottom. (Due to the remarkable the bath sponge's remarkable regenerative ability, sponge tissue left attached to the substrate can regenerate, especially if the sponge is cut from the bottom; (Stevely and Sweat 1985)).

For decades, harvesting sponges in the Florida Keys has sustained the livelihoods of commercial fishermen. Our results suggest that the regulations put forth in the Florida Administrative Code have helped to sustain this fishery in an ecologically responsible manner. The recently occurring episodic cyanobacteria blooms will affect both the sponge fishery and the ecosystem, if they become a regular occurrence. These blooms have proven to be more harmful to the sponge community than decades of commercial fishing. Clear focus should be given to understanding why these blooms have developed and to minimizing their effects, for the benefit of both the fishery and the ecosystem.

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