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THE RECOVERY OF SPONGE POPULATIONS IN FLORIDA BAY AND UPPER KEYS FOLLOWING A WIDESPREAD SPONGE MORTALITY

FLORIDA FISH AND WILDLIFE CONSERVATION COMMISSION

CONTRACT FINAL REPORT

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Executive Summary

- The 2002 data (nearly ten years after the mortalities) clearly document that significant sponge abundance recovery has occurred. However, recovery is far from complete. Recovery is not uniformthroughout the areas sampled, and several "important" species – in terms of contribution to sponge community biomass – have not exhibited significant recovery.

- The clearest picture of sponge recovery was found at Marathon (Figure 15). Total number of sponges, Both Identified and Miscellaneous Unidentified sponges is now approximately the same as found before the sponge mortalities.

- Although the Marathon Identified sponge species have returned to their former abundance, care must be taken in interpreting the data presented in this fashion. Not all these species have significantly recovered. Almost all of the recovery of this group of sponges is attributable to significant increases in *Ircinia* sp. (Figure 5), *Ircinia strobilina* (stinker sponge, Figure 17) and *Spheciospongia vesparia* (loggerhead sponge, Figure 7). The increase in *Ircinia* sp. and *Ircinia strobilina* is striking. Both species have exhibited an approximately three-fold increase compared to their abundance prior to the mortalities. The other species in this category have exhibited either inconsistent recovery (*Hippospongia lachne* and *Spongia barbara*) or no recovery at all (Ircinia campana).

- The picture of sponge recovery at Long Key (Figure 4) is less clear. Abundance of the Identified sponges is still a fraction (39.5%) of the abundance found prior to the mortalities. The major contributor to the observed increase in abundance, as is the case in Marathon, is *Ircinia* sp. The commercial yellow sponge (*Spongia barbara*) has also completely recovered. There is little or no evidence supporting significant recruitment of *Spheciospongia vesparia* (loggerhead sponge), *Ircinia campana*, *I. strobilina* (stinker sponge) and *Hippospongia lachne* (sheepswool sponge).

- Although the data are limited to 2001 and 2002, there appears to be significant recruitment of *Ircina* sp. and the commercial yellow sponge (*Spongia barbara*) at the Arsnicker Keys South site. There was no evidence of recruitment of the other Identified species. Data from Arsnicker Keys South appear to be comparable to Long Key data.

- The absence of the vase sponge (*Ircinia campana*) is striking. This species was once an abundant, large sponge, accounting for almost 10% of total sponge community biomass. Now only rare specimens are observed at the study sites (they are still found in near-shore areas). Given that there is no evidence of recovery after nine years, it is difficult to even speculate when recruitment will begin.

- Prior to the mortalities, the loggerhead sponge accounted for 59% of the sponge community biomass. There has been consistent, significant recovery at Marathon and current (2002) abundance is essentially the same as found prior to the mortalities. However, the mean size (diameter) is significantly smaller than observed in 1991. Marathon loggerhead sponge biomass will be comparable to pre-mortality biomass within the next 2-3 years. Future data is needed to demonstrate significant loggerhead sponge recovery at Long Key and Arsnicker Keys South.

- Current (2002) data and field reconnaissance as well as past project reports have documented, in general, the recovery of the commercial sponge species (*Hippospongia* and *Spongia*). Sponge harvesting activity has been observed in areas were commercial sponges had been previously eliminated. However, data supporting consistent recruitment of the sheepswool sponge at the Marathon site is lacking.

- *Ircinia* sp. is the most successful species in reestablishing itself after the mortalities. It has recovered in all the study surveys.

- It is now possible to identify several sponge species that are short-lived, and that widely fluctuate in abundance. In a sense, it may be impossible to say that these species have truly recovered because their abundance is probably constantly changing. Sponge species that are in this category are: *Adocia* sp., *Cinachyra* sp., *Halichondria melanadocia*, *Haliclona molitba*, *Hytrios* sp. *Niphates erecta*. and *Tedania ignis*.

- In addition to the species in the Identified sponge category, there are also examples of long-lived species that are repopulating the study areas in a longer term fashion, without significant declines. These species include: *Anthosigmella varians* and *Spongia barbara dura*.

INTRODUCTION

From 1992 through 1994, widespread sponge mortalities in Florida Bay and the middle and upper Keys decimated sponge population abundance throughout the affected area (1,000 km^2). The sponge mortalities were closely associated with micro algal blooms dominated by a small cyanobacterium, *Synechococcus* sp. The project described here provides an analysis of abundance data collected over an eleven-year period that encompasses sponge abundance before and after the mortalities.

The objective of the project when it began was to provide resource managers with information needed to assess potential ecological impacts resulting from commercial sponge harvesting. The sponge mortalities began just when the initial field work was being completed. Following the mortalities, the objective was to evaluate the long-term recovery of sponge populations. As the years have progressed, increasingly detailed sponge abundance data have been collected.

To date (2002), a total of ten surveys have been completed during the past eleven years. A clearer and more detailed picture of sponge population recovery has now emerged. There are now statistically significant trends in sponge abundance that can enable natural resource managers to evaluate the rate and nature of sponge population recovery. Significant recovery of the most "important" species – in terms of sponge population biomass – has occurred in the Marathon area. However, recovery is not yet complete at this location and recovery at the other sampling locations is much less apparent.

Due to the long-term nature of the work, it has been possible to identify several species that are short-lived and that widely fluctuate in abundance. These species represent a small fraction of the total sponge community biomass. From an ecological viewpoint it will be impossible to judge recovery of these populations – recovery is a constantly moving target. However, we are now able to follow the recovery of long-lived species that comprise the major portion of sponge biomass and that appear to be consistently increasing in abundance. With this information it will be possible to truly evaluate sponge population recovery from a natural resource management perspective.

Over the past seven years, the detailed results of this ongoing project have been provided to the Florida Dept. of Environmental Protection, Florida Marine Research (now the Fish and Wildlife Conservation Commission). The basic methodology has changed little. However, more accurate navigation equipment (DGPS) has been used since 1998.

Funding for the project has been provided by FDEP, Florida Sea Grant College Program and Florida Keys National Marine Sanctuary Program. Over the years, sponge identification assistance has been provided by Dr. Shirley Pomponi (Harbor Branch Oceanographic Institute) and Dr. Michelle Kelly (Auckland University of Technology).

METHODS AND MATERIALS

A detailed description of survey techniques and all sampling locations was previously provided to the Florida Dept. of Environmental Protection (1995 Contract Final Report). The initial 1991 survey included sampling at 15 areas and also included estimating the volume of sponge biomass at each area.

Beginning in 1993, effort was focused on surveying sponge populations at two of the initial 15 sampling areas: one site offshore from Long Key, the other sited offshore from Marathon (Figures 1, 2, & 3; Table 1). In 1995, a third area in Everglades National Park (ENP) was added to the survey (Figure 2, Table 1). Some limited additional survey work has also been conducted at two of the initial sampling sites (Marker Three, 1995; Inshore Long Key, 1997 - 1999; Figure 2). Beginning in 2001 new sampling site within ENP (Arsnicker Key, Figure 2) was established. Due to conversion from LORAN to GPS navigation equipment, the reestablishment of the ENP site in 1995 was judged to be questionable.

At each sampling area, sponge abundance was determined by counting all sponges within twelve 100 meter (m) by two meter transects ($200m^2$). Within each transect, specific abundance data were recorded for the following commercial (species of the genera *Hippospongia* and *Spongia*) and non-commercial species:

Hippospongia lachne (sheepswool or wool sponge)
Spongia barbara (yellow sponge)
Spongia graminea (glove sponge)
Spheciospongia vesparia (loggerhead sponge)
Ircinia campana (vase sponge)
Ircinia strobilina (stinker sponge)
Ircinia sp.

This group of sponges was referred to as "1991 Identified Sponges". All other sponges were pooled together into a Miscellaneous Unidentified category.

Sponge Species Included in 1994 Survey

In 1994, an effort was made to begin collecting more specific sponge abundance data by recording data for additional sponge species. The following sponge species were included in the data (previously they would have been lumped into the miscellaneous unidentified category). However, throughout the report the Miscellaneous Unidentified sponge category consistently refers to all sponges other than the seven species identified in the 1991 work.

Anthosigmella varians
Cinachyra sp.
Halichondria melanadocia
Aplysina sp.

Sponge Species Included in 1995 Survey

In 1995, a third area within Everglades National Park (ENP) was included in the survey (Figure 2, Table 1). This was the first time the area had been surveyed since 1991. Problems with the reestablishment of the location of this site have been noted in past project reports and a new reference site was established in 2001 (Figure 2; Table 1).

In order to more fully define the sponge community at each survey area and increase the ability to detect fluctuations in abundances of other species, abundance data for additional species were recorded. This was made possible by a collaboration with a sponge taxonomist (Dr. Shirley Pomponi, Harbor Branch Oceanographic Institution). The identified sponge species added in the 1995 survey were as follows:

Tethya crypta
Hyrtios sp.
Haliclona molitba
Niphates erecta
Callyspongia vaginalis
Spongia barbara dura (hard head sponge)
Aaptos sp.
Tedania ignis
Biemna sp.

Initially, in 1994, sample sizes for all species were not necessarily the same. *Niphates erecta* was counted at eight transects at Long Key. *Hyrtios* sp. and *Haliclona molitba* were included in four transects at Long Key. All three of these species were included in the surveys of the Marathon and Everglades National Park Areas. These three species have been counted in all transects at all sampling areas since 1995.

Sponge Species Included in 1997 Survey

Abundance data for four additional species were collected during the 1997 field work. Dr. Shirley Pomponi, Harbor Branch Oceanographic Institution, was responsible for these identifications.

Lissodendoryx sp.
Clathriidae
Dysidea ethera
Stelleta kalitetilla

Determination of Station Locations

During the initial phases of the survey work (1991 and 1993), LORAN C was used to determine station latitude and longitude coordinates. Beginning in 1994, station location coordinates were determined using the Global Position System (GPS). The station locations were first determined using LORAN C, and GPS latitude/longitude coordinates were recorded for future reference. There were some discrepancies between the latitude/longitude coordinates provided by the LORAN C and GPS systems. We assume we were still in close proximity to the 1991 Long Key and Marathon sampling sites as the same LORAN C unit was used to locate the latitude/longitude coordinates. However, because we were not able to use LORAN C in the 1995 ENP survey, the location of this survey site has changed since the 1991 survey. This problem has been discussed in past Contract Reports.

In order to more accurately determine station locations, Differential GPS equipment (Garmin GPS 38 Personal Navigator with the manufacturer's conversion kit) was used to determine station coordinates during the 1998-2002 field work. During the 1998 field work we marked our anchoring locations with rebar stakes and flagging tape. Because of fouling growth, these markers were difficult to locate and have not been used to establish permanent transects. However, in the course of running the 1999–2002 transects, markers (rebar stakes) have been encountered, documenting that the sampling sites are closely grouped.

Statistical Analysis

Data were compiled using Quattro Pro spreadsheet software (version 6.01 for Windows 95). Statistical analyses were conducted using the software statistical package SigmaStat (version 2.0 for Windows 95, Jandel Corporation). Each data set was tested for normal distribution and equality of variance. If both these tests were passed, a One Way Analysis of Variance (ANOVA) was used to test for differences among three or more means. An All Pairwise Multiple Comparison Procedure (Tukey Test) was conducted to determine which means were different.

When the data set failed the test for either normality of distribution or equality of variance, the Kruskal-Wallis Analysis of Variance on Ranks (the non-parametric analog of One Way ANOVA) was used to test for differences among three or more medians. If a significant difference in means was found, tests were run to determine which medians were different. Dunn's All Pairwise Multiple Comparison procedure was used when the sample sizes in the different treatment groups equal, the Student Newman-Keuls (SNK) Test was used to determine which medians were different.

RESULTS

A total of 29 sponge taxa have been reported during the surveys (Table 2). There is now a reasonably complete description of the sponge fauna and relative abundance at the three survey areas (Table 3, 4, 5). Abundance data was collected for approximately 95% of the sponge species found.

In general, a comparison of the ranked sponge abundance in past years (1997-2002) are reasonably consistent. The most prevalent sponges are usually the most common species from year to year. However, some of these species can fluctuate widely in abundance from year to year. In some cases, there was a notable change in the ranked abundance of a species in an area. The trends in abundance for all of the individual species are discussed below.

Long Key Abundance Data

1991 Identified Sponges

Overall, there is trend showing a significant increase in the abundance of all the sponges lumped into this category (Figure 4). The abundance of 1991 Identified sponges in 2002 is still a fraction (39.5%) of the number of sponges found in 1991. Sponge abundance in 1999-2002 was significantly higher than the abundance found in 1993 and 1994 ($P<0.05$). The small abundance increase observed in 2002 was not significantly greater than 2001. The presentation of these data grouped together is misleading, however. Almost all of the observed increase was attributable to increased abundance of *Ircinia* sp. (Figure 5). Small increases in yellow sponge (Figure 6) and loggerhead sponge (Figure 7) contributed to the increase to a much lesser degree.

Hippospongia lachne (sheepswool sponge): For the first time since the mortality a single sheepswool sponge was found within the transects, but this was not statistically significant. The lack of recruitment contrasts with the dramatic increase in sheepswool sponge abundance observed at the Inshore Long Key sampling site (approximately two miles to the south, year 2000 Project Report). The occurrence of a specimen in the transects may indicate that recruitment will become evident in the near future.

Spongia barbara (yellow sponge): Yellow sponge abundance has exhibited a rapid and significant ($P<0.05$) recovery beginning in 1997 (Figure 6). Abundance has remained relatively constant since 1998 and is essentially the same as found in 1991.

Spongia graminea (glove sponge): Not reported in area either before or after the sponge mortalities.

Spheciospongia vesparia: There has been a significant ($P<0.05$) increase in abundance. The 2001 and 2002 data are significantly greater than the 1993 and 1994 data. The 2002 data remain significantly lower than the data prior to the mortality (1991). There does not appear to be significant recruitment in the past seven years. The 2001 and 2002 data are not significantly different from the 1995-2000 data.

Past project reports have speculated that increased abundance seen in the years immediately after the mortality did not indicate new recruitment, but may have resulted from regeneration of a few specimens that were not completely killed (some living tissue survived). A comparison of loggerhead size data (sponge diameter) from Marathon, Long Key and Arsnicker Keys South demonstrated a highly significant ($P<0.001$) smaller size at Marathon compared to the other two stations. These data seem to at least partially confirm the speculation that the specimens of larger loggerhead sponge found at Long Key represent regeneration of specimens that were not completely killed and do not indicate recruitment of new sponges in recent years. Future surveys will be needed to document that significant recruitment is occurring.

