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Advancing One Health in Urban Seafood Markets: A Genetic and Social Analysis of Dried Sea Cucumber in Three New York City Chinatowns

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Abstract: This study employs a multidisciplinary methodology across natural and social sciences to examine relationships between biodiversity loss at sea and urban consumption with a focus on sea cucumber and dried seafood markets in New York City (NYC). The study identified 34 dried seafood retailers across three NYC Chinatown boroughs: Manhattan, Brooklyn, and Queens. Samples of sea cucumber were collected with Chinese-language labels indicating the commodity was from South America, a region of conservation concern. Comparison samples were taken from sea cucumbers labeled from Mexico and Japan. A mitochondrial DNA barcoding method was used to examine the taxonomic origin of 103 samples. Sequence data were successfully obtained from 74 of the samples, 8 of which were classified as brown sea cucumber (*Isostichopus fuscus*), an endangered species for which harvest is banned in several locations. Semi-structured interviews with dried seafood retailers and consumers (n = 64), moreover, revealed associations between consuming sea cucumber and enhancing human health and limited knowledge of product origins. Collectively, the findings reveal socio-ecological dynamics wherein endangered species on the market coupled with geographic market labeling practices and varying degrees of retailer and consumer knowledge negatively bear on marine biodiversity. Furthermore, given that brown sea cucumbers are abundant on the market, there is a need for developing genetic markers that can trace geographic origin to determine if species were legally harvested. These results indicate that more robust market labeling, training, genetic research, and public outreach are required to advance One Health in urban seafood markets.

Keywords: seafood markets; One Health; sea cucumber; sustainability; urban metabolism

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1. Introduction

One Health, as defined by the One Health Initiative Task Force, refers to "collaborative efforts of multiple disciplines working locally, nationally, and globally, to attain optimal health for people, animals and our environment" ([1], p. 9). In this article, we adopt a multidisciplinary methodological approach to address One Health at the interface of urban seafood consumption and marine biodiversity loss. Market labeling practices and socio-ecological characteristics of dried seafood are crucial in this regard.

We focus on sea cucumbers because they interpolate between multiple senses of human and ecosystem health. These soft-bodied marine invertebrates operate like vacuum cleaners of the ocean floor. Their bioturbation and deposit-feeding activities are crucial to regulating sediments and bioremediation—processes essential to maintaining healthy marine ecosystems [2]. Moreover, accumulation of bacterial and algal mats and reduced

growth in seagrass occur after significant removal of sea cucumbers [3]. In addition to marine ecosystem health, sea cucumbers have long been considered crucial to human health. From the Ming dynasty onward (14th century C.E.), sea cucumbers have been referred to as "ocean ginseng" due to their association with medicinal properties [4,5].

Associations of sea cucumbers with human health have led to high market concentration in major cities, particularly within Asian communities. Chinatown neighborhoods in New York City (NYC) are among the highest concentration of Asian diasporic communities in the United States, thereby making these areas ideal sites for researching urban consumption of sea cucumber and other dried seafood. Due to widespread human consumption, some species of sea cucumber are vulnerable. Out of 1716 species of sea cucumber with a global annual market value upwards of USD 200 million, 16 were listed on the International Union for the Conservation of Nature (IUCN) Red List as vulnerable or endangered [6–8].

On the NYC retail market, however, sea cucumbers are not listed by species. Instead, they are labeled geographically by country or region of projected origin. This market labeling system creates a series of problems for consumers and retailers. How can retailers and consumers know what kind of sea cucumber they are purchasing? What are the relationships between market labels and the genus or species of the animal on the market? What knowledge and training about dried seafood do retailers possess? And how do retailers communicate their knowledge to clientele?

To consider these questions, we deployed a multidisciplinary methodology drawing on biological sampling and genetic testing of market samples, as well as interviews and observations with retailers and consumers across three NYC Chinatowns. This approach builds on work that has demonstrated the productive possibilities for multidisciplinary analyses with social and natural science methodologies, particularly through the integration of genetic and interview methods [9–11]. These works demonstrate how thinking across social science and molecular genomic methods can reveal new aspects of socio-ecological systems and their internal dynamics. In this vein, we queried the relationship between species composition and market labels by randomly sampling and testing dried sea cucumbers. Furthermore, interviews with retailers and consumers served to delineate social dynamics undergirding dried seafood markets. Below, we discuss these methods and our findings after grounding and contextualizing the study in relation to urban metabolism and One Health geographies.

