South Pacific Studies Vol.38, No.1, 2017

Seasonal Abundance of Sphaeromatidae (Crustacea: Isopoda) from Sandy Beaches in Okinawa-jima Island, Japan

MOTTAGHI Arezoo [1*], SHIMOMURA Michitaka [2], REIMER James Davis [1,3]

1: Graduate School of Engineering and Science, University of the Ryukyus, 1 Senbaru, Nishihara, Okinawa 903-0213, Japan
2: Department of Natural History, Kitakyushu Museum of Natural History and Human History, 2-4-1 Higashida, Yahatahigashi-ku, Kitakyushu 805-0071, Japan
3: Tropical Biosphere Research Center, University of the Ryukyus, 1 Senbaru, Nishihara, Okinawa 903-0213, Japan
** Corresponding author*
E-mail: arezoomottaghi@yahoo.com

Abstract

Isopods are an important part of the marine food web and of many ecosystems, but often their ecology is poorly studied. In this study, isopods were collected at six sandy beaches around subtropical Okinawa-jima Island between May 2015 and February 2016, spanning four seasons. Seasonal patterns of isopods were revealed via comparison of the numbers of Sphaeromatidae (Crustacea: Isopoda) collected each season. The highest and lowest numbers of Sphaeromatidae were observed in spring 2015 and winter 2016, respectively. These results are very similar to studies in other regions that have also seen isopod numbers peak in spring. In general, these results are important when comparing environmental assessments across different seasons, particularly as isopods and other small crustaceans are often used as bioindicators in environmental assessments.
Key words: ecology, Okinawa, reproduction, seasonal variation, Sphaeromatidae

Introduction

Isopoda belongs to the crustacean superorder Peracarida, and their larvae brood in a marsupium. Isopod crustaceans are identifiable by the presence of one pair of uropods that are attached to the pleotelson, and pereopods with only one branch. Isopods are present in a wide variety of both marine and terrestrial habitats, and it is estimated that there are greater than 10,300 formally described species (POORE and BRUCE 2012). Isopods species may have one or more feeding patterns (including predators, scavengers, detritivores, filter feeders or parasites) and through their recycling and decomposition abilities, isopods play an important role in the food web (WARBURG 1987).

Received: 20 December, 2016
Accepted: 28 November 2017

As stated by Poore and Bruce (2012) more than 60% of isopods are aquatic (marine or estuarine). Within Isopoda, family Sphaeromatidae's members have a dorsoventrally or almost completely flattened body. Additionally, ornamentation and sexual dimorphism is common in this family. Most species of Sphaeromatidae are found in depths of less than 1,000 m. However, the ecology of isopods in general and Sphaeromatidae in particular is poorly studied (Poore and Bruce 2012).

Additionally, isopods can act as potential natural bioindicators (Cortet *et al*. 1999, Paoleti and Hassal 1999, Longo *et al*. 2013). Veloso *et al*. (2011) reported that the endemic isopod *Excirolana braziliensis* (Richardson, 1912) could be used as a potential human impact bioindicator on Brazilian sandy beaches. As the main island of Okinawa-jima faces similar human impact problems as Brazil, including over-exploitation of coastal shorelines, increasing urbanization, and coastal construction, which all threaten the ecological integrity of coastal systems (Reimer *et al*. 2015, Mottaghi *et al*. 2017), using isopods as bioindicators could be a potentially prudent and wise decision, as they are often abundant and easy to collect (Poore and Bruce 2012). In this study, isopods were collected from intertidal coral rubble and sand samples at paired disturbed (n=3) and non-disturbed (n=3) sites around Okinawa-jima Island, Japan, over a period of four seasons. We counted the numbers and genera of sphaeromatid isopods from our collections and compared them to examine how the numbers and diversity of sphaeromatids changed over seasons.