Ircinia strobilina (stinker sponge): Significant recruitment has not occurred (Figure 17). Only one or two specimens have been found in the transects each year since 2000.

Ircinia campana (vase sponge): Since the sponge mortalities, no specimens have been found in the transects. Prior to the mortalities it was an abundant sponge in the area (7.6 specimens/200 m^2).

***Ircinia* sp:** There has been a consistent trend of increased abundance (Figure 5). The increased abundance observed in 2001 and 2002 confirmed that the increase is indeed significant ($P<0.05$).

Miscellaneous Unidentified Sponge Category

The abundance of the miscellaneous unidentified category exhibits a different pattern from the identified sponge category (Figure 4). The abundance of these sponges declined in 1993 and 1994, but was not significantly different from 1991 data. Additional sponge die-off events were observed after the 1993 sampling (Stevely and Sweat, pers. obs.).

There was a substantial and significant ($P<0.05$) increase in miscellaneous unidentified sponges in 1995 compared to sponge abundance prior (1991) and during the sponge die-offs (1993 and 1994). Since 1995, abundance has tended lower. Data from 1999-2001 are significantly lower that the 1995 data ($P<0.05$) and are now statistically indistinguishable from abundance data prior to the mortalities (1991).

These data suggest that opportunistic species were able to rapidly populate the area in 1995 after the mortalities, and have subsequently declined in abundance. Data collected from all the sampling areas during the study have documented that many of the species in the Miscellaneous Category undergo wide fluctuations in abundance on a short-term basis (one to three years).

The observed decline in the Miscellaneous Category since 1995 can be attributed to declines in the abundance of *Halichondria melanadocia*, *Cinachyra* sp., *Adocia* sp., *Haliclona molitba*, and *Tedania ignus*

Abundance of Sponge Species Surveyed 1994-2002

Halichondria melanadocia: Abundance significantly ($P<0.05$) increased in 1995 and 1997, and contributed to the increased abundance of the Miscellaneous Category of sponges observed in 1995. There has been a dramatic abundance decline since 1999 ($P<0.05$). Abundance of this species has widely fluctuated (increased and decreased) over an eight year period (Figure 8).

***Cinachyra* sp:** This species exhibited significant ($P<0.05$) declines and increases during the sampling period (Figure 9). Observed abundances in 1999 and 2001 were significantly higher than 1997 data. Current (2002) abundance is significantly lower than 1994 and 1995 data.

Anthosigmella varians: The 2002 data confirm a consistent and significant ($P<0.05$) increase in abundance (Figure 10). The species appears to be a long-lived species and is repopulating the area.

Spongia barbara dura (hard head sponge): The 2002 data confirmed that abundance since 1997 is significantly greater than the 1993-1995 data (immediately after the mortality). Abundance has remained constant from 1997-2002 (Figure 11).

Abundance of Sponge Species Surveyed 1995-2002

***Adocia* sp:** There has been a significant ($P<0.05$) decline in abundance (Figure 12). Immediately following the sponge mortalities (1995), *Adocia* sp. was a prominent component of the sponge fauna in the area. Now the abundance is approximately an order of magnitude lower than the 1995 data.

***Hyrtios* sp:** The data confirmed a significant ($P<0.05$) decline (essentially disappearance) in abundance from 1995 compared to subsequent surveys (1997-2002). Marathon *Hyrtios* sp. abundance has also shown the species to undergo large annual fluctuations in abundance (Figure 13).

Haliclona molitba: The 2002 data confirm that there has been a significant decrease in abundance since 1995 (Figure 14). There has been no significant change in abundance since 1997.

Niphates erecta: There was a significant increase ($P<0.05$) in the 2002 data compared to 1995-2000 data (Figure 15). Abundance data appeared to remain constant from 1995 through 2000.

Although data was recorded for the following species, because of low abundance (and sometimes uncertain identification), the data were insufficient to detect significant trends. These species included: *Aplysina* sp, *Aaptos* sp., *Lissodendoryx* sp., Clathriidae sp., *Dysidea ethera, Geodia* sp., *Callyspongia vaginallis.*

Marathon Abundance Data

1991 Identified Sponges

No specimens of the Identified spongers were present in the 1993 data immediately following the mortality. There has been a significant ($P<0.05$), consistent increase in abundance (Figure 16). However, there was no increase observed in the 2002 data. Current (2001-2002) abundance is essentially the same as found in 1991.

Superficially, it appears that there has been complete recovery of this group of sponges. However, this is not the true situation. Most of the recovery is attributable to significant increases in *Ircinia* sp. (Figure 5), *Ircinia strobilina* (Figure17), and loggerhead sponge (Figure 7). The increase in *Ircinia* sp. and *Ircinia strobilina* abundance is striking. Both species have exhibited an approximately three-fold increase in abundance compared to their abundance prior to the mortalities. Several other species in this group have shown either small or no increases.

Hippospongia lachne (sheepswool or wool sponge): Since 1998 a few (0-4) specimens have been found within the transects (Figure 18). A consistent, significant recovery of sheepswool sponge is not yet evident.

Spongia barbara (yellow sponge): Not present in area before die-off.

Spongia graminea (glove sponge): There appears to be evidence that some recruitment has occurred (Figure 18), but this cannot be validated statistically. Current (2002) abundance data remains significantly ($P<0.05$) lower than the abundance found prior to the mortalities (1993)

Spheciospongia vesparia (loggerhead sponge): There has been a consistent, statistically significant ($P<0.05$) increase in loggerhead sponge abundance since 1999 (Figure 7). Current (2002) abundance is essentially the same as found prior to the mortalities (1993). However, total recovery can not be claimed as the median size of the loggerhead sponge is highly significantly smaller ($P<0.001$) than the median size prior to the mortality. It must be acknowledged that this is a crude comparison. No loggerhead size data was collected at this exact location in 1991. The comparison was based on loggerhead size data collected at a different location.

Ircinia campana (vase sponge): For first time since the mortalities, two specimens of vase sponge were found within the transects. Over the past five years, rare specimens were seen in the vicinity. At this point (2002), there is still no evidence of significant recovery.

Ircinia strobilina (stinker sponge): There has been a consistent, significant ($P<0.05$) increase in abundance in 1999, 2000, and 2001 (Figure 17). No significant increase was observed in 2002. The abundance of stinker sponge now exceeds the abundance found in 1991 prior to the mortalities. The more conservative Tukey Test did not indicate a significant difference between the 1991 and 2001-2002 data. The less conservative Student-Newman Keuls (SNK) method indicates that 2001 and 2002 data are significantly greater. Current (2001 and 2002) stinker sponge abundance is approximately three-fold greater than the abundance found in 1991. It appears that the stinker sponge population is now more abundant than found in 1991, but this will have to be confirmed with future data.

***Ircinia* sp:** The pattern and analysis of the *Ircinia* sp. data was very similar to the stinker sponge data. There has been a consistent, significant ($P<0.05$) increase in abundance in 1998-2001 (Figure 5.). No significant increase was observed in 2002. The abundance of *Ircinia* sp. now exceeds the abundance found in 1991. The more conservative Tukey test did not indicate a significant difference between the 1991 and 2001-2002 data. The less conservative SNK method indicates that 2001 and 2002 data are significantly greater. It appears that the *Ircinia* sp. population is now more abundant than found in 1991.

Miscellaneous Unidentified Sponge Category

The data clearly show a significant decline in 1993 ($P<0.05$; Figure 16). Data from 1994-1999 remained significantly lower than the 1993 data. Significant increases were observe in 2000 and 2001. Current (2001 and 200) are not significantly different from the 1993 data. This group of sponges has returned to the abundance found in 1993. The increased abundance found in 2000-2002) is primarily attributable in increases in *Cinachyra* sp., *Halichondria melanadocia, Niphates erects, Hyrtios* sp., and *Adocia* sp. The trends observed for each species in this category are as follows.

Abundance of Sponge Species Surveyed 1994-2002

Halichondria melanadocia: There were notable and statistically significant increases ($P<.001$) in 2000 and 2001 (Figure 8). *H. melanadocia* abundance has clearly increased in the years following the mortality. In 1999, it ranked as the seventh in abundance, but now (2001 and 2002) it ranked as the third most abundant species at Marathon. There was an abundance decrease in 2002 compared to 2001. The more conservative Tukey test did not show the decline as significant. The less conservative SNK method indicated that the decline was significant.

***Cinachyra* sp:** The data clearly show significant ($P<0.05$) changes in abundance. There was a significant decrease from 1994 compared to 1997-99, and then a significant increase in 2000 and 2001. There was a decrease in the 2002 data, but these data are not statistically distinguishable from the 2000 and 2001 data (Figure 9).

Anthosigmella varians: There has been a consistent, significant ($P<0.05$ increase in abundance since 1994 (Figure 10).

Spongia barbara dura (hard head sponge): The hard head sponge significantly increased ($P<0.05$) following the sponge mortalities, but the increase has leveled off in recent years (Figure 11). The pattern is almost identical to that seen at Long Key, except recruitment was evident a year or more earlier (1995) at Marathon than it was at Long Key (1997).

Abundance of Sponge Species Surveyed in 1995-2002

***Adocia* sp:** There was a dramatic, significant ($P<0.001$) increase in abundance since 1995 (Figure 12). In 2000, it was the most abundant species found in this location (approximately a 17-fold increase compared to 1995). Since 2000 there have been significant abundance declines in 2001 and 2002, but abundance remains significantly higher than 1995-1997 data. The Marathon *Adocia* sp. data is one of the clearest examples widely fluctuating changes in abundance.

***Hyrtios* sp:** This species has undergone several significant ($P<0.05$) decreases and increases during the duration of the study (Figure 13). Abundance data was significantly lower in 1997-1999 compared to 1995. There was a significant increase in 2000 compared to 1997 and 1998 data. Following 2000 there were significant declines in 2001 and 2002.

Haliclona molitba: There was a significant ($P<0.05$) decline in abundance during the study (Figure 14). Abundance data observe 2000-2002 has remained consistently lower than 1995-1992 data,

Niphates erecta: Significant ($P<0.05$) decreases and increases in *Niphates erecta* abundance have occurred (Figure 15). There was a significant decline in the 1999 data compared to 1995-1998 data). There was a significant increase in the 2001 and 2002 data compared to 1999 data.

Although data was recorded for the following species, because of low abundance (and sometimes uncertain identification), the data were insufficient to detect trends. These species included: *Aplysina* sp, *Tethya crypta, Aaptos* sp., *Lissodendoryx* sp., Clathriidae, *Dysidea ethera, Geodia* sp., *Callyspongia vaginallis.*

Arsnicker Keys South Abundance Data
Everglades National Park

In 2001, a new reference sampling site (referred to as Arsnicker Keys South; Figure 2) was established in Everglades National Park (ENP). The selection of this new site was based on field reconnaissance conducted during the 2000 field work (Contract Report 2000). Past Contract Reports have clearly stated concern that the ENP site (Contract Reports 1995-2000) had not been

correctly located when post mortality surveys were begun in 1995 (two years after work began at Long Key and Marathon). The reason for this problem was a change from LORAN to GPS navigational systems. The 1998-2000 positional data for the former ENP site are accurate (DGPS) and the site can be returned to in future years.

The Arsnicker Keys South site is approximately 2.5 miles north of the Long Key site in approximately the same water depth (7-8 ft). The Arsnicker South and Long Key sites appear to be suitable for comparing commercial and non-commercial sponge populations within and outside of ENP. However, based on field observations over the past three years (2000-2002) there appears to be some sampling problems at the Arsnicker Keys South station. Benthic drift algae tends to much more abundant in this area during the summer months, and makes it more difficult to count smaller, less conspicuous species. This problem was noted in the 2000 Contract Report. Because of the benthic drift algae problem, and because our past work has documented wide fluctuations in many of the species that were initially lumped into the Miscellaneous Sponge category, emphasis in this report (2002) is focused on the 1991 Identified Sponges. This strategy was suggested in the 2000 Contract Report. However, data for most of the species found in the area are being collected and will be reported on in the future when meaningful trends become apparent.

1991 Identified Sponges

No discernable trend is apparent based on two years of data (Figure 19). The small decrease in abundance observed in 2002 was not statistically significant. Abundance of this group of sponges is similar to the abundance found at Long Key (Figure 19). The slightly higher abundance found at Arsnicker Keys south compared to Long Key is primarily attributable to higher abundances of *Ircinia* sp. It appears that, similar to Long Key, there is not clear evidence of recovery of this group of sponges, especially when compared to the Marathon data (Figure 16). Unfortunately, there is no abundance data for this specific site prior to the mortality. However, given that the data collected from other areas documented the complete elimination of these sponges, it seems reasonable to assume that this group of sponges were either completely or almost completely eliminated after the mortalities. The data for each of these species in this category is discussed below.

Hippospongia lachne (sheepswool sponge): One specimen was found in the transects in 2001, no specimens were found in 2002. It is not yet evident that recovery of this species is occurring.

Spongia barbara (yellow sponge): Yellow sponges were found within the transects (Figure 6), indicating some recovery has occurred. The abundance found at Arsnicker Keys South, although lower, was not significantly different from the abundance observed at Long Key. It seems reasonable to assume that some recovery has occurred.

Spongia graminea (glove sponge): Not present in area before mortalities.

Spheciospongia vesparia (loggerhead sponge): No significant increase in abundance was observed (Figure 7). The abundance observed at Arsnicker Key South was similar to the abundance found at Long Key. Furthermore, the mean size (diameter) of loggerhead sponges was not significantly from Long Key and was highly significantly larger than loggerhead sponges found at Marathon. As noted in the Long Key results section (page 6) we speculate that the loggerhead sponges found at Arsnicker Keys South are specimens that regenerated after the mortality, and do not represent new recruitment.

Ircinia campana (vase sponge): No specimens were found. These data confirm the almost total lack of recruitment of this species at the study sites.

Ircinia strobilina (stinker sponge): Stinker sponge were found in this area (Figure 17). These data suggest that recruitment may be occurring, since they were totally eliminated at the other sampling areas after the mortalities. More data is needed, however, to establish a statistically significant trend.

***Ircinia* sp.**: This species was present (Figure 5). No significant trend between years 2000 and 2001 is apparent. These data appear to be consistent with Long Key and Marathon data and it appears that significant recruitment has occurred.