2. Theory and Context: Urban Metabolism and One Health

Urban geographers have long argued that nature is not separate from cities. While often held in distinct categorical realms, the *urban* and *nature* have been productively theorized as internally related [12–15]. Gandy ([14], p. 2), for instance, theorizes what he calls the "metropolitan nature" of New York City through the social metabolism of water piped in from rural hinterlands to the city. Furthermore, Gandy brings attention to the politics of pollution stemming from everyday human activities that become spatially concentrated in the city. Swyngedouw [15] similarly illustrates intimate relationships between social power and the provisioning of water from faraway places to residents in the city of Guayaquil, Ecuador. These accounts problematize nature in cities through interactions between social and biophysical processes. Interventions that consider extensive socio-ecological relations embedded in urbanization drew attention to the social metabolic processes that mutate a range of natural materials into urbanized commodity forms.

Urban metabolism has become a prominent conceptual framework in the exploration of internal relations between nature and cities [16]. Urban political ecologists, for example, trace the transformation of nature into commoditized forms as they enter the socio-ecological orbit of cities. This includes the extensive reach of urbanization processes into hinterlands [17]. Scholarship on urban ecological relationships in Manila, Philippines, for example, has shown how fish brought into the city inextricably tie urban food networks to aqueous resource frontiers [18]. In this vein, others have illustrated how urban metabolic processes and oceanic hinterlands are internally related through marine fish-

eries, global trade, and urban consumption [11,19]. In this article, we extend concepts of urban metabolism to the consumption of sea cucumbers and other dried seafood in NYC.

As marine animals, such as sea cucumber, enter the metabolic circuits of the city, their natural lives transform into urban commodities. After harvesting, sea cucumber body walls are salted and dried. Once dried, sea cucumbers can remain on the urban market for years, often stored and displayed in clear glass containers. Social dimensions underlying consumption, such as the accuracy of market labels and retailer knowledge, therefore, are key to defining pathways for more sustainable urban consumption. Hence, in this article, we consider relevant social dimensions undergirding the dried seafood market, as well as the relationship between market labels and species or genus composition of sea cucumbers on the urban market as crucial to the urbanization of nature. A deeper understanding of these relationships is central to advancing One Health globally.

One Health approaches to sustainability maintain that public health is not a purely human matter. Instead, in a One Health framework, relationships between humans and animals, as well as ecosystems and social processes, are interconnected. While the discourse of One Health emerged to address the global spread of diseases, such as H1N1 in the early 2000s [20], with the realization that global biological health is intimately tied to food provisioning, the field shifted to focus on food systems. Sustainably managing processes through which food is provisioned is integral to One Health [21]. Research shows that as humans exploit marine animals, the sustainable harvesting of seafood is fundamental to healthy marine ecosystems [22]. Sea cucumbers are particularly important to the maintenance of healthy ocean ecosystems. Moreover, their consumption is widely associated with bolstering human health.

Despite the widespread harvest and consumption of sea cucumbers, trade within U.S. cities remains understudied. To date, research on the market composition of dried seafood has largely been confined to Hong Kong and mainland China [23,24]. Extant work, however, illustrates that the majority of dried seafood sold on Hong Kong markets is predominantly sourced from international fisheries [23,24]. Dried seafood on the urban market, therefore, needs to be thought of as both urban and global in scale, encapsulating fisheries, cities, and trade the world over. Research on global sea cucumber fisheries illustrates that ineffective fishing management predominates across international contexts [25]. Ineffective fisheries management alongside rising urban demand for sea cucumbers has heightened stresses on wild populations [5].

Sea cucumbers are widely associated with traditional medical uses, such as strengthening bodily functions [26,27]. The popularity of sea cucumbers within urban markets contributes to stressors on numerous species [28,29]. Some species, such as *Stichopus hermanni*, *Thelenota ananas, Thelenota anax, Holothuria fuccogilva,* and *Actinopyga mauritiana* are highly valued for medicinal uses [30]. Yet, in many cases, market labels do not indicate species or genus. In NYC markets, for instance, sea cucumbers are labeled in relation to the projected region of harvest, as we analyze in the following sections. Furthermore, dried sea cucumber is difficult to identify with species or geographic origin based on morphology, making it challenging to validate and track trade patterns. Genetic species identification with DNA barcoding shows promise to deepen understanding of sourcing patterns in seafood markets and identify potential incongruence between geographic distribution patterns of harvested species and the claimed region of origin [31].

