Marine Pollution Bulletin 166 (2021) 112266

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Baseline

Microplastic ingestion in jellyfish *Pelagia noctiluca (Forsskal, 1775)* in the North Atlantic Ocean

Jorge Rapp[a,*], Alicia Herrera[a,c], Daniel R. Bondyale-Juez[a], Miguel González-Pleiter[b], Stefanie Reinold[a], Maite Asensio[c], Ico Martínez[a], May Gómez[a]

[a] *Marine Ecophysiology Group (EOMAR), IU-ECOAQUA, Universidad de Las Palmas de Gran Canaria, Campus Universitario de Tafira, Las Palmas de Gran Canaria, Canary Islands, Spain*
[b] *Departamento de Biología, Facultad de Ciencias, Universidad Autónoma de Madrid, Cantoblanco, E-28049 Madrid, Spain*
[c] *Asociación para la Conservación Medioambiental Latitud Azul, Av Mesa y López 57-15A, Las Palmas de Gran Canaria, Spain*

ARTICLE INFO

Keywords:
Microplastic
Ingestion
Bloom
Jellyfish
Pelagia noctiluca

ABSTRACT

The present study is the first evidence-based study about the ingestion of plastic and microplastics in jellyfish *Pelagia noctiluca* in the North Atlantic Ocean. A bloom of this organism was collected from Gran Canaria Island coast. It was digested using KOH to quantify the plastic particles and by separating the umbrella from tentacles. About 97% of the organisms analysed showed the presence of microdebris. The majority of the microfibers were with blue or uncorrected fibre concentrations and mainly composed of cotton. Their presence in the gastro-vascular cavity of the jellyfish was confirmed. These results warn about the impact of various factors such as jellyfish health, the transfer to jellyfish predators, human consumption of jelly fish, and the transport of carbon and microplastics in the water column.

Marine plastic pollution is a growing concern to the scientific community, environmental policy makers, and the society to such an extent that our age is referred to as the “Plastic Age”. Marine plastic debris, microplastics in particular, are a serious problem because of their size and associated pollutants that can be ingested by marine organisms and can pass through the trophic web (Carbery et al., 2018; Gall and Thompson, 2015; Ivar Do Sul and Costa, 2014). The effects they can have on the health of organisms are still unknown. The ingestion of microplastics has been documented in numerous species of marine mammals and birds, fish, molluscs, crustaceans, echinoderms (Derraik, 2002; Fossi et al., 2018; Franzellitti et al., 2019), and also in cnidarians such as corals (Hall et al., 2015) and true jellyfish (Macali et al., 2018).

According to Moore et al. (2001), there has been a number of works discussing the distribution and abundance of microplastics and its impact on planktonic communities, especially in the oceanic surface layers (Cole et al., 2013; Desforges et al., 2015; Sun et al., 2016).The concentration of plastic pollution in oceanic gyres is highest and it increase the chances of interaction between microplastics and organisms (Botterell et al., 2020; Cózar et al., 2014). Moreover, Choy et al. (2019) have shown that plastic distribution extends deeper in the water column causing further impact on the niche of zooplanktonic communities, such as the sometimes overlooked gelatinous zooplankton. Here, we studied the impact of microplastics on the scyphozoan jellyfish, *P. noctiluca*.

This scyphozoan is an important nonselective predator of several types of zooplankton and ichthyoplankton, showing the same nocturnal migration of their preys and that plays an important role in the control of marine food webs (Purcell et al., 2007; Rosa et al., 2013; Sabatés et al., 2010). Even though their presence has been observed at depths of 1400 m, it normally concentrates in surface waters (Canepa et al., 2014). Moreover, this pelagic organism is a holoplanktonic species; therefore, lacks a benthic stage in its life-cycle, a characteristic which explains why this jellyfish is widely distributed (Canepa et al., 2014) all around North Atlantic and Mediterranean Sea (Licandro et al., 2010).