DISCUSSION AND CONCLUSIONS

A clearer picture of the recovery of sponge populations following the mortalities continues to emerge. The abundance of those sponges grouped into the Identified Species category (species for which specific abundance data was collected before the mortalities) has increased significantly at the Long Key and Marathon sites (Figures 4, 16). These seven species, chosen either because of their abundance and size or because of their commercial importance, accounted for approximately 73% of the sponge community biomass prior to the mortalities. Taken as a whole, the data suggest that these species are long-lived, and do not appear to undergo significant short-term population declines. From a resource management perspective (quantity of habitat provided, capacity for pumping water and filter feeding, stability of abundance) these are the most important species to monitor.

However, the presentation of the data for each species grouped together can be misleading. Often the observed increases are attributable to highly significant increases of only two to three species. Furthermore, when individual species are considered, the trends between Long Key and Marathon are considerably different.

The long-term nature of the study enables us to better interpret the data for the Miscellaneous Sponge category (species for which specific abundance data was not collected before the mortalities). Many of these species are short-lived and widely fluctuate in abundance. In a sense,

it may be impossible to say that all these species have truly recovered because their abundance is probably constantly changing. These data will eventually make a significant contribution to the understanding of sponge biology and population structure. The response of sponge biologists to presentation of the project findings at the 2002 International Sponge Biology Conference was that these data represent the first documentation of such population fluctuations on a long-term basis. These species are discussed in greater detail in a following discussion section.

Much of this year's Project Report focuses on trends at the Long Key and Marathon sites. Data for the Identified Sponge category at the Arsnicker Keys South site is also presented. Although this data will prove useful, because of a lack of specific data prior to the mortalities and short-term nature of data (2001-2002) it is not yet possible to establish many clear trends.

Long Key

1991 Identified Sponges

The evidence of recovery at Long Key is not nearly as clear as the trends seen at Marathon. The abundance of this group is still a fraction (39.6%) of the numbers of sponges found in 1991 (Figure 4). The observed increase in 2001 and 2002 is significant. However, the observed increase is almost entirely attributable to the increase in *Ircinia* sp. (Figure 4). The commercial yellow sponge (*Spongia barbara*) has completely recover (Figure 5), but because of its relatively low abundance, its contribution to the observed increase is relatively small.

The small increase in loggerhead sponge (Figure 7) could not be validated as statistically significant. There is a highly significant ($P<0.001$) difference in the current (2002) abundance at Long Key compared to Marathon. In 1991, there was no significant difference in loggerhead sponge abundance at Long Key and Marathon. Past Project Report have speculated that the observed abundance of loggerhead sponge at Long Key is attributable to regeneration of specimens that were not completely killed my the mortalities. The observed highly significant ($P<0.001$) larger size of the few specimens found at Long Key compared to loggerhead sponges found at Marathon tends to at least partially validate this speculation.

For the first time since the mortalities a specimen of sheepswool sponge (*Hippospongia lachne)* was found in the transects. However, there is no evidence that significant recruitment is occurring. In recent years (2001-2002), a few specimens of vase sponge (*Ircinia campana*) have been found in the transects, but these data do not indicate any significant recruitment. The stinker sponge (*Ircinia strobilina*) has not been found in the study area since 1991.

Miscellaneous Unidentified Sponge Category

The abundance of the Miscellaneous Unidentified category exhibits a different pattern from the identified sponge category (Figure 4). The abundance of these sponges declined in 1993 and 1994, but was not significantly different from 1991 data. Additional sponge die-off events were observed after the 1993 sampling (Stevely and Sweat, pers. obs.).

There was a substantial and significant ($P<0.05$) increase in miscellaneous unidentified sponges in 1995 compared to sponge abundance prior (1991) and during the sponge die-offs (1993 and 1994). Since 1995, abundance has tended lower. Data from 1999-2001 are significantly lower that the 1995 data ($P<0.05$) and are now statistically indistinguishable from abundance data prior to the mortalities (1991).

The data suggest that opportunistic species were able to rapidly populate the area in 1995 after the mortalities, but have subsequently declined in abundance. Data collected from all the sampling areas during the study have documented that many of the species in the Miscellaneous Category undergo wide fluctuations in abundance on a short-term basis (one to three years).

The observed decline in the Miscellaneous Category since 1995 can be attributed to declines in the abundance of *Halichondria melanadocia*, *Cinachyra* sp., *Adocia* sp., *Haliclona molitba*, and *Tedania ignus*

Marathon

1991 Identified Sponges

The clearest evidence of recovery is evident at Marathon (Figure 16). There have been consistent, significant increases in abundance to the point that the abundance of the Identified Sponges category is essentially the same as observed prior to the mortalities. It appears that there has been complete recovery, but this is not the true situation. Almost all of the recovery is attributable to significant increases in *Ircinia* sp.(Figure 5), *Ircinia strobilina* (Figure 17) and *Spheciospongia vesparia* (loggerhead sponge; Figure 7). The increase in *Ircinia* sp. and *Ircinia strobilina* abundance is striking. Both species have exhibited an approximately three-fold increase in abundance compared to their abundance prior to the mortalities. Loggerhead sponge (accounting for 59% of the sponge community biomass prior to the mortalities) has shown consistent increases since 1999 and current abundance is essentially the same as found prior to the mortalities. However, complete recovery of loggerhead sponge biomass cannot be claimed. Loggerhead sponge size is highly significantly smaller than found prior to the mortalities.

There is evidence of some recruitment of sheepswool (*Hippospongia lachne*) and glove sponge (*Spongia graminea*), but there has not been a significant, consistent trend in recent years (Figure 18). Future data will be needed to document their recovery to the abundance found before the mortalities.

A consistent pattern seen at Marathon and throughout all the study areas is no evidence of any recovery of the vase sponge (*Ircinia campana*).

Miscellaneous Sponge Category

Although there was no evidence of significant recruitment through 1999, data from recent years (2000-2002) indicates that the abundance of sponges lumped into this Miscellaneous Sponge category has increased significantly and is indistinguishable from the abundance observed prior to the mortalities (Figure 16). The increases seen in recent years is attributable to *Halichondria melanadocia, Niphates erecta, Cinachyra* sp., *Adocia* sp. and *Hyrtios* sp. However, as will be discussed in a following section, these species can both decrease and increase in abundance on a short-term basis, and all of these species were not simultaneously increasing in abundance from 2000 to 2002.

Arsnicker Keys South (ENP)

The limitations in interpreting the data from this site were noted previously. The abundance observed at Arsnicker Keys South was similar to the abundance found at Long Key (Figure 19). The slightly higher abundance found at Arsnicker Keys South compared to Long Key is primarily attributable to higher abundances of *Ircinia* sp. (Figure 5).

Although data prior to the mortalities were not available, due to the complete elimination of the Identified Category of sponges at the other sampling sites, it seems reasonable to assume that these sponges were also eliminated here. If this assumption is correct, then there has been significant recruitment of *Ircinia* sp. (Figure 5), stinker sponge (*Ircinia strobilina*, Figure 17), and yellow sponge (*Spongia barbara*, Figure 6). Similarly to the pattern seen at Long Key, there does not appear to be significant recruitment of loggerhead sponge (*Spheciospongia vesparia*; Figure 7). No sheepswool sponge were found in the transects.

Sponges for Which Data Collection Began After the Mortalities

Since 1994, the number of species for which abundance data has been collected, has increased from 7 to 27. It is now possible to evaluate changes in abundance of sponge species representing approximately 95% of the species found at the study areas. However, it is not possible to document the effects of the sponge mortalities on each of these species since specific data prior to the mortalities were not collected. For many species that occur at low abundances, either no significant changes in abundance can be detected or there are simply no changes. However, as more data is collected trends for several species are becoming apparent.

It is now possible to identify certain sponge species that undergo fairly rapid (one to two year time frame) significant changes in abundance. These sponge populations may be highly variable in time and space as there are examples of a species decreasing at one sampling location while abundance

was increasing in another sampling area. A comparison of ranked sponge abundance at each sampling area (prior contract reports) over the years shows that significant changes in the rank of several of the most abundance sponges can occur from year to year. Sponge species that have shown significant annual fluctuations in abundance include: *Halichondria melanadocia, Cinachyra* sp., *Adocia* sp., *Hyrtios* sp. *Niphates erecta* and *Haliclona molitba.* A different pattern was seen for *Anthosigmella varians*: consistent and gradual increases in abundance at both Long Key and Marathon.

Halichondria melanadocia: The 2002 data further confirm that this species is capable of significant increases and decreases in abundance on an annual basis (Figure 8). Significant changes have occurred at both Marathon and Long Key. At times abundance can be increasing at one site while decreasing at the other site. Weidemayer 1977 (Shallow Water Sponges of the Western Bahamas) considered *H. melanadocia* to be a n opportunistic species. These data confirm this hypothesis.

***Cinachyra* sp:** *Cinachyra* sp is always found attached firmly to a hard substrate. The 2002 data confirm significant abundance decreases and increases in the data from all sampling areas (Figure 9). Obviously, *Cinachyra* sp. abundance can significantly fluctuate on an annual basis and it can be a rapid colonizer. Personal observations of Dr. Pedro Alcolado (Ministry of Fisheries, Cuba) appear to concur with these data. In Dr. Alcolado's opinion, *Cinachyra* sp. is a prolific colonizer, but with high juvenile mortality as they are only abundance when small sized.

Past contract reports have speculated that *Cinachyra* was resistant to the sponge mortalities, due in large part to its high abundance in post mortality surveys. We still consider this true because its abundance remained high in both 1994 and 1995 at Long Key, even though continued mortalities were seen in the area during 1994. However, it is also a rapid colonizer and its high abundance after the sponge mortalities may also be attributable to its ability to rapidly colonize.

Anthosigmella varians: A consistent highly significant abundance increase at both Long Key and Marathon was confirmed by the 2002 data. Contrary to most of the other sponge species lumped into the Miscellaneous Category, *A. varians* appears to be a long-lived species that has been consistently increasing in abundance without significant short-term declines. We recall *A. varians* as abundant before the mortality, but we lack specific data.

Spongia barbara dura (hard head sponge): There are no reported commercial landings of this species, and it was not considered a commercial species when the study started in 1991. There has been significant recruitment at both Long Key Marathon. Abundance has remained very consistent for the past five years.

***Adocia* sp:** The species is a tube forming sponge with a fairly consistent "lavender" color. It grows attached to hard substrate but can also be frequently found unattached among seagrasses. It appears to be an opportunistic species, exhibiting dramatic abundance increases and decreases on

what can be an annual basis (Figure 12). At one time (2000) it was the most abundant species at Marathon. The 2002 data confirm a highly significant decline since 2000.

***Hyrtios* sp:** In general, this species has declined in abundance since 1995 (Figure 13). *Hyrtios* sp. is now less abundant then it was immediately (1-2 years) after the sponge mortalities. It is not known whether the abundance found in 1995 reflected rapid colonization during post mortality conditions. The significant increase seen in 2000 at Marathon confirms that it can widely fluctuate in abundance on a short-term basis.

Haliclona molitba: In general, this species has declined in abundance since 1995 (Figure 14). Although present at the Long Key area in 1995, it is now only infrequently found. Over the years, abundance has both declined and increased at Marathon. These data suggests it is an opportunistic species, capable of exhibiting large population fluctuations on an annual basis.

Niphates erecta: Over the years *N. erecta* has been one of the most commonly occurring species at all three sampling areas. During the past seven years there have been significant decreases and increases at both Long Key and Marathon (Figure 15). Niphates erecta appears to be a short- lived species that can widely fluctuate in abundance. It appears to be a fairly ubiquitous sponge species (it can also be observed in coral reef habitats).

Table 1. Sampling Sites for 2002 Sponge Survey (7/11/02 – 7/19/02).

Area	Station	Garmin 12 - DGPS Decimal Minutes
Long Key	LK1	24°51.232 80°48.801
Long Key	LK2	24°51.240 80°48.793
Long Key	LK3	24°51.212 80°48.816
Marathon	Mar1	24°46.485 81°03.779
Marathon	Mar2	24°46.476 81°03.753
Marathon	Mar3	24°46.476 81°03.739
Arsnicker Keys South (ENP)	Arsnicker1	24°53.863 80°49.063
Arsnicker Keys South (ENP)	Arsnicker2	24°53.876 80°49.012
Arsnicker Keys South (ENP)	Arsnicker3	24°53.858 80°49.120

Note: Sponge harvesters were observed producing sheepswool sponge (*Hippospongia lachne)* at 24°50.015/80°56.913 (7/14/02) and 24°49.605/80°56.505 (7/15/02).

Table 2. Sponge taxa reported during 2002 sponge survey, all sampling areas (Long Key, Marathon, Everglades National Park).

Aaptos sp.
Adocia sp..
Amphimedon erina
Anthosignella varians
Aplysina sp.
Biemna sp.
Callyspongia vaginalis
Chondrilla nucula
Cinachyra sp.
Clathriidae
Dysidea ethera
Geodia gibberosa
Haliclona molitba
Halichondria melonadocia
Hippospongia lachne
Hytrios sp.
Ircinia sp.
Ircinia campana
Ircinia strobilina
Lissodendoryx sp
Niphates erecta
Pseudaxinella lunaecharte
Spheciospongia vesparia
Spongia barbara
Spongia barbara dura
Spongia graminea
Stelleta kalitetilla
Tedania ignis
Tethya crypta

Table 3. Ranked abundance of sponges identified in 2002, Long Key.

Sponge Species	Mean Number of Sponges/Transect ($200m^2$)	Standard Deviation/Transect	Total Number of Sponges Found in Twelve Transects ($2,400m^2$)
Niphates erecta	14.42	6.79	173
Cinachyra sp.	8.50	6.16	102
Ircinia sp.	7.50	2.81	90
Anthosignella varians	5.25	3.49	63
Tethya crypta	5.08	4.52	61
Haliclona molitiba	3.67	2.02	44
Biemna sp.	3.58	4.32	43
Halichondria melonadocia	2.67	2.10	32
Tedania ignis	1.50	3.15	18
Spheciospongia vesparia	1.25	1.14	15
Adocia sp.	1.17	1.11	14
Spongia barbara dura	1.00	.95	12
Spongia barbara	1.00	1.04	12
Lissodendoryx	0.92	1.31	11
Aplysina sp.	0.67	0.98	8
Ircinia campana	0.17	0.39	2
Ircinia strobilina	0.17	0.29	2
Hippospongia lachne	0.08	0.29	1
Hytrios sp.	0.08	0.29	1
Chondrilla nucula	Present	Present	Present

Note: Species observed off of transect or included in miscellaneous category: *Aaptos* sp., *Geodia gibberosa, Dysidea ethera, Stelleta kalitetilla.*

Table 4. Ranked abundance of sponges identified in 2002, Marathon.