We focus here on markets in NYC Chinatowns because these areas have the highest concentrations of sea cucumber and other dried seafood in the U.S. Chinatowns in North America developed in the context of racialized settler colonial anxieties toward people of Asian descent and economic exclusion of Asian-American migrants [32,33]. In the wake of the Chinese Exclusion Act and widespread migration from the U.S. West, NYC Chinatown communities transformed into strong economic areas organized around international trade and culinary businesses that catered to both Euro-American and Asian-American tastes. Asian American residents in NYC continue to experience anti-Asian sentiment in the wake of the COVID-19 pandemic [34–37]. In this context, NYC has a sub-

stantial Chinese diasporic community and disproportionately high availability of dried seafood relative to other major U.S. cities.

We conducted research across the three major NYC Chinatown neighborhoods including those in Manhattan, Brooklyn 8th Avenue and Sunset Park, and Flushing Main Street. These neighborhoods span three boroughs and support one of the largest Chinese diasporic communities in North America. Each has its own history and community composition. Manhattan Chinatown is the oldest of the three, supporting predominantly Cantonese-speaking communities with historical ties to racialized exclusions of the late 1800s and early 1900s. Presently, the area caters widely to tourists. Flushing Chinatown grew rapidly in the 1970s with immigrants from mainland China and Taiwan. It is largely Mandarin-speaking but also has Cantonese-speaking residents and exhibits strong commercial vitality. Brooklyn's Sunset Park and 8th Avenue developed over the last several decades with many working-class immigrants from mainland China. It has both Cantonese- and Mandarin-speaking residents. Dried seafood markets are abundant in each of these neighborhoods.

3. Materials and Methods

This study draws on multidisciplinary methods across social and natural sciences. Collectively, multidisciplinary methods including biological sampling and genetic testing, as well as visual surveys and qualitative interviews, allow us to examine relationships between market labels and species composition, as well as the social dynamics of retail and consumption that undergird NYC dried seafood markets.

3.1. Site Survey and Interviews

Three of the authors—authors one, three, and four—conducted visual surveys of dried seafood retailers in NYC to verify commodities on sale and their market labels. Dried seafood shops in Manhattan, Flushing, and Brooklyn exhibited seafood both inside and outside stores. Each seafood item was labeled with the geographical place of origin in Chinese characters and a price listed by weight. After identifying retail stores and conducting visual surveys, we carried out semi-structured interviews with retailers and consumers, while making field observations [38]. Most retailers and consumers interviewed were immigrants to NYC and nearly all had limited English. The first author speaks Mandarin and English. Authors three and four speak Cantonese, Mandarin, and Taishanese, as well as English. Interviews were conducted in the language preference of the interviewee.

Altogether, we interviewed 64 people, including 54 retailers and 10 consumers from June to December of 2021 and March to April 2023 (See Supplementary Files S1 and File S2). We interviewed retailers ranging from 30–70 years old. Interviewees, in some cases, were reluctant to share market information, such as details about their suppliers, due to strong competition among dried seafood retailers (Interviews 6, 7, 13, 14,16, 22, 23). This is relevant to note because dried seafood retail shops are agglomerated in urban space, with many shops in close proximity to one another. Interviews were coded inductively for key themes and patterns, which are discussed below.

3.2. Sea Cucumber Sampling Procedure

After identifying stores and conducting interviews, author one applied standard random sampling to collect biological samples of dried sea cucumbers. We sampled two to three sea cucumbers at price parity from each vendor. Samples were collected from 12 vendors in Manhattan, 11 vendors in Brooklyn, and 11 vendors in Flushing (See Figure 1). On the NYC market, sea cucumbers are listed geographically according to the projected place of harvest. For example, sea cucumber labels may read "South America" or another region or country of origin.