The sampled region of this study is directly influenced by the circulation at eastern margin of the Atlantic (Canary current) which passes through the Canary archipelago bringing surface water from the North Atlantic and Mediterranean regions (Casanova-Masjoan et al., 2020). These areas of the Atlantic have been overlooked in jellyfish research as

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* Corresponding author.
E-mail addresses: jorge.rapp101@alu.ulpgc.es (J. Rapp), alicia.herrera@ulpgc.es (A. Herrera), daniel.bondyale101@alu.ulpgc.es (D.R. Bondyale-Juez), mig.gonzalez@uam.es (M. González-Pleiter), stefanie.reinold101@alu.ulpgc.es (S. Reinold), maite.asensio@hotmail.com (M. Asensio), ico.martinez@ulpgc.es (I. Martínez), may.gomez@ulpgc.es (M. Gómez).

https://doi.org/10.1016/j.marpolbul.2021.112266
Received 4 April 2020; Received in revised form 9 March 2021; Accepted 9 March 2021

evidenced by the figures in Brotz et al. (2012). However, reality shows that the islands of the Canary archipelago are showered by periodical jellyfish outbreaks. The main species responsible for problematic blooms are *Pelagia noctiluca* and *Physalia physalis* according to Rodríguez et al. (2015). The only records to assess jellyfish blooms are jellyfish sting reports and the recently implemented government program "Red-PROMAR" that has sightings reported by voluntary observers based on citizen science (Rodríguez et al., 2015). Sting reports showed an increase during the summer months; however, this could also be due to an increase in beach usage (Rodríguez et al., 2015). The databases of RedPROMAR show high presence of *P. physalis* between December and April, and of *P. noctiluca* between April and August. The number of sightings varies widely through the years. However, in recent years, *P. noctiluca* is the reason for some of the biggest blooms observed in the region (Deidun, 2012). News outlets in 2012 reported a total of 54 t of jellyfish carcasses cleaned from Las Canteras beach (Gran Canaria, Canary Islands, Spain) that was decreased to 10 t on the 26th of June, 2012 (Darriba, 2014). In May 2014, 1.3 t were cleaned and outbreaks that repeated in 2019 and 2020 were less. For *P. noctiluca*, these outbreaks have been described to be affected by surface temperature and circulation (Canepa et al., 2014; Bellido et al., 2020). However, these models are more extensively applied in the Mediterranean, where *P. noctiluca* blooms are more frequent (Fig. 1).

Both North Atlantic and Mediterranean Sea are regions known for their high concentration of microplastics contamination, especially in the convective areas (Cózar et al., 2014; Eriksen et al., 2014; Van Sebille, 2015). Surface ocean circulation causes these regions to affect the ocean areas of the south. The surrounding waters on the eastern margin of the North Atlantic are a hot spot of marine microplastics contamination because of their geolocation (Álvarez-Hernández et al., 2019; Baztán et al., 2014; Herrera et al., 2018a; Herrera et al., 2020a, 2020b; Rapp et al., 2020; Reinold et al., 2020). *P. noctiluca* in surface waters is exposed to wind and current forces similar to the passive particles in suspension (Macali et al., 2018). This increases the probability of possible interactions between jellyfish and debris.

In this study, we investigate the natural *P. noctiluca*-microplastic interaction and its impact during a jellyfish bloom, with special attention to ingestion and entanglement of microplastics.

During the summer of 2019, a jellyfish bloom occurred in the Gran Canaria island (Canary Islands, Spain) similar to those documented by Rodríguez et al. (2015) in this region. A total of 30 *Pelagia noctiluca* were collected that were floating near the shore of Las Canteras beach (28° 7.854′N; 15° 26.775′W) (Fig. 2). They were stored separately and frozen at −20 °C for later analysis.

In the laboratory, the surface of the jellyfish was carefully rinsed with bidistilled water. Then, the umbrella and tentacles of the jellyfish were analysed separately to determine whether the microdebris were within the gastrovascular cavity or adhered to the tentacles. Later, following the protocol proposed by Herrera et al. (2018b), both parts were digested with KOH solution at 10%. The digestion took place for 24 h at 60 °C. Finally, the plastics were analysed under a binocular stereomicroscope (Leica S9i with integrated CMOS camera); differentiated by types (Rezania et al., 2018) and colours.

All necessary measures were taken to avoid airborne fibre contamination (Herrera et al., 2018b; Rapp et al., 2020). All materials were carefully washed with bidistilled water. The samples were processed inside a hood and cotton laboratory coats were used in all steps of the process. Moreover, during the processing, an open petri dish with a wet filter was put to check the airborne contamination inside the fume hood.