Sponge Species	Mean Number of Sponges/Transect ($200m^2$)	Standard Deviation/Transect	Total Number of Sponges Found in Twelve Transects ($2,400m^2$)
Cinachyra sp.	29.08	17.67	349
Niphates erecta	25.42	7.73	305
Halichondria melanadocia	23.92	11.33	287
Lissodendoryx	23.92	7.38	287
Adocia sp.	23.33	4.94	280
Ircinia sp.	21.58	7.14	259
Anthosigmella varians	16.27	5.64	194
Ircinia strobilina	11.83	4.45	142
Hyrtios sp.	9.17	5.69	110
Spheciospongia vesparia	6.08	3.34	73
Spongia barbara dura	2.42	1.83	29
Tethya crypta	2.25	1.96	27
Aplysina	2.17	0.94	26
Haliclona molitiba	1.33	1.07	16
Spongia graminea	0.75	0.75	9
Callyspongia vaginalis	0.67	0.78	8
Biemina	0.50	1.00	6
Hippospongia lachne	0.17	0.39	2
Ircinia campana	0.08	0.29	1
Tedania ignis	0.08	0.29	1
Chondrilla nucula	Present	Present	Present

Note: Species observed off of transect or included in miscellaneous category: *Geodia gibberosa, Aaptos* sp., *Dysidea ethera, Amphimedon erina, Pseudaxinella lunaecharte,* Clathriidae.

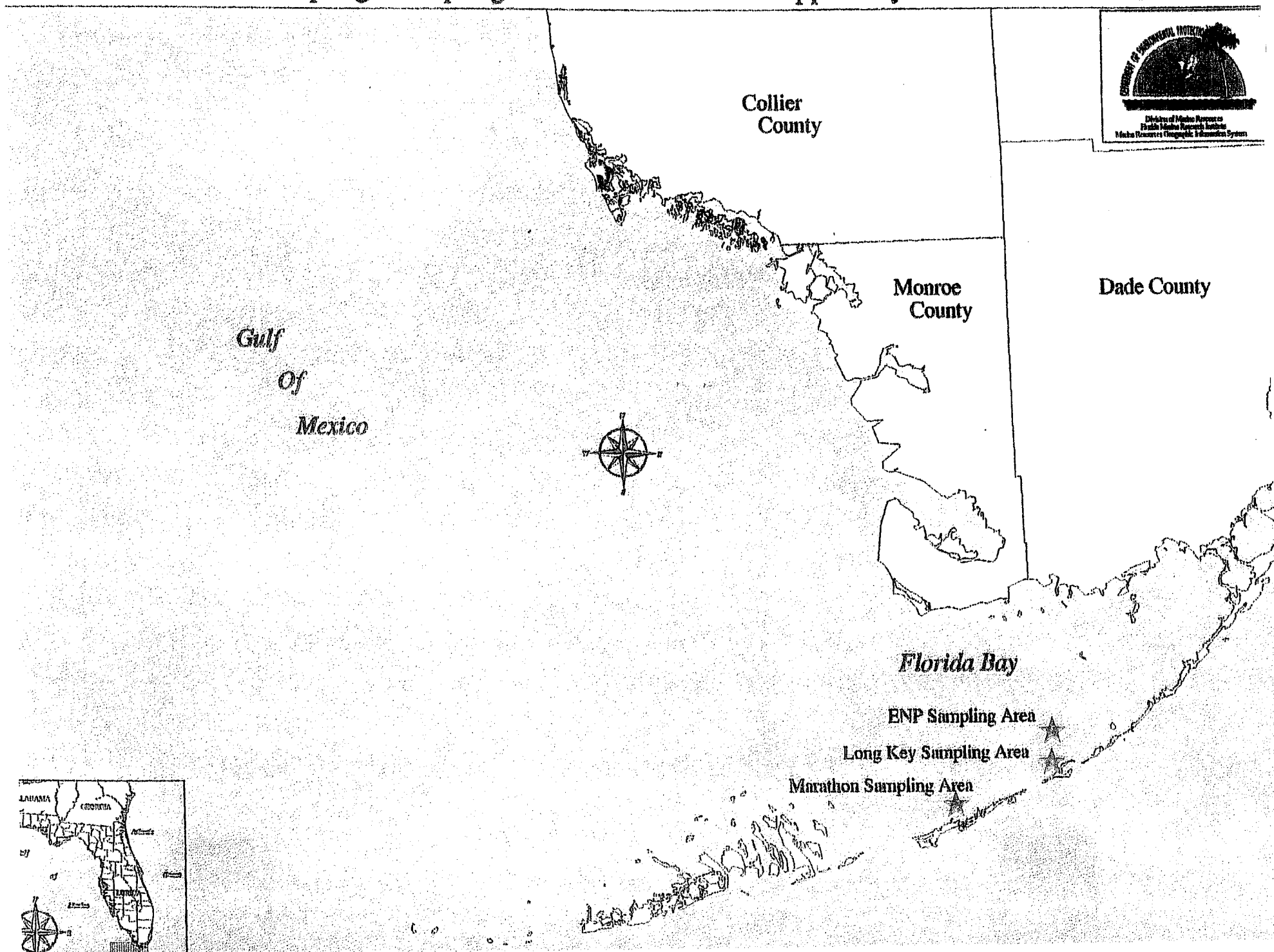
Table 5. Ranked abundance of sponges identified in 2002, Arsnicker South (ENP).

Sponge Species	Mean Number of Sponges/Transect (200m^2)	Standard Deviation/Transect	Total Number of Sponges Found in Twelve Transects (2,400m^2)
Halachondria melonadocia	13.83	6.12	166
Tedania ignis	9.5	4.48	114
Ircinia sp.	9.33	4.19	112
Cinachyra sp.	6.50	5.40	78
Ircinia strobilina	2.42	1.83	29
Niphates erecta	1.92	1.24	23
Haliclona molitiba	1.83	2.21	22
Biemna	1.67	2.06	20
Spongia vesparia	1.17	1.34	14
Spongia barbara dura	0.83	1.03	10
Spongia barbara	0.42	0.51	5
Adocia sp.	0.08	0.29	1
Chondrilla nucula	Present	Present	Present

Note: Species observed off of transect or included in miscellaneous category: *Aaptos* sp., *Geodia gibberosa*, *Dysidea ethera*, *Hyrtios*, *Stelleta kalitetilla*, *Hippospongia lachne*.

Sponge Sampling Areas In Middle And Upper Keys

Figure 1

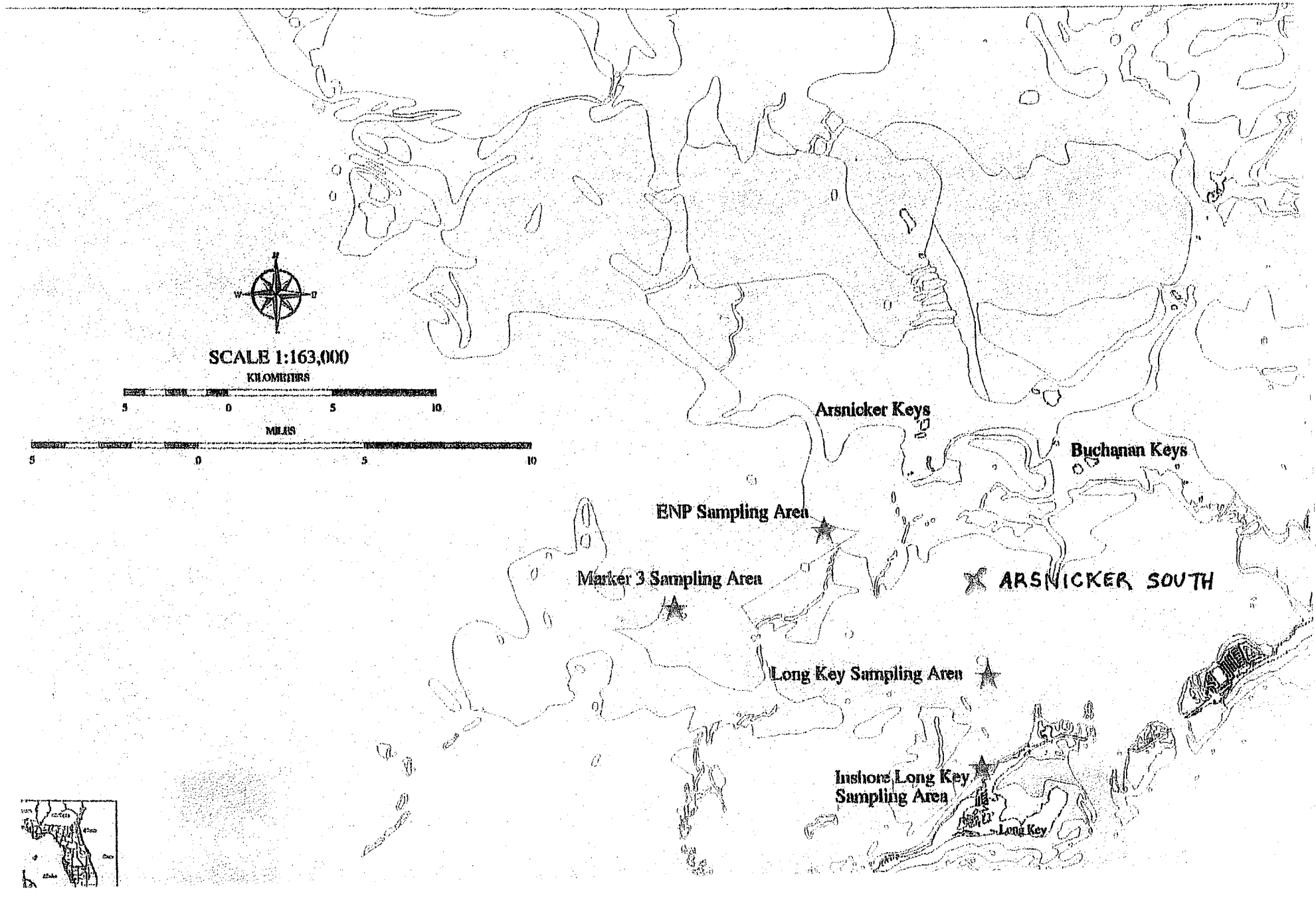


Depth Range 3

Depth Range 6

Sponge Sampling Areas Near Long Key & ENP

Figure 2



Sponge Sampling Area Near Marathon

Figure 3

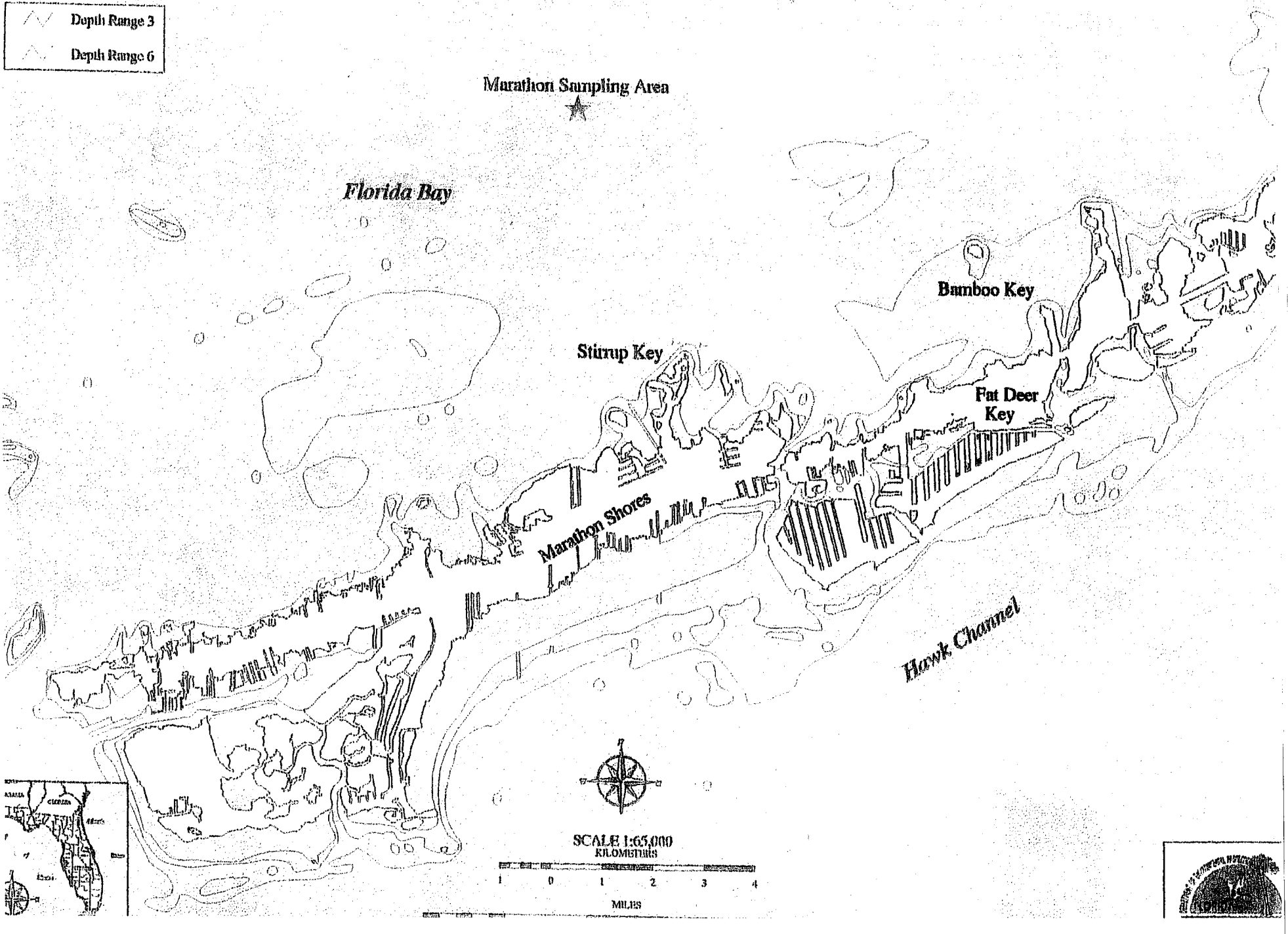


Figure 4. Long Key Sponge Abundance Miscellaneous and Identified Sponges, 1991-2002.