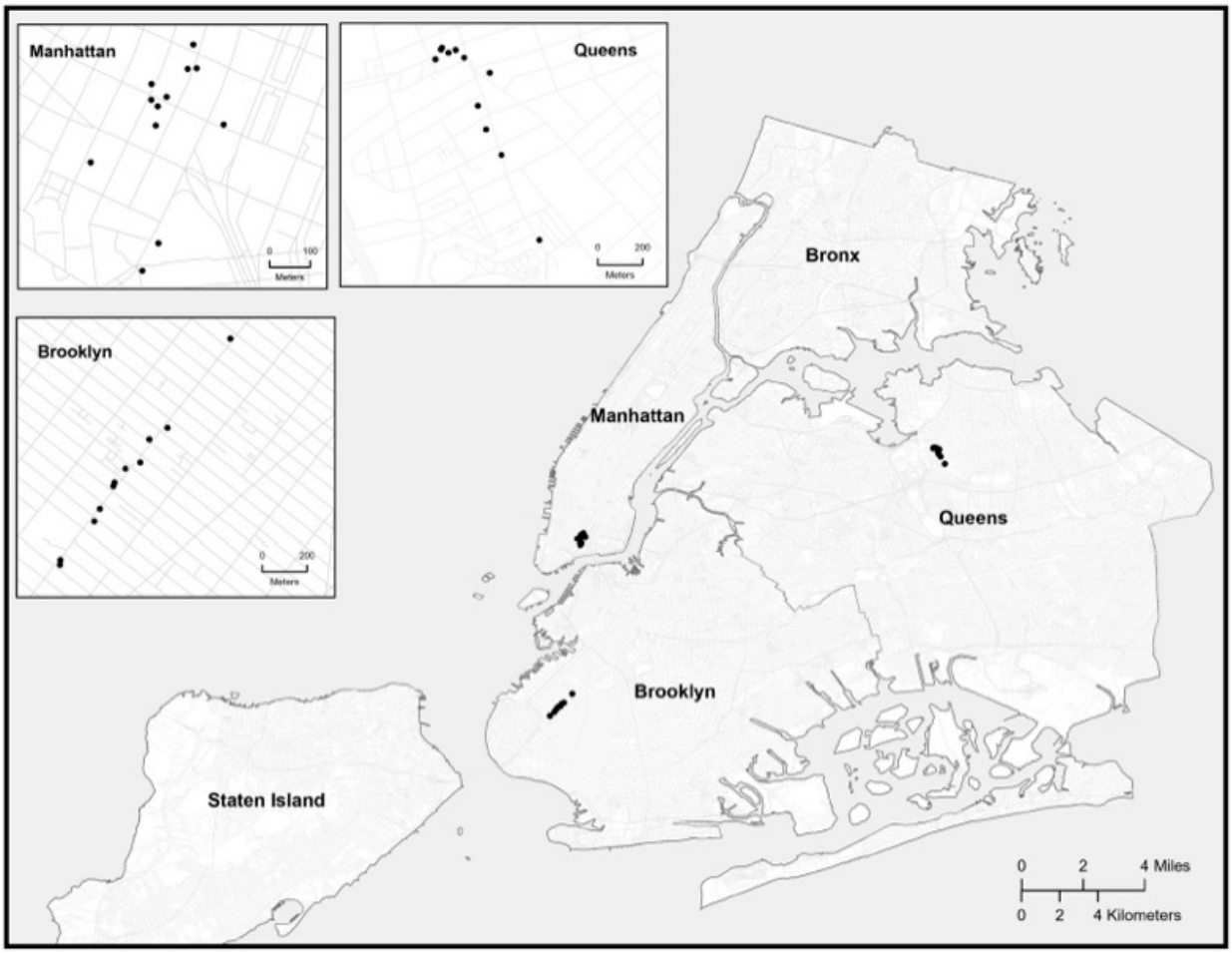

Figure 1. Map of sea cucumber sample sites across three NYC boroughs. Each black dot represents a retail shop sampled for this study.

Author one sampled primarily from containers labeled 'South American Sea Cucumber' (南美刺参) because this region is abundant on the market and is a region of conservation concern. The brown sea cucumber (*Isostichopus fuscus*), for instance, is an endangered species found on the Pacific side of South America. A small number of 'Mexican Sea Cucumber' (墨西哥刺参), 'Mexican Red Sea Cucumber' (墨西哥红刺参), and 'Japanese Sea Cucumber' (日本辽工刺参) were randomly selected as comparative samples. In total, author one collected 103 sea cucumbers consisting of 88 sea cucumbers labeled South American, 9 sea cucumbers labeled Mexican Sea Cucumber, 6 labeled Mexican Red Sea Cucumber, and 3 labeled Japanese Sea Cucumber. With these 103 samples, author two was able to conduct reliable genetic tests on 74 samples. The average price for South American Sea Cucumber, at the time of sampling in December 2021, was USD 188 per pound. The price range was between USD 169 and 229 per pound with larger sea cucumbers priced higher. These samples were purchased from retailers and taxonomically classified using DNA barcoding [39].