To determine the type of the polymers identified in the organisms, the analysis of the chemical composition of the items found in 30% of the analysed jellyfish was carried out (both in umbrella and tentacles). The chemical composition of all particles was spectrophotometrically analysed by micro Fourier Transform Infrared Spectroscopy (μFTIR), using a Perkin-Elmer Spotlight 200 Spectrum two apparatus with mercury cadmium telluride detector. For this, the analysed particles were placed on KBr, which was used as a slide, and their spectra were recorded in microtransmission mode using the following parameters:

Fig. 1. Photograph taken by Alicia Herrera of a *Pelagia noctiluca* jellyfish along the coast of Gran Canaria, Canary Islands (Spain). The organism has a blue plastic particle between its tentacles. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Fig. 2. Las Canteras beach (28° 7.854′N; 15° 26.775′W), sampling area located in the northeast of Gran Canaria Island, in Canary Islands.

spot 50 μm, 32 scans, and spectral range 550–4000 cm^{-1} with 8 cm^{-1} resolution. The spectra were compared with Omnic 9 database and with spectra from our own database showing >70% matching in all cases, which was considered enough for positive identification of plastic materials.

Based on the whole collection, 29 out of the 30 jellyfish assessed showed the presence of microdebris (Fig. 3). These results show how gelatinous zooplankton is being impacted by this debris, although the specimens did not appear to be negatively affected by the plastic presence.

The analysis by parts reveals that a greater impact was observed in the tentacles than in the umbrella (Table 1), with the incidence of 86.7% and 53.3%, respectively (Fig. 3). The tentacles section of the organisms sampled had an average of 2.47 ± 2.01 items while in the umbrella sections those were 1.17 ± 1.70. The maximum value obtained for each part was high: 7 in the tentacle sections and 8 in the umbrella sections (Table 1).

Fibres were the most abundant type of debris found in jellyfish followed by plastic fragments and lines (Fig. 4.a). The main colours of the total debris were blue (62.8%) and transparent (14.3%) (Fig. 4.b).

Taking only into account the chemical composition of the microfibres, the major part of this item was composed of cotton (71%), followed by rayon/viscose fibres (6.45%). Acrylic, cellophane, cellulose, linen, and polypropylene (PP) fibres were also found (Fig. 5.a). The fragments were composed of PP and Polyethylene (PE).

A percentage of the fibres found demonstrated clear natural origin (those composed wholly or partly of cellulose and cotton) (González-Pleiter et al., 2021). A representative part of the analysed fibres is composed wholly or partly of acrylics, linen, and PP (synthetic fibres, Fig. 5b) or composed partly of linen, cellophane. and rayon/viscose (semi-synthetic fibres, Fig. 5c and d) (González-Pleiter et al., 2021).

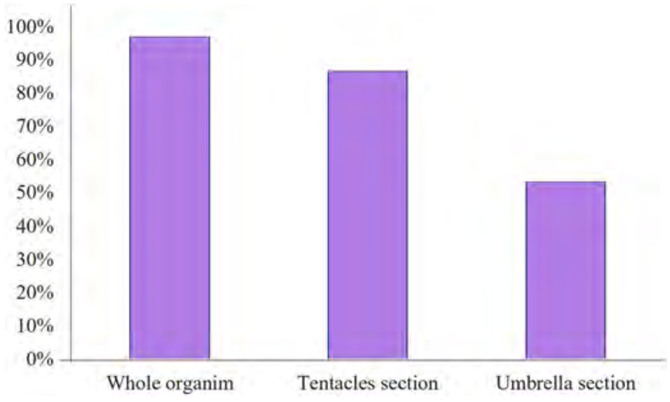

Fig. 3. Percentage of microdebris present in all of the 30 *P. noctiluca* samples.

Table 1
Statistical analysis of the abundance of microdebris found in tentacles and bell of the jellyfish samples.

Part of jellyfish	Number of microdebris items found in *P. noctiluca* (*n* = 30)		
	Mean ± Sd	Max	Min
Tentacle	2.47 ± 2.01	7	0
Umbrella	1.17 ± 1.70	8	0

Sd: Standard deviation; Max: maximum; Min: minimum.

With the presence of microplastic debris within the gastrovascular cavity, the ingestion of microplastics by jellyfish during the bloom is checked.

The effects of these microplastics on the health of the organisms are unknown (Botterell et al., 2020). Cole et al. (2013) showed microplastics ingestion in several zooplankton species including gelatinous organisms such as doliolids, but did not confirm the ingestion by hydrozoans. Similarly, Costa et al. (2020), demonstrated some negative effects of ingestion of microplastics such as polyethylene spheres on the behaviour and health of ephyra stages of the jellyfish *Aurelia* sp. Hence, ephyra of *P. noctiluca* could also be vulnerable to microplastics ingestion. A negative impact on *P. noctiluca* populations that increased its mortality rate could affect its ecological role and destabilize regional food webs (Doyle et al., 2013; Purcell et al., 2007; Rosa et al., 2013; Sabatés et al., 2010).