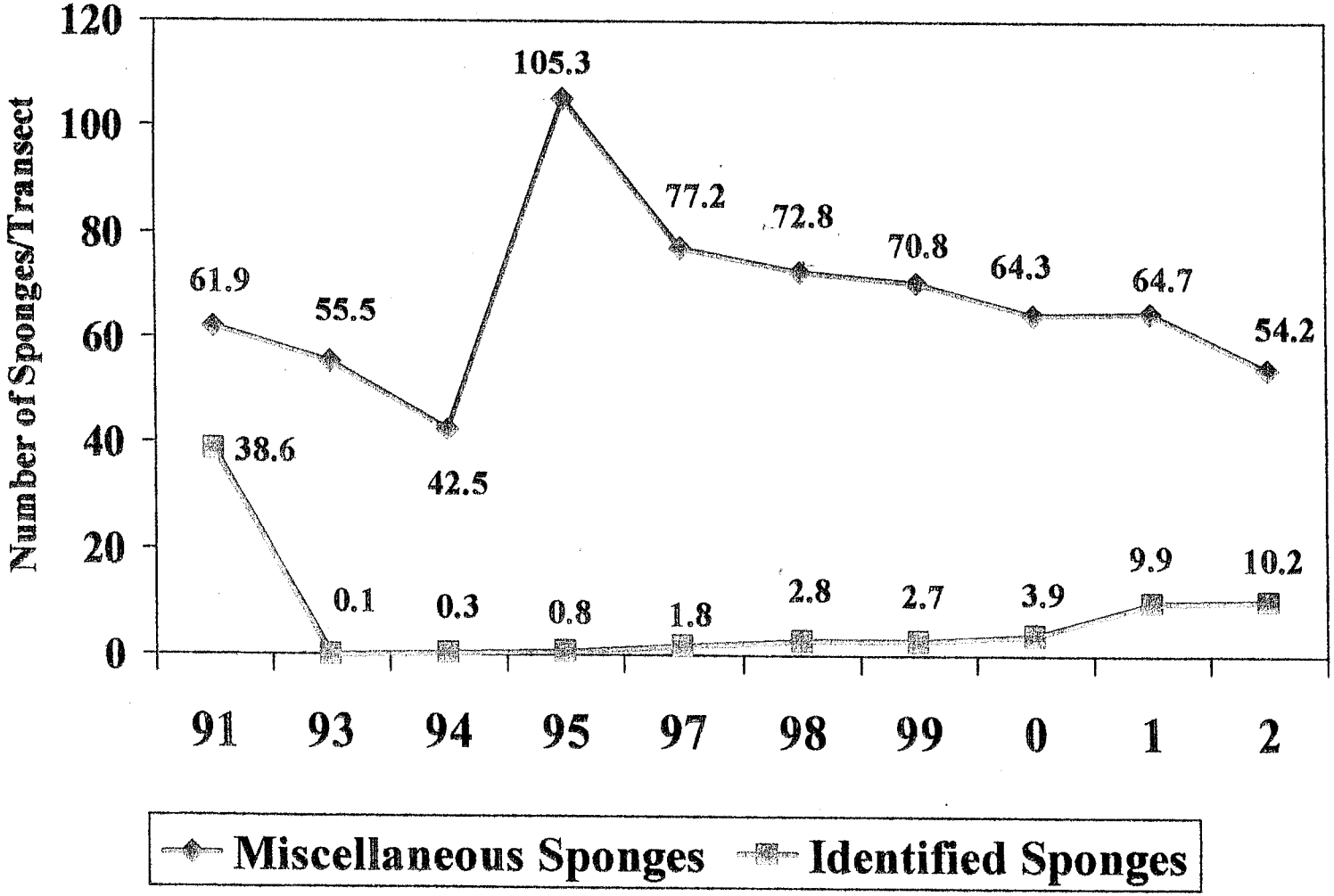


Figure 5. *Ircinia* sp. Abundance
Long Key and Marathon, 1991-2002. Arsnicker Keys, 2001-2002.

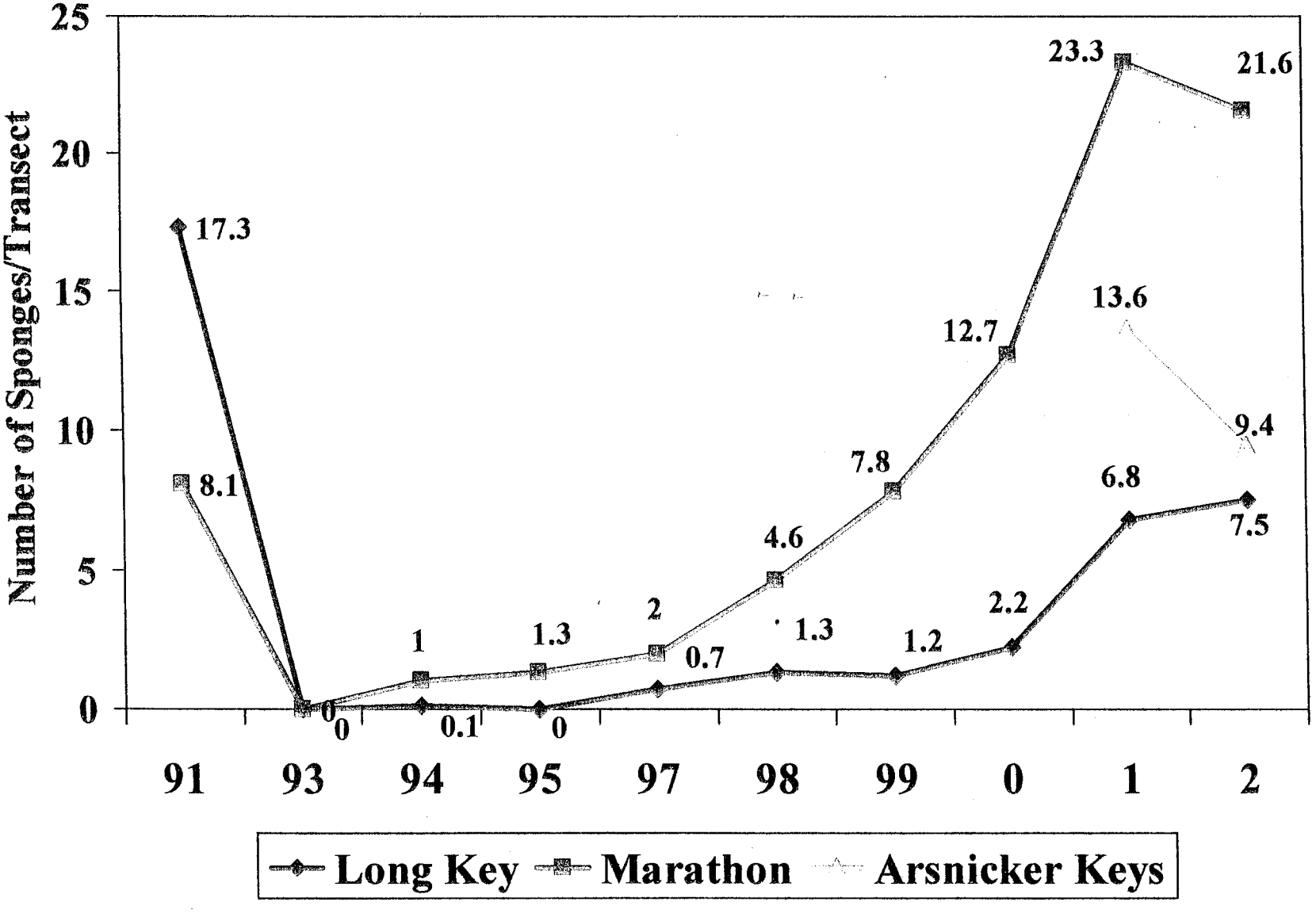


Figure 6. Abundance of Yellow Sponge, Long Key, 1991-2002. Arsnicker Keys South, 2001-2002.

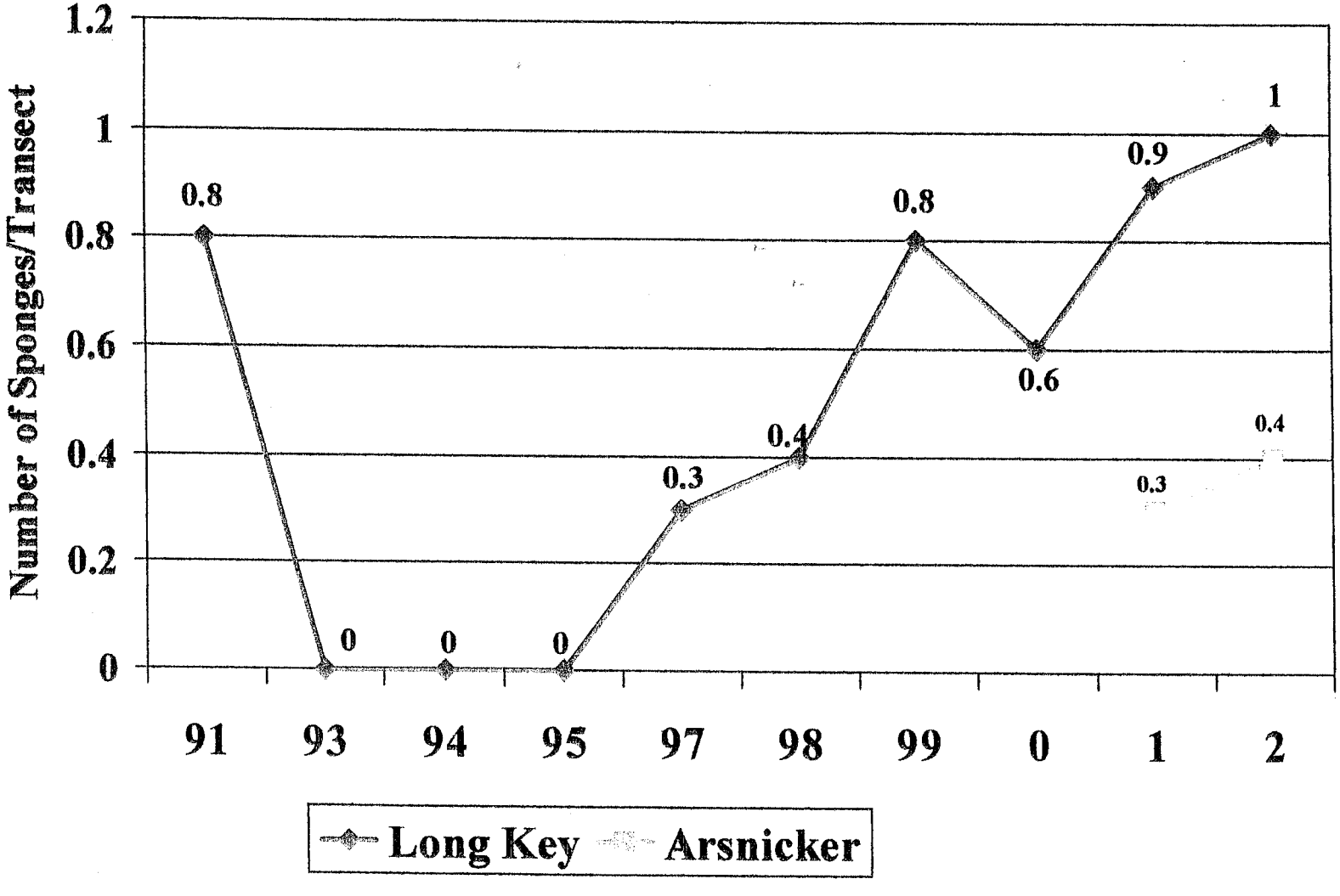


Figure 7. Loggerhead Sponge (*S. vesparia*) Abundance Long Key and Marathon, 1991-2002. Arsnicker Key, 2001-2002.

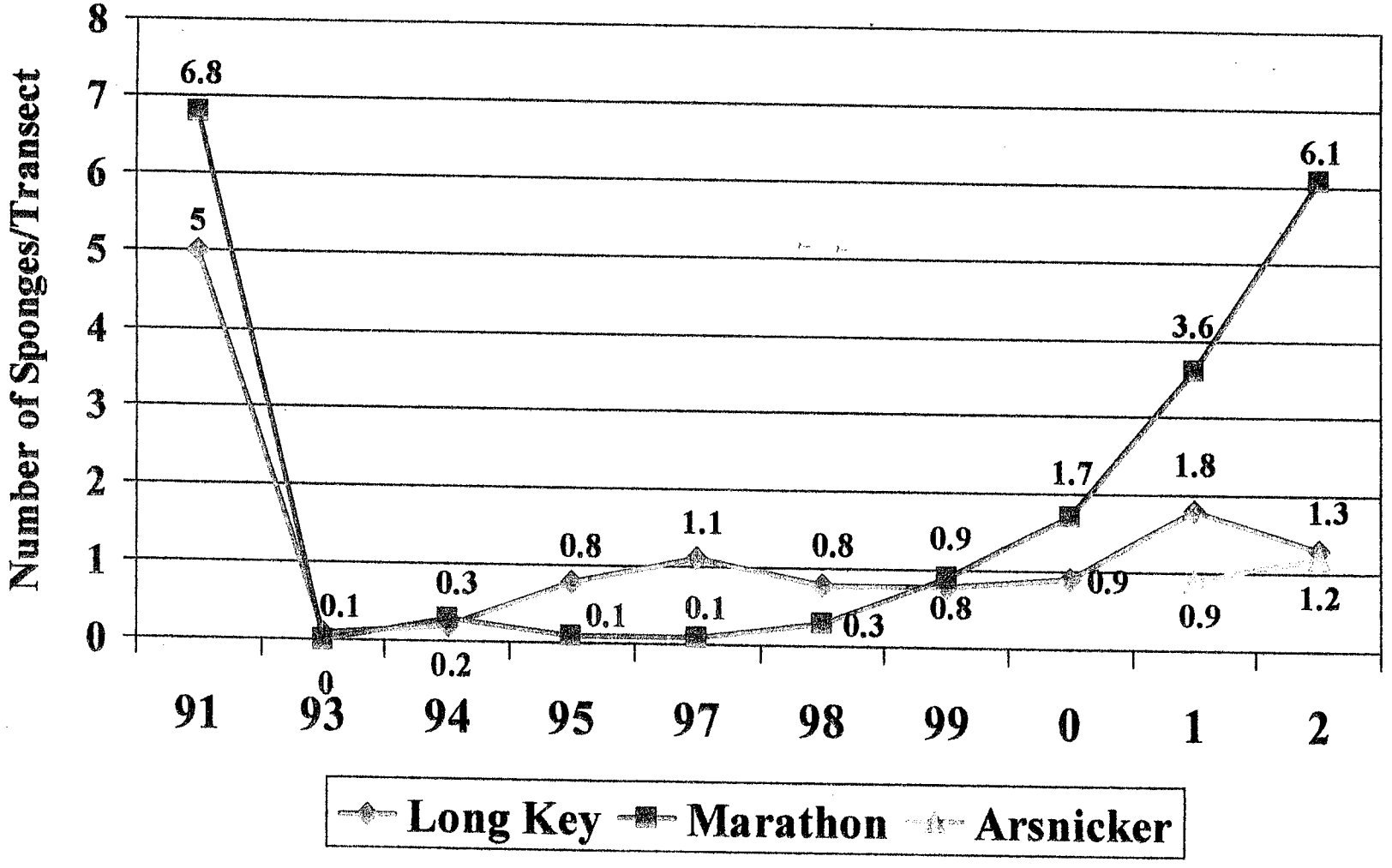


Figure 8. *Halichondria melanadocia* Abundance Long Key and Marathon, 1994-2001. Arsnicker, 2001-2002.