Materials and Methods

Isopods in this study were collected as part of a previous study (Mottaghi *et al*. 2017) comparing infaunal crustacean diversity across locations; all raw data analyzed in this study were generated from this previous study. Six sandy beaches were investigated, two each on the west (Ginowan 1 (26°16'53.4"N, 127°43'54.5"E) and Ginowan 2 (26°17'03.6"N, 127°44'21.6"E)), south (Odo 1 (26°05'26.2"N, 127°42'31.6"E) and Odo 2 (26°05'11.2"N, 127°41'43.9"E)) and east (Azama 1 (26°10'40.5"N, 127°49'45.6"E) and Azama 2 (26°10'45.7"N, 127°49'28.9"E)) coasts of Okinawa-jima Island (Fig. 1). For the two beaches within each coastline, one was considered as disturbed, and the other as non-disturbed, as detailed in Mottaghi *et al*. (2017). At each site for

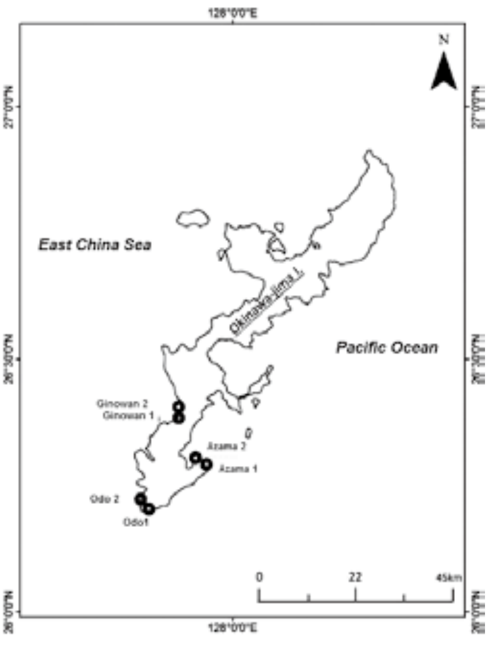

Fig 1. Map of sampling locations around Okinawa-jima Island, Japan, in this study.

each sampling, three 1 × 1 meter (=1 m^2) quadrats were placed randomly in water of depths of less than 1 meter. Environmental data (DO, pH, salinity, seawater temperature, turbidity, and conductivity) were recorded and infaunal crustacean sampling was performed from inside each quadrat as described in Mottaghi *et al*. (2017).

Surveys were conducted once per season at each site, on sunny or partly cloudy and non-rainy days at low tide (between 0.47 m and 0.78 m height) during daytime between May 2015 to February 2016 (May 2015 = spring, July 2015 = summer, November 2015 = fall and February 2016 = winter; seasons decided based on sea surface temperature changes) (Fig. 1).

Isopods were collected from sediment and coral rubble samples from each site within each beach (n=72 total sampling events; 6 sites, 3 quadrats, 4 seasons). Following the methods of White (2013), a 12-liter bucket was filled one-fourth full with sediment from each quadrat, one fourth full with seawater from the sample site and finally at each quadrat, coral rubble was added to bucket as well to be full.

Immediately after collection, approximately 10 ml of formalin was added to each bucket and after five minutes rest, the bucket's contents were thoroughly mixed and sieved through a 500 μm mesh sieve. This procedure was repeated seven times per bucket.

The sieves' contents were transferred to sampling jars containing 99.5% EtOH. The following day samples were roughly sorted and all isopods were separated from the collection, identified to the genus level, and counted (Table 1).

DO, pH, salinity, seawater temperature, turbidity, and conductivity were measured within each quadrat with a multi-parameter water quality meter (DKK-TOA, model WQC-24, Tokyo), as detailed in Mottaghi *et al*. (2017). These measurements were recorded from all six sites on the same day as each seasonal survey (Table 1).

Table 1. Sphaeromatidae isopod numbers and seawater environmental parameters of sites examined in this study around Okinawa-jima Island, Japan.