3.3. Genetic Barcoding, Sequencing, and Species Identification

Author two deployed a mitochondrial DNA barcoding method to analyze species identifiers in GenBank and compared the findings with geographical market labels. Related studies conducted in Chinese cities showed high degrees of inaccuracy between market labels, species, and projected places of origin [40]. We hypothesized there may be similar inaccuracies in NYC markets. Samples were purchased already dried and transferred to the lab.

We extracted DNA from each sample by first wrapping the dried specimen in a clean paper towel and cardboard and then using a hammer to break off pea-sized pieces. We selected one or two pieces of yellow or translucent brown tissue from the inner side of the body wall (to minimize the effects of potential cross-contamination from external contact between specimens that had been stored together) and placed them in distilled water in a 1.5 mL tube to rehydrate at 55 °C for at least 12 h. A rice-grain-sized piece of the rehydrated tissue was then placed in 90 µL Thermo Fisher Scientific Genomic Digestion Buffer and 20 µL Proteinase K and after overnight lysis, the DNA was purified with the magnetic beads protocol described by Kučka and Chan [41].

Because the DNA in the dried sea cucumber tissue was highly degraded, we were not able to consistently amplify the full mitochondrial Cytochrome C Oxidase Subunit I (COI) barcoding region using the primer set from Byrne et al. [42], so we instead used the COI-B primer pair from Xing et al. [31] to target a 257 bp region of this gene (a mini-barcode). PCR amplification was performed in 25 µL reactions with 1 µL DNA extract, 0.2 µM each primer, 1x Qiagen Multiplex PCR Master Mix, and 0.2 µM bovine serum albumen (BSA). For amplification, we used an initial denaturation step at 95 °C for 3 min, followed by 35 cycles of 95 °C for 1 min, 42 °C for 50 s, and 72 °C for 1 min, and a final extension for 10 min at 72 °C. Amplification success was confirmed by visualizing the PCR products on agarose gels. Successful amplicons were cleaned with Exo-Sap-IT (Thermo Fisher Scientific, Waltham, MA, USA) following the manufacturer's instructions and were Sanger sequenced with the COI-B forward primer using the Big Dye Terminator v3.1 cycle sequencing kit (Applied Biosystems, Foster City, CA, USA) on an Applied Biosystems instrument at the Cornell Institute of Biotechnology.

The chromatograms for the resulting sequence data were visually inspected and the noisy sequence at the ends was trimmed off. We queried each of our sequences against the full NCBI nr/nt database using the web-based Nucleotide Basic Local Alignment Search Tool (BLASTn) with default parameter settings. We made a species-level taxonomic assignment for sequences that matched a reference sequence at >98% sequence similarity and showed no additional BLAST hits with >96% similarity to any other species. When we observed matches at >96% similarity to multiple different species within the same genus, we could not confidently assign them to species and made a genus-level taxonomic assignment. When sequences showed hits to multiple genera within 96% similarity or when there were no hits with >96% sequence similarity, we considered the taxonomic assignment inconclusive. In making these assignments, we ignored hits to a single record for *Synaptula reciprocans* (Genbank Accession GQ920785.1) because its sequence similarity with *Holothuria* sp. appeared taxonomically inconsistent.

4. Results and Discussion

The key results are summarized here followed by a more detailed analysis and discussion. Our successful genetic tests of 74 samples revealed 8 instances of the brown sea cucumber (*Isostichopus fuscus*), an endangered species, as well as large variation in the composition of species traded in different neighborhoods. The brown sea cucumber is listed as endangered on the IUCN Red List [43]. Given that brown sea cucumbers are abundant on the market, developing genetic markers that can trace geographic origin to verify legal harvesting practices is necessary, as discussed below. Moreover, we found a general association of sea cucumber with enhancing human health and that retailers operate with limited knowledge of product origins and rely on combinations of personal experience and media representations to communicate health benefits to consumers.