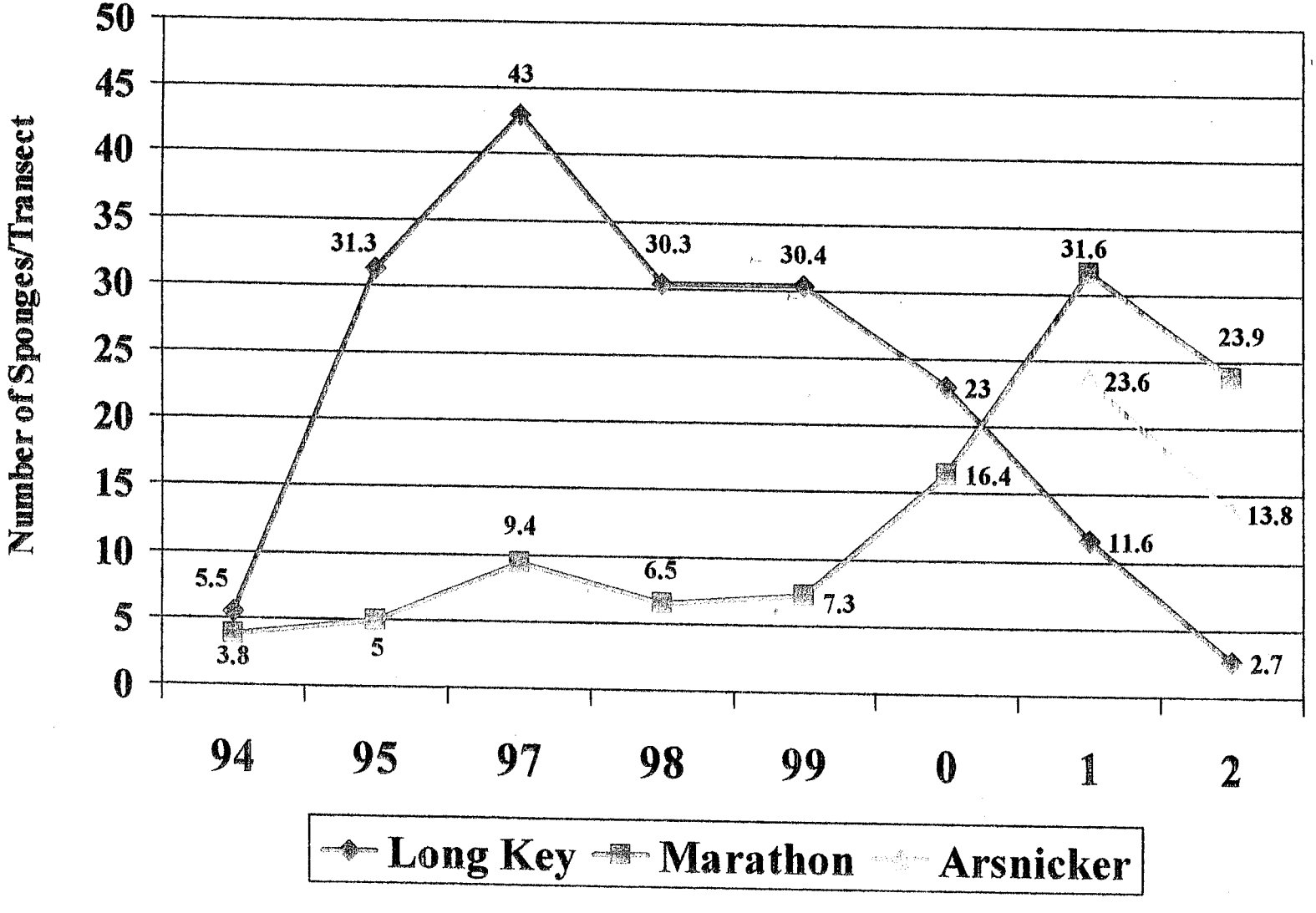


Figure 9. *Cinachyra* sp. Abundance
Long Key and Marathon, 1994-2002. Arsnicker Key, 2001-2002.

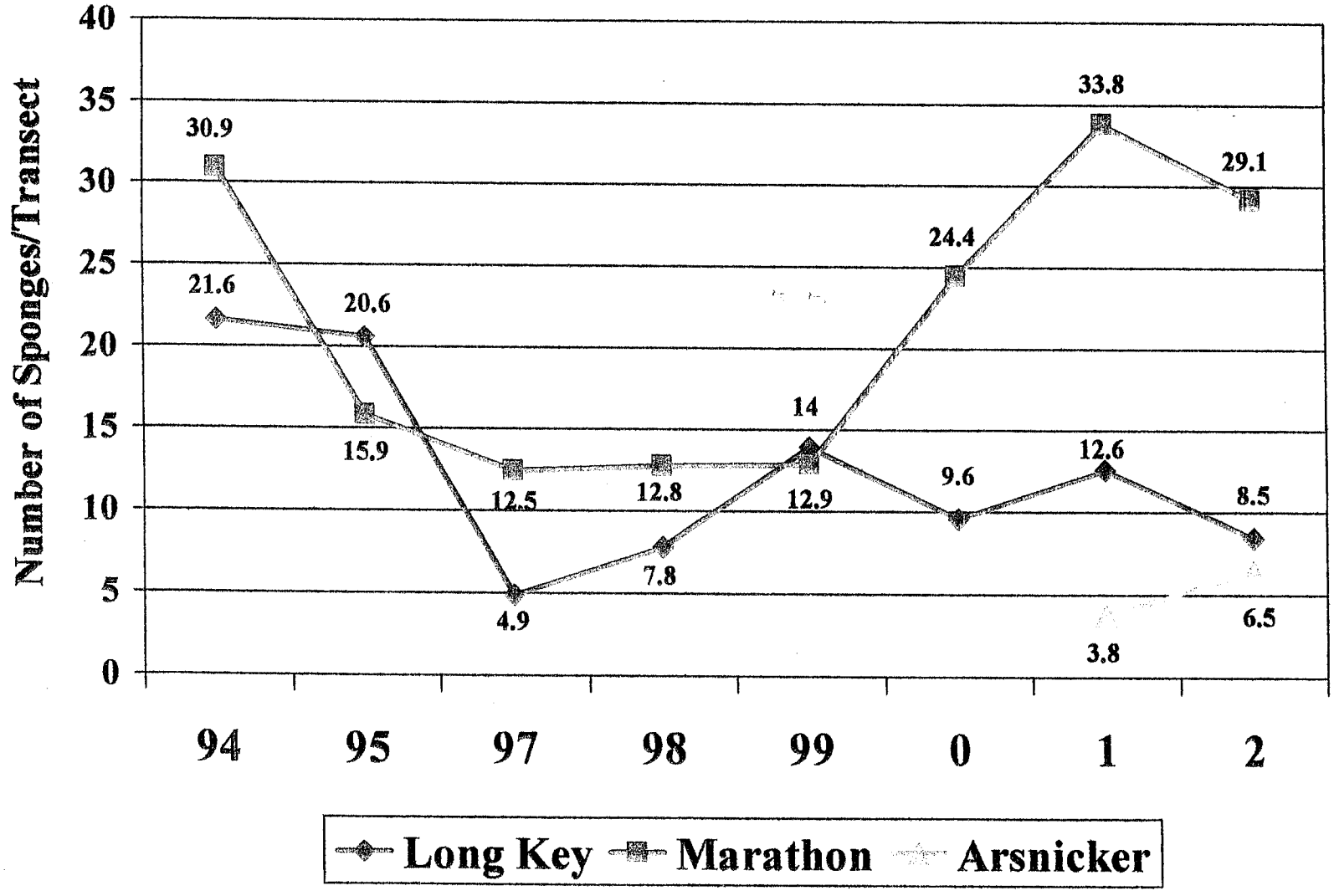


Figure 10. *Anthosigmella varians* Abundance Long Key and Marathon, 1994-2001. Arsnicker, 2000-2001.

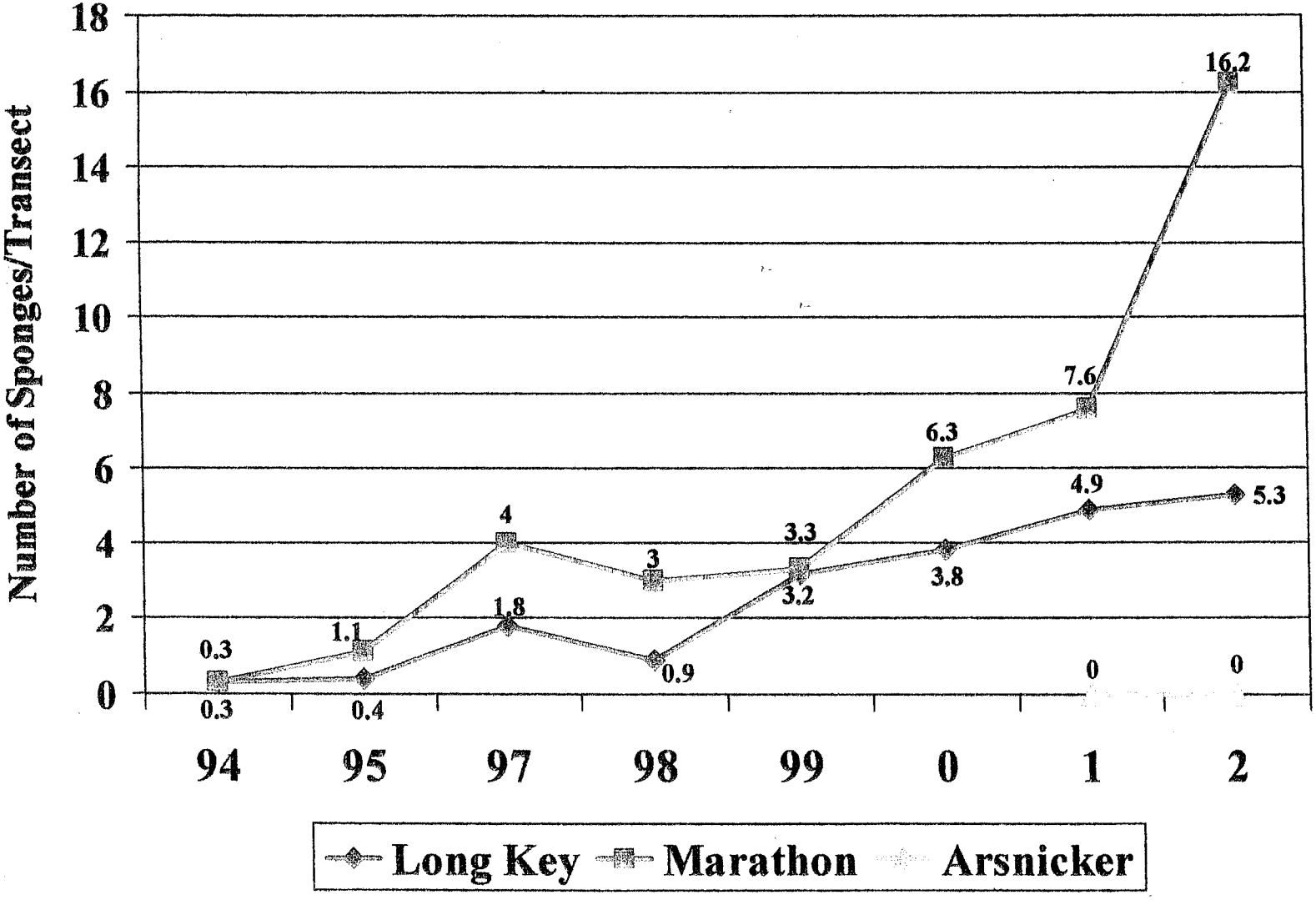


Figure 11. *Spongia barbara dura* (Hardhead) Abundance Long Key and Marathon, 1993-2001. Arsnicker Key, 2001-2002.

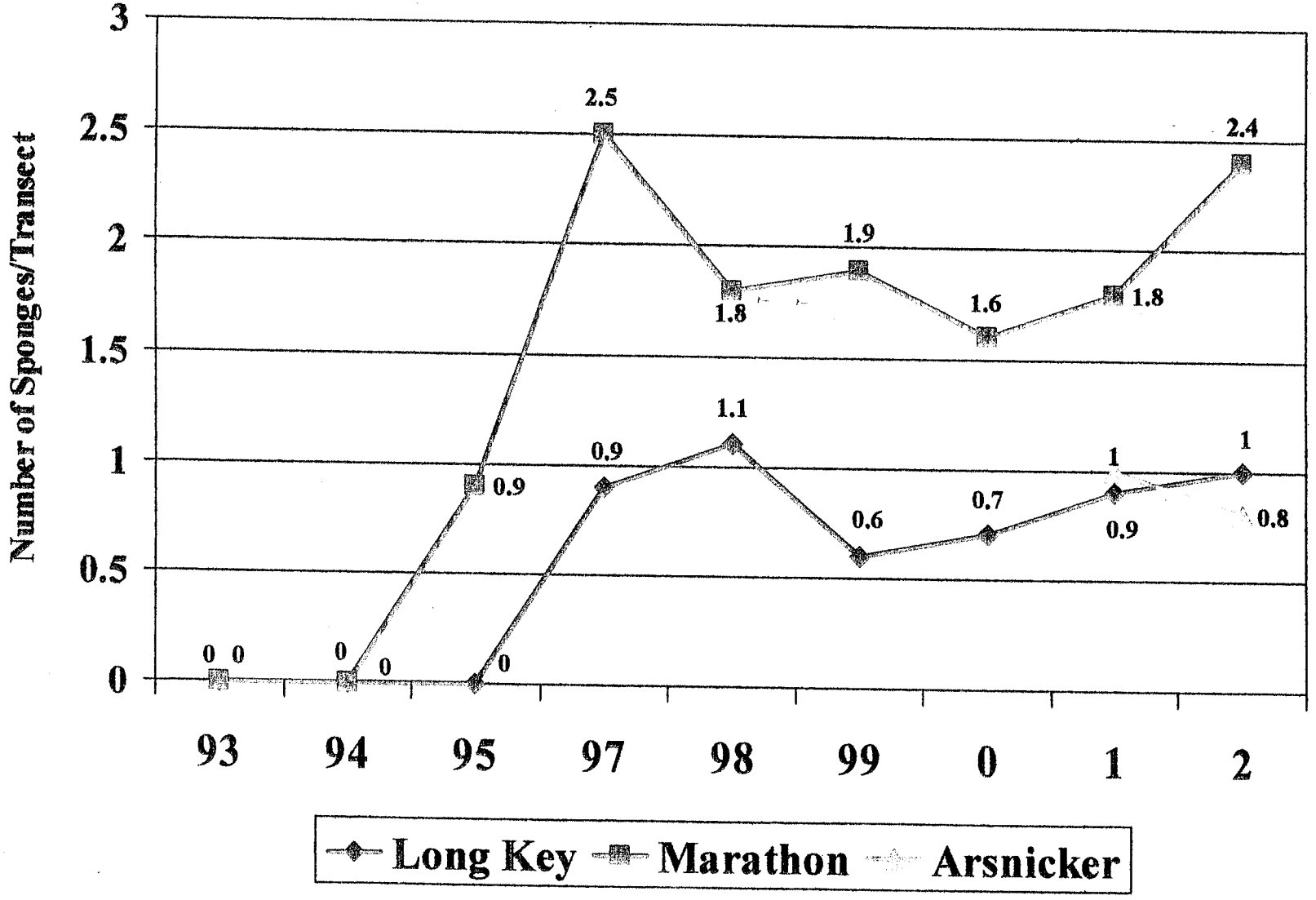


Figure 12. *Adocia* sp. Abundance
Long Key and Marathon, 1995-2001. Arsnicker Key, 2000-2001.