Site and season	*Holotelson* sp. 1	*Dynamenella* sp.1	*Cymodoce* sp.1	total	Seawater environmental parameter					
					pH	DO (Mg/L)	Con. (S/m)	Tur. (Mg/L)	Temp. (℃)	Sal. (PPT)
G1S	36	0	0	36	8.4	7.4	4.8	12.2	25.4	31.5
G2S	42	0	0	42	8.6	12.5	4.6	19.4	24.3	29.9
O1S	0	13	0	13	8.5	9.7	4.9	9.0	26.8	32.3
O2S	0	12	0	12	8.6	9.6	4.9	8.0	25.3	32.3
A1S	0	14	1	15	8.6	9.8	4.9	10.0	25.7	32.1
A2S	0	12	0	12	8.6	9.7	4.9	11.2	26.1	31.7
G1U	7	0	0	7	8.4	7.0	4.8	9.2	29.9	32.4
G2U	13	0	0	13	8.4	7.0	4.9	9.4	30.6	32.9
O1U	10	0	0	10	8.4	7.2	4.8	7.3	34.1	32.9
O2U	5	2	0	7	8.4	6.4	4.8	6.4	33.7	32.9
A1U	5	0	0	5	8.4	6.1	4.8	7.8	32.8	32.7
A2U	6	0	0	6	8.4	7.0	4.9	6.9	34.6	33.1
G1F	1	0	0	1	8.5	7.0	4.8	9.2	27.9	31.5
G2F	7	1	0	8	8.5	7.0	4.6	9.4	27.6	31.9
O1F	2	0	0	2	8.6	7.2	4.9	7.3	28.1	32.3
O2F	1	0	0	1	8.5	6.8	4.9	6.4	27.7	32.3
A1F	5	0	0	5	8.4	6.9	4.9	7.8	28.5	32.1
A2F	5	0	1	6	8.6	7.1	4.9	6.9	28.7	31.7
G1W	0	0	0	0	8.4	7.5	4.8	9.2	18.7	30.7
G2W	3	0	0	3	8.3	7.7	4.8	9.4	18.6	29.8
O1W	0	0	0	0	8.3	7.4	4.8	7.3	19.1	31.0
O2W	2	0	0	2	8.4	7.6	4.9	6.4	19.0	30.8
A1W	2	0	0	2	8.4	6.4	4.8	7.8	19.6	30.5
A2W	5	0	0	5	8.4	7.0	4.9	6.9	19.8	29.9

In the "Site and season" column, the first letter stands for sites (Ginowan, Odo or Azama), the second letter indicates the site number and the third letter the season (S = spring, U = summer, F = fall, W = winter). Abbreviations of seawater environmental parameters ; DO = dissolved oxygen, Con. = conductivity, Tur. = turbidity, Temp. = temperature, Sal. = salinity.

Results

Among 72 coral rubble/sand samples, three genera of sphaeromatid isopods (*Holotelson* sp. 1, n = 157; *Dynamenella* sp. 1, n= 54; *Cymodoce* sp. 1 n= 2) were collected from all sampling sites and during all four seasons. All related information is available in Table 1. Generally, numbers of sphaeromatids were highest in spring 2015 (n=130), and were much higher than numbers present in summer 2015 (n=48), fall 2015 (n=23), and winter 2016 (n=12).

In all seasons and sites the dominant genus was *Holotelson*, followed by *Dynamenella* and thereafter *Cymodoce* (Fig. 2).

Spearman rho correlations for abundance of Sphaeromatidae versus pH (r_s=0.37), DO (r_s=0.41), temperature ($r_{s=}$0.31), salinity ($r_{s=}$0.39), conductivity ($r_{s=}$0.03), and turbidity ($r_{s=}$0.39) were calculated but they were all low and not significant, and therefore the null hypothesis (no correlation between isopod numbers and environmental parameters) was accepted.