A considerable presence of microplastics in *P. noctiluca* was observed in this study. Based on umbrella microplastics presence, one out of every two jellyfish would have ingested plastic before being sampled, showing a higher percentage of affected jellyfish than the values reported in the Mediterranean Sea (Macali et al., 2018). A possible hypothesis for this high incidence is that the area where the jellyfish were collected is a closed bay that has high concentration of microplastics and high microplastic/zooplankton ratio (Herrera et al., 2020a, 2020b). In addition, other studies in the region also showed a high percentage of microplastics ingestion in fish (Herrera et al., 2019).

As discussed in Macali et al. (2018), this could be an important entry pathway of microplastics debris to the trophic webs. Jellyfish are prey for a wide variety of predators (Pauly et al., 2008) including humans (Brotz and Pauly, 2017). The importance of jellyfish in the diet of multiple lifeforms is growing and we understand their role better as

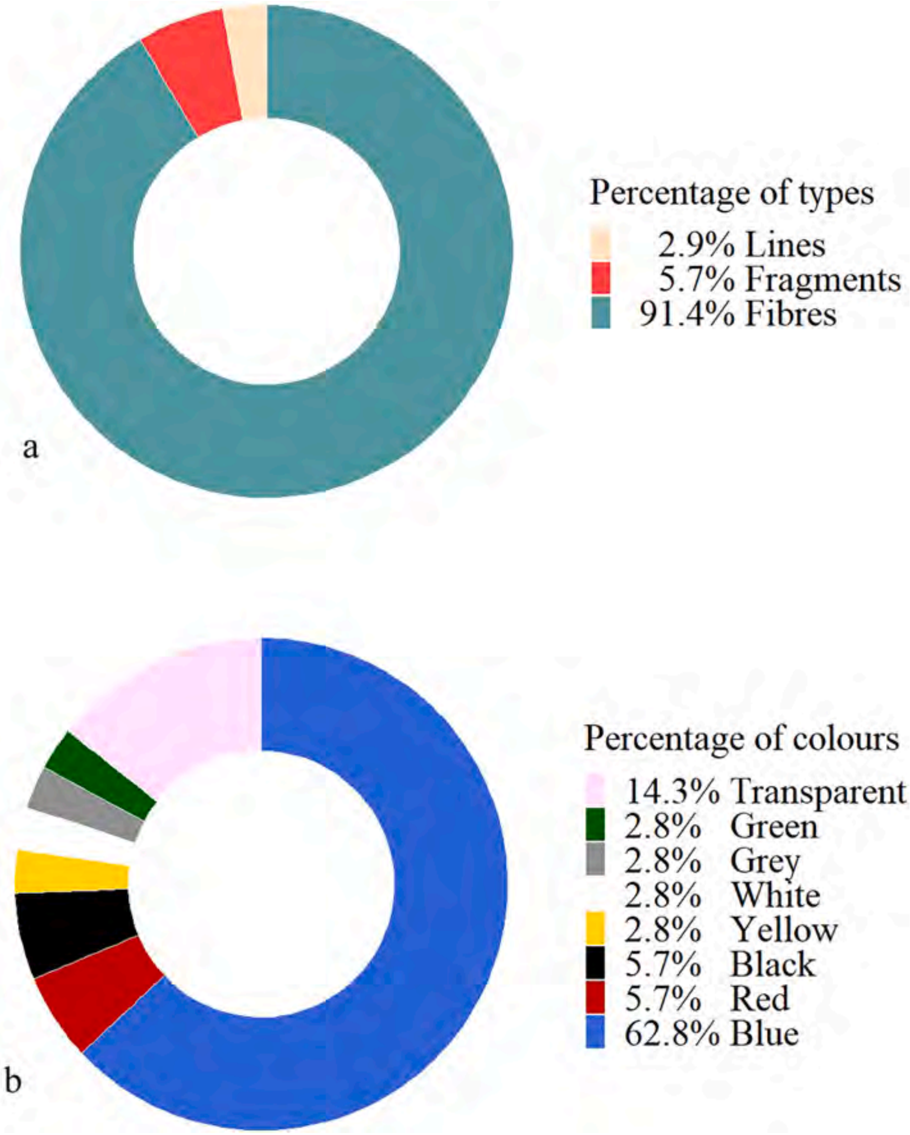

Fig. 4. Percentage of types (a) and colours (b) of the microdebris found in the gastrovascular cavity of *P. noctiluca* samples.