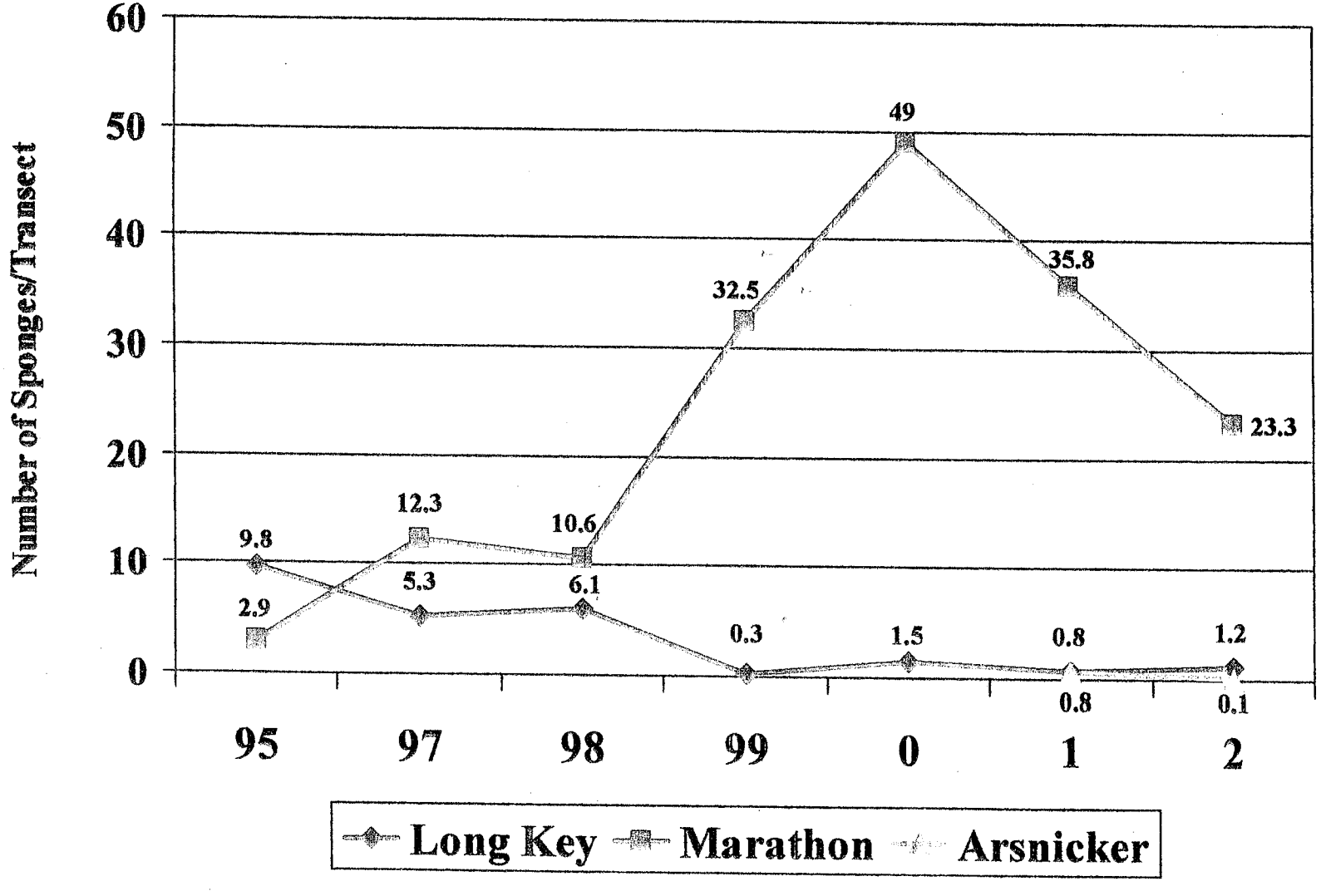


Figure 13. *Hyrtios* sp. Abundance
Long Key and Marathon, 1995-2002.

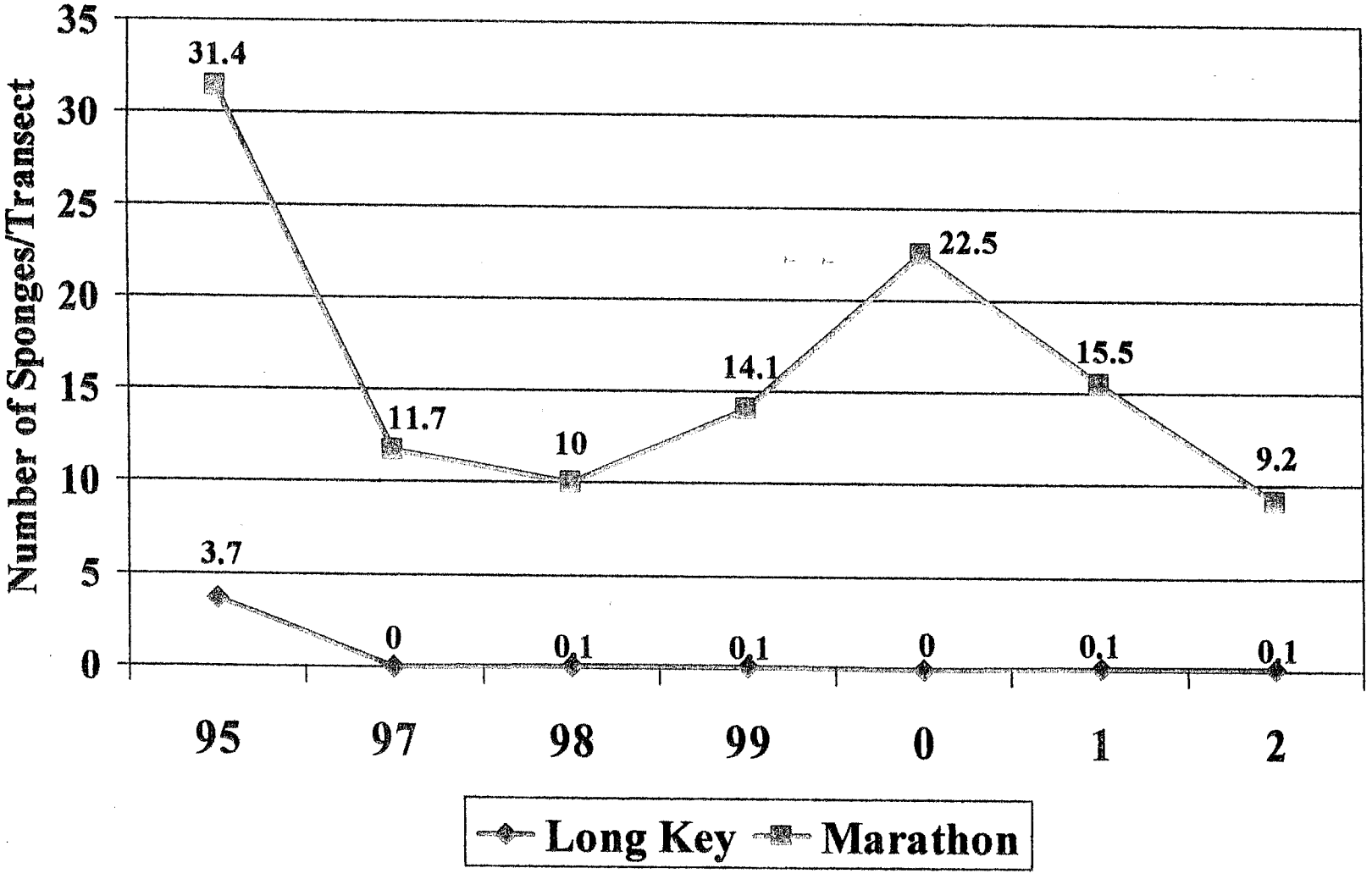


Figure 14. *Haliclona molitba* Abundance
Long Key and Marathon, 1995-2001. Arsnicker Key, 2000-2001.

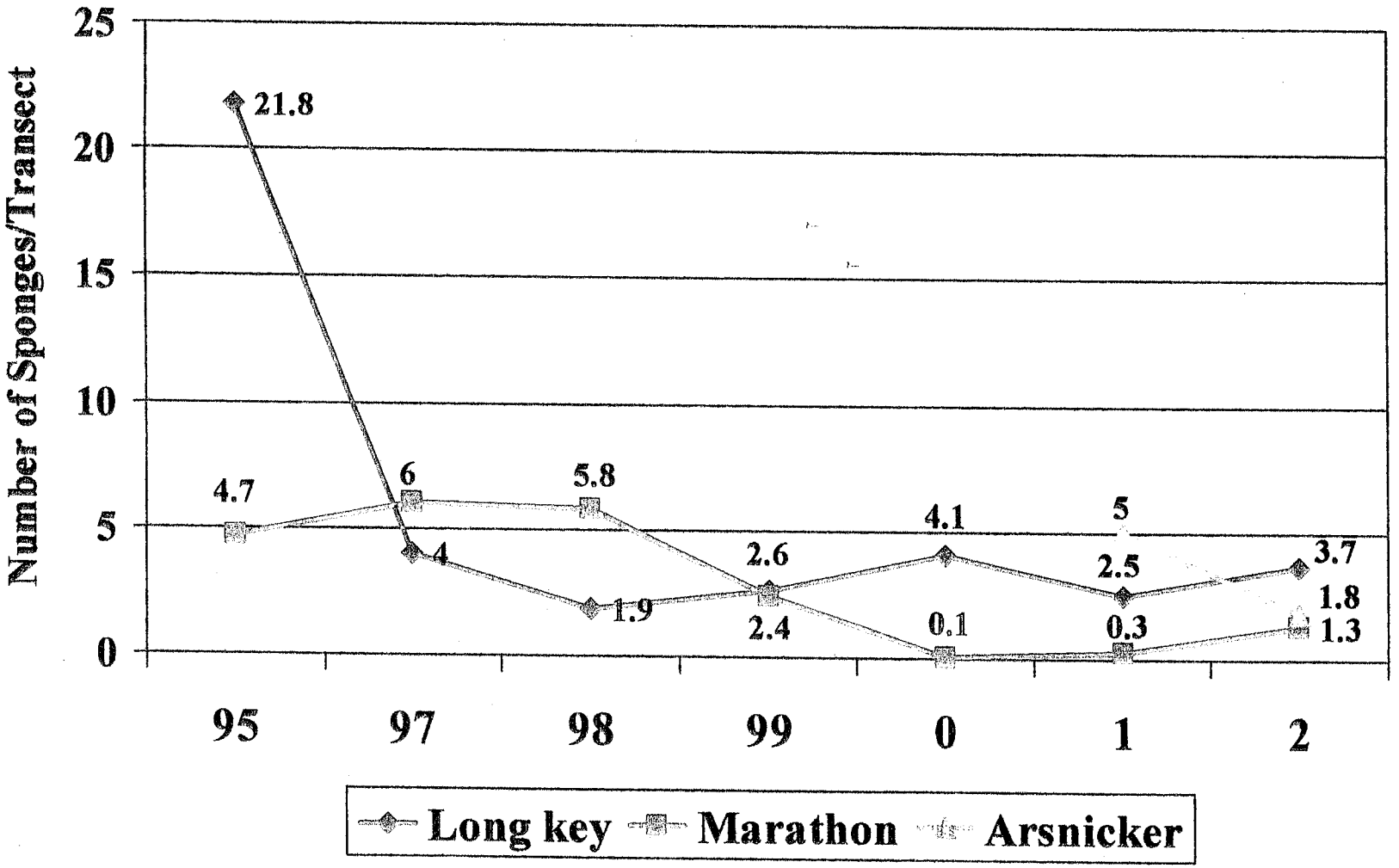


Figure 15. *Niphates erecta* Abundance
Long Key and Marathon, 1995-2002. Arsnicker Key, 2001-2002.