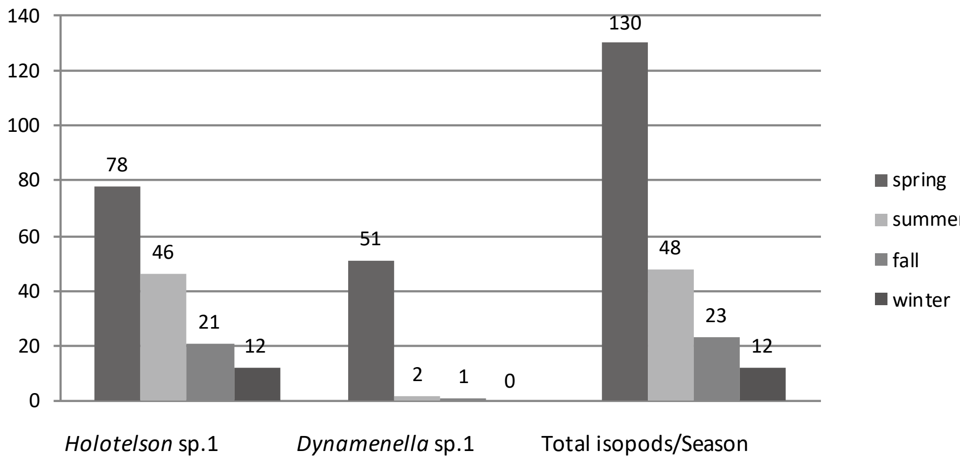

Fig 2. Seasonal variation (spring, summer, fall 2015 and winter 2016) in abundance of three genera of Sphaeromatidae isopods at six sites around Okinawa-jima Island, Japan. There were only two individuals of *Cymodoce* sp. 1 observed during the study and therefore this species was not included here.

Discussion

According to our findings, there was a clear seasonal distribution pattern with a peak in spring 2015 for sphaeromatid isopods in Okinawa. Similar to our results, invertebrate species inhabiting different marine environments have been reported as being most and least abundant in spring and winter months, respectively, including isopod species from several other families (Dexter 1979, Jaramillo *et al*. 1996). Additional similar examples include Jones (1974), who reported the abundance of the isopod genus *Jaera* (Leach, 1814) in Castletown Estuary, Isle of Man, with highest abundances during spring (with a peak in May, similar to our results) and lowest abundances during winter months; and KANG and YUN (1988), who documented that Sphaeromatidae at Busan, Korea, in the East China Sea showed highest and lowest numbers of individuals in April (=123 individuals) and February (only 29 individuals), respectively, very similar to our observed results.

However, there are many other studies that have shown very different seasonality abundance patterns for crustaceans from many locations. For example, BUSHEK and BOYD (2006) reported on the marine isopod *Synidotea laevidorsalis* (Miers, 1881) from Delaware Bay, USA, and found that the highest and lowest abundances were during summer and winter, respectively. Another study conducted in mangrove estuaries along the northeastern coast (Cape York Peninsula) of tropical Australia showed that meiofauna densities were highest during autumn (ALONGI 1987). TAYLOR (1997) reported on seasonal variation in densities of mobile epifauna over a 2 to 3 year period in northeastern New Zealand, and during the first two years, highest abundances were observed during autumn/winter. However, for third year of the study the abundance patterns changed and the highest abundance was observed during spring. Thus, our observed pattern of high isopod abundances in spring and low abundances in winter may not be the same every year, and longer-term studies may help clarify these trends. However, it is clear that isopods and other meiofauna often have clear seasonal changes in numbers, and this needs to be taken into account during surveys.

Interestingly, another family (Gnathiidae, sponge-dwellers with a parasitic larval phase) from the northern part of Okinawa-jima Island have been reported to have lowest and highest abundances during summer and late winter to early spring, respectively (OTA *et al*. 2008). Although gnathiids have different life cycles and habitats from sphaeromatids, this previous survey can serve as another example for of seasonal fluctuations in isopods in Okinawa.

In our results the highest numbers of isopods were those of *Holotelson* sp. 1, which were found in all four sampling seasons, suggesting that at least some species of this genus reproduce year round in the sandy intertidal beaches around Okinawa-jima Island. On the other hand, *Cymodoce* sp. individuals were present only on the east coast, and only once each during spring 2015 and fall 2015, and *Dynamenella* sp. 1 was not present at any site during winter 2016.

Overall, these results demonstrated that there is seasonal pattern for genera of Sphaeromatidae in the sands around Okinawa-jima Island. However, as such surveys have not been performed in the Ryukyu Archipelago before, with the closest previous example from Korea (KANG and YUN 1988), and as the population dynamics, ecology, and biodiversity of this family are generally poorly known, further studies on larger scales, such as including more sampling sites over longer time spans, are highly recommended.

Acknowledgements

We wish to give special thanks to all who assisted us with this study. The senior author was supported by a JSPS 'Zuno-Junkan' grant entitled "Studies on origin and maintenance of marine biodiversity and systematic conservation planning". Comments from the editor and three reviewers greatly improved an earlier version of this manuscript.

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