preys and not as "dead-ends" or "last resort" (Hays et al., 2018; Thiebot and McInnes, 2020). For that, jellyfish act as a vector for plastic ingestion to selective feeders (Setälä et al., 2018), especially routine feeders like leatherback sea turtles. Heaslip et al. (2012) observed that *Dermochelys coriacea* consume 73% of jellyfish of its body mass per day. In the case of the Canary archipelago, disproportionate jellyfish blooms are not very frequent but jellyfish populations, which include *P. noctiluca*, but not exclusively, play a relevant role in regional trophic models as described by Couce-Montero et al., 2015. On the other hand, commercial jellyfish fisheries for human consumption should be concerned about the vulnerability of jellyfish to microplastics contamination. Research on microplastics contamination in the order *Rhizostomeae*, the main order of commercially harvested jellyfish, and in other areas have to be conducted.

Furthermore, taking into account the biological characteristics of these organisms, their wide dispersion in the oceans and high interaction with microplastics, as observed in this study, jellyfish could be a clear bioindicator of plastic contamination. This same approach is taken into account in Macali and Bergami (2020), who propose jellyfish as invertebrate bio-indicators to monitor plastic contamination in pelagic waters, along with associated organisms in the food chain, recommending their inclusion in future monitoring studies. This jellyfish monitoring in the Canary Islands may serve to understand the surface water material transported in this region of the Atlantic. Apart from bio-indication, the level of contamination that impact these organisms may help to research the mechanisms that control jellyfish transport in this region. For instance, Mghili et al., 2020 reported high *P. noctiluca* stranded in the Mediterranean coast of Morocco from July to December of 2018 that coincides with less number in Canary Islands. In 2019, this same article shows a high number of stranded individuals during the first months of the year which stop around February. In the same year, the number of *P. noctiluca* increased during the second half of the year from May to December. A combined study on the components transported by surface water circulation may point out their sources apart from helping to understand how they impact each other.

Other gelatinous zooplankton species have been affected by microplastics ingestion that was caused by their filter feeding nature (Choy et al., 2019; Cole et al., 2013; Katija et al., 2017; Wieczorek et al., 2019). Apart from their trophic role, gelatinous zooplankton plays an important function in carbon sequestration (Doyle et al., 2013). Wieczorek et al. (2019) tested and suggested that salp faecal pellets that contain microplastics will decrease their sinking speed. In the case of jellyfish, their carcasses provide a significant source of carbon input to the seabed (Lebrato et al., 2012; Sweetman and Chapman, 2015). We consider that