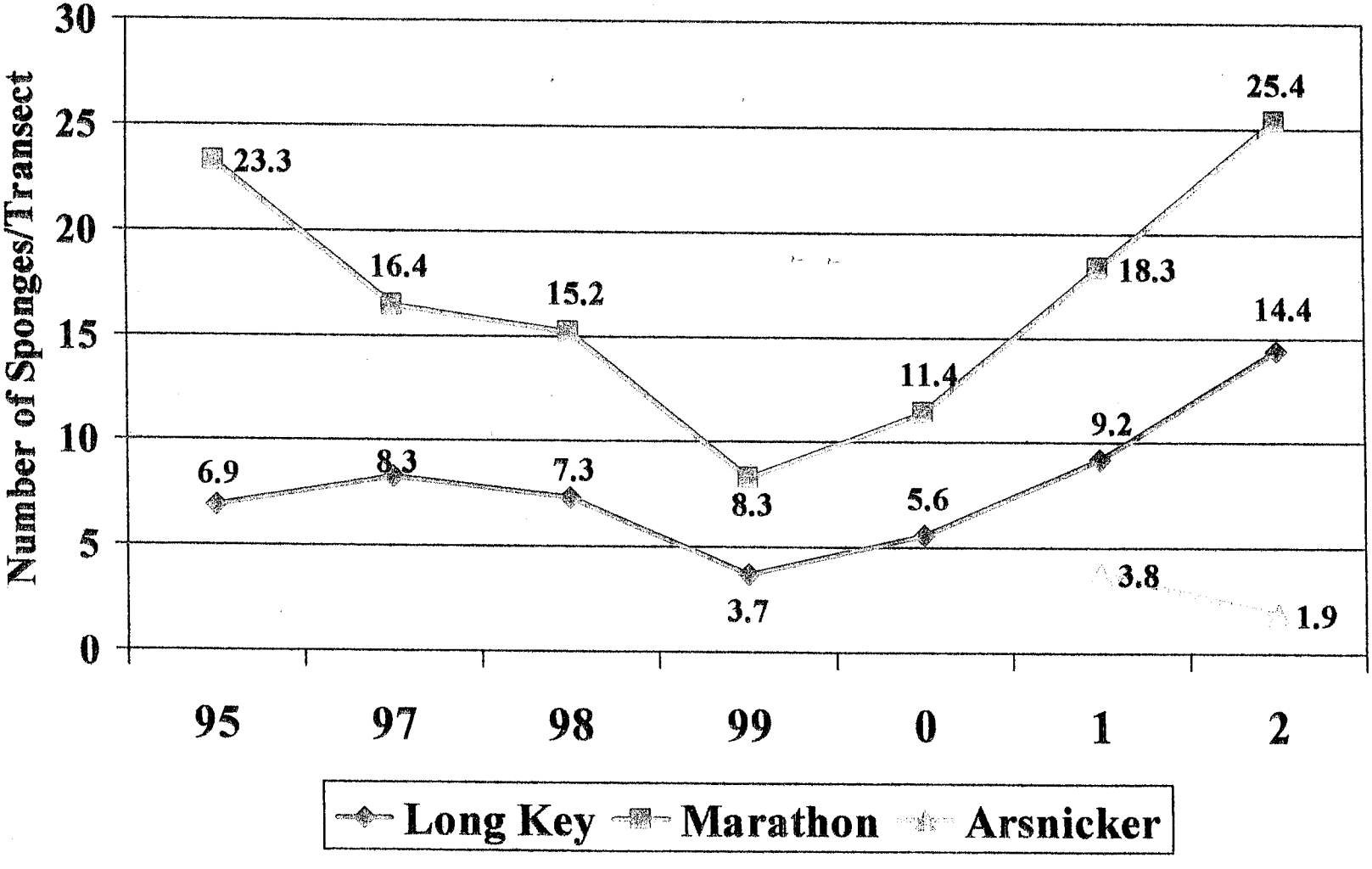


Figure 16. Marathon Sponge Abundance Misc. and Identified Sponges, 1991-2002.

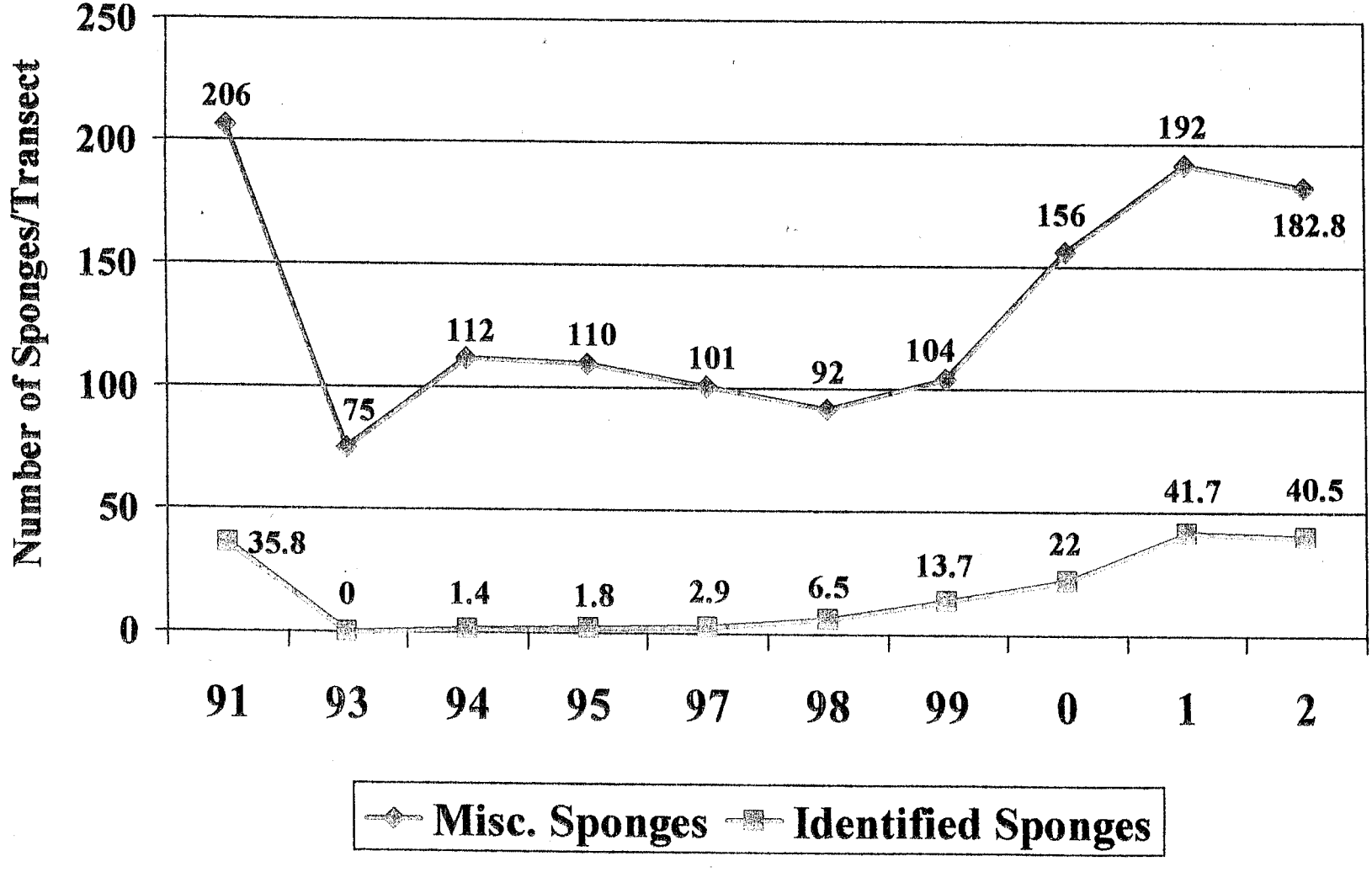


Figure 17. *Ircinia strobilina* (Stinker Sponge) Abundance Long Key and Marathon, 1991-2002. Arsnicker Key, 2001-2002.

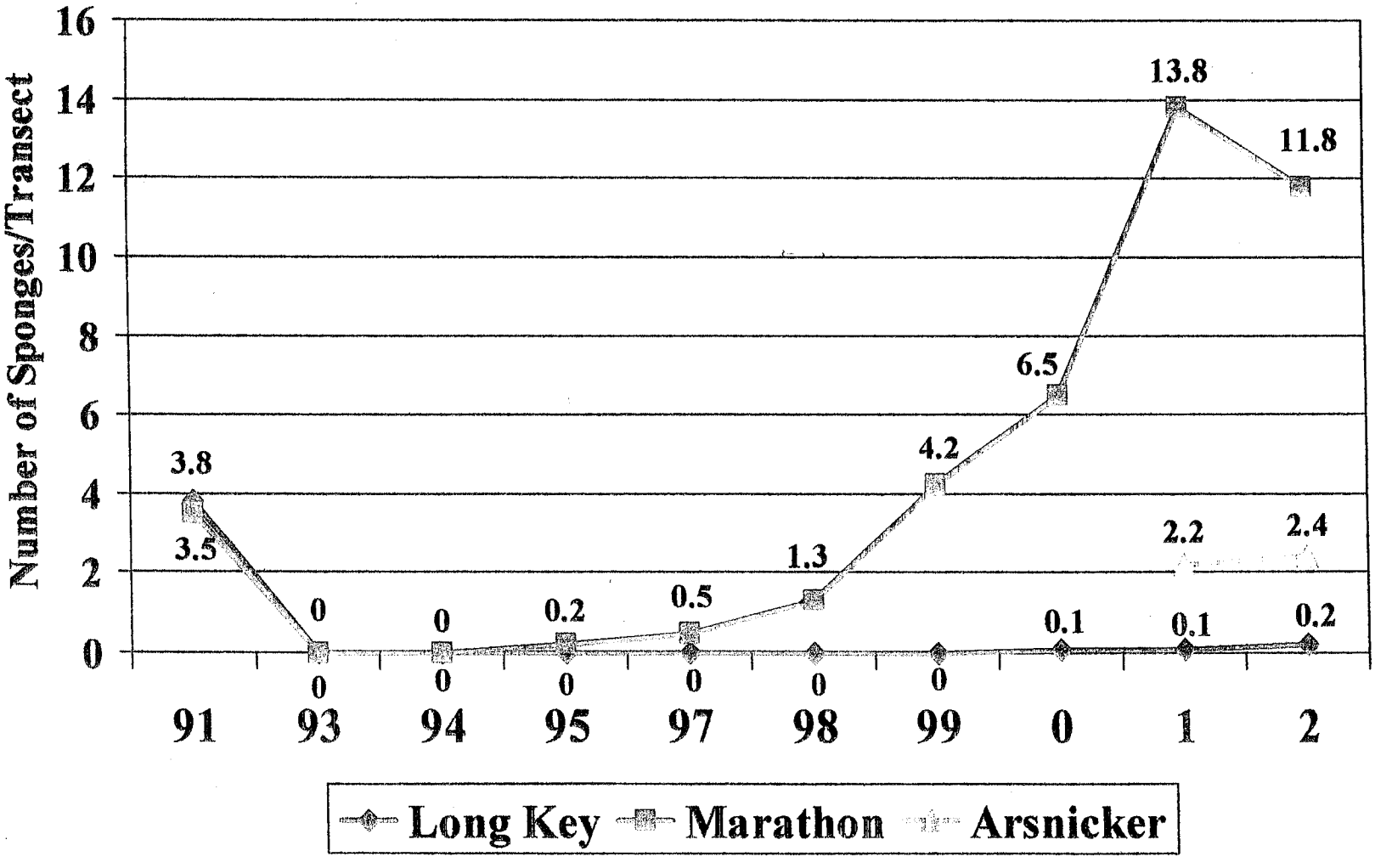


Figure 18. Sheepswool Sponge and Glove Sponge Abundance Marathon, 1991-2002.

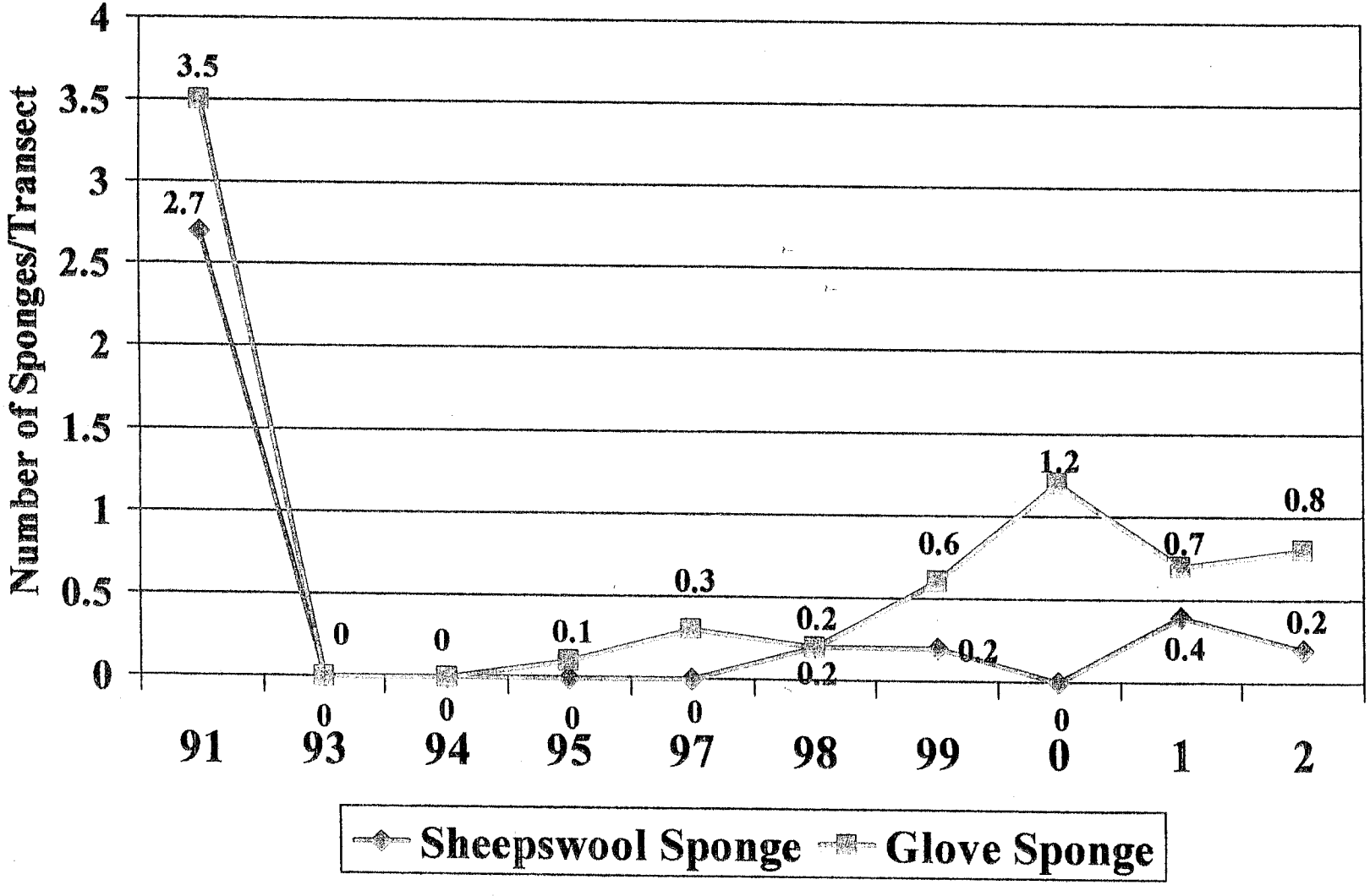


Figure 19. Identified Sponge Abundance Long key and Arsnicker Keys South, 2001-2002.