4.1. Findings from the Genetic Survey

We obtained sequence data for 74 sea cucumber samples (22–28 from each of the three sampling neighborhoods). Based on our taxonomic assignment criteria, we were able to classify 19 of the samples to species level and 31 samples to genus level, while we could

not confidently identify the taxonomic identity of the remaining 24 samples based on our targeted COI-I mini-barcode (See Supplementary File S3).

Four different genera were represented among our samples and a comparison of the taxonomic composition of the samples collected from the three different neighborhoods suggests differences in sourcing patterns, which was corroborated through interviews (taxonomic relationship between the detected species and genera are shown in Supplementary Figure S1). For example, sea cucumbers from the genus *Actinopyga* made up more than half of the identified samples collected in Flushing but were not encountered in the other two neighborhoods (See Figure 2). Similarly, the *Isostichopus* genus made up a substantial proportion of samples in both Flushing and Brooklyn but was not detected in Manhattan (Figure 2). Interestingly, a greater proportion of the Manhattan samples could not be taxonomically classified compared to the other neighborhoods (16 out of 24 in Manhattan, compared to only 3 out of 28 in Flushing and 4 out of 22 in Brooklyn, Figure 2). This lower classification rate could be caused by a higher degradation level, resulting in more sequencing errors in the Manhattan samples (although we did not see evidence of increased noise in the sequencing chromatograms). Interviews with retailers did not suggest significant differences in how commodities are handled, which could otherwise explain this cross-neighborhood disparity. Alternatively, a higher proportion of samples from this neighborhood may be from species and genera that are not yet represented in the available reference sequence database (a majority of the Manhattan samples did not show sequence similarity >96% to any reference sequence), suggesting divergent sourcing patterns compared to the other neighborhoods where most samples showed high similarity to known reference species (See Supplementary File S3).

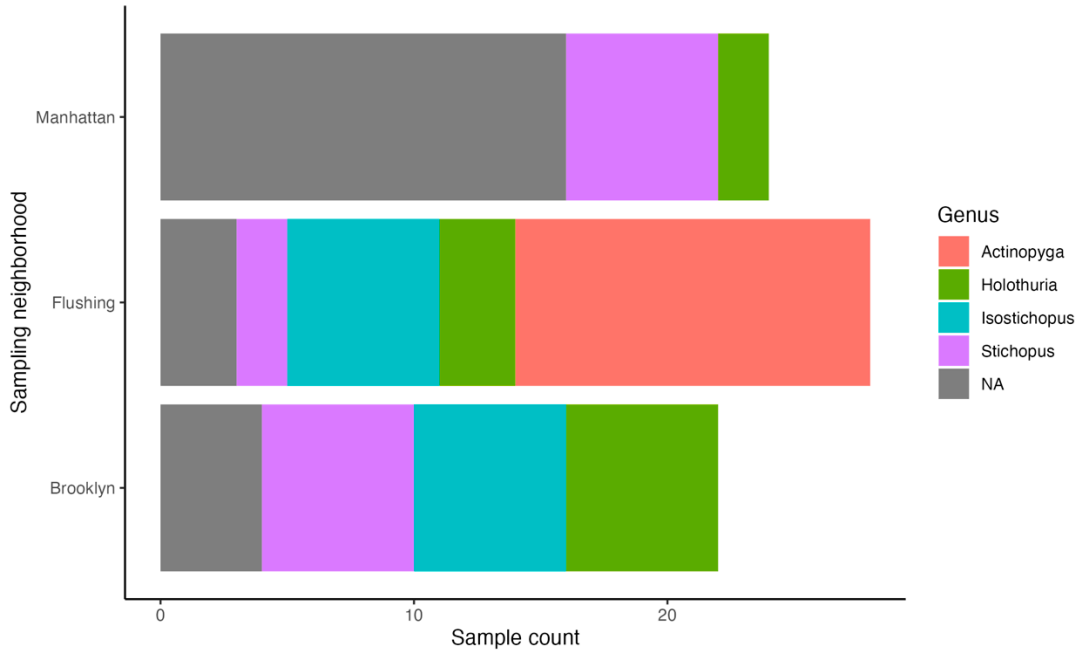

Figure 2. Counts of