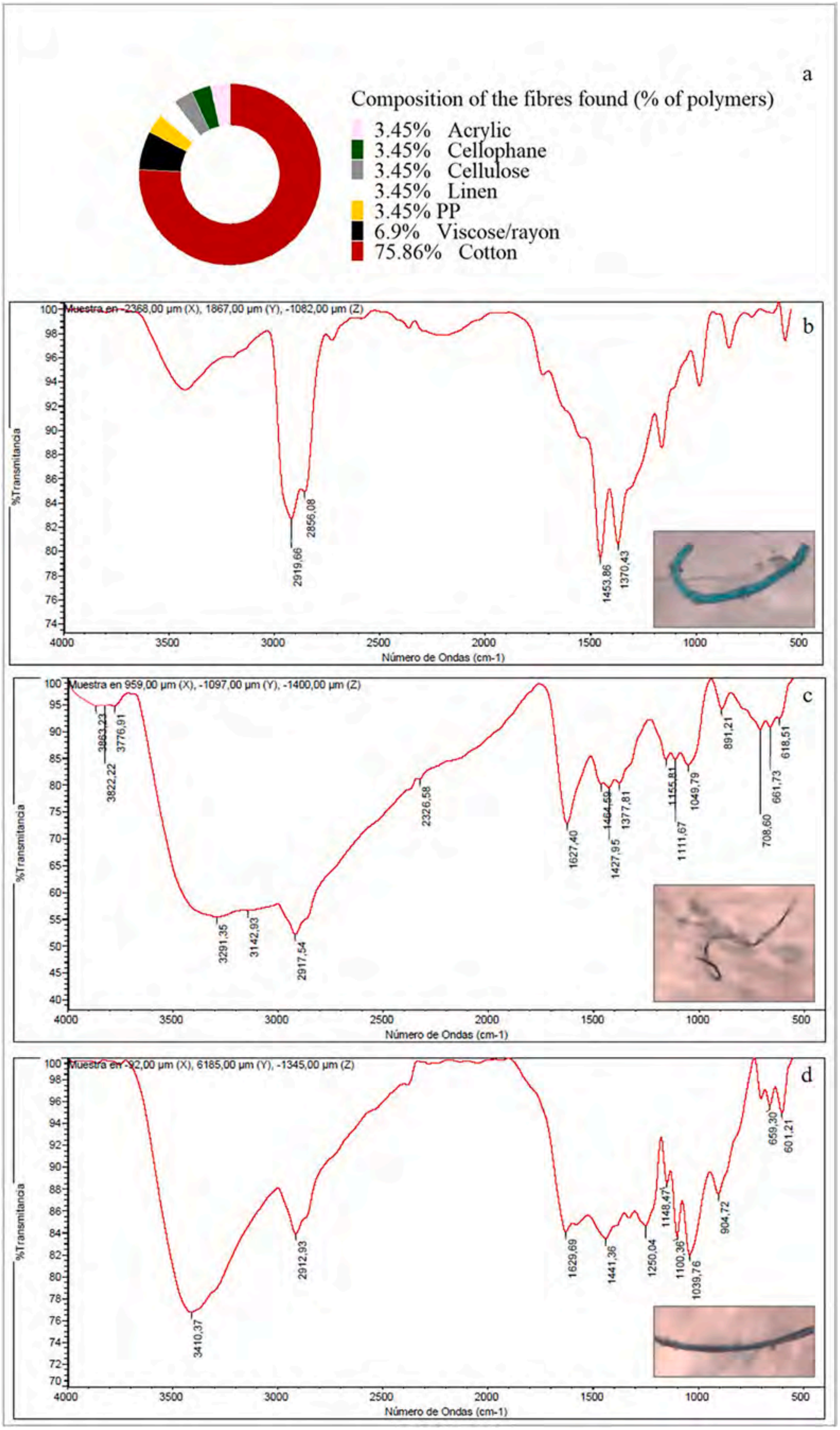

Fig. 5. Chemical composition of 21 microdebris found in about 30% of the jellyfish samples (a). Subsamples analysed by µFITR polymer classification and used according to González-Pleiter et al. (2021). µFTIR spectra and microphotography of (b) Blue synthetic PP fibre, (c) Semi-synthetic rayon/viscose fibre (d) Semi-synthetic cotton-linen fibre. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

since jellyfish are exposed to, and ingest microplastics their effect on the sinking of jellyfish should be assessed. The large bloom formation by several jellyfish species could either experience a decrease in sinking speed as observed by Wieczorek et al. (2019) or serve as source of plastic sinking as suggested by Choy et al. (2019). The analysis of seabed sunk jellyfish carcasses could shed some light on this route of plastic transport to deeper layers and its possible impact on benthic jellyfish scavengers (Ates, 2017).

The well being of organisms that ingest microplastics requires further study. But this study confirms common ingestion of microplastics by *P. noctiluca* that suggests possible ingestion by other jellyfish species. This may have implications on plastic ingestion by jellyfish predators, on plastic contamination on harvested jellyfish species for human consumption, and on carbon transport and plastic sinking by large jellyfish blooms exposed to widely distributed ocean microplastics.

CRediT authorship contribution statement

J. Rapp: conceptualization, data analysis, writing-original draft; **A. Herrera**: conceptualization, methodology, writing-review and edit, supervision; **D.R. Bondyale-Juez**: conceptualization, writing-original draft; **M. González-Pleiter**: investigation, data analysis; **S. Reinold**: investigation; **M. Asensio**: investigation; **I. Martínez**: conceptualization, methodology, writing-review and edit; **M. Gómez**: validation, writing-review and edit, funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This work was supported by the projects IMPLAMAC (MAC2/1.1a/265), Interreg MAC (European Fund to Regional Development, Macaronesian Cooperation), and INDICIT II (European Commission, MSFD-SECOND CYCLE: IMPLEMENTATION OF THE NEW GES DECISION AND PROGRAMMES OF MEASURES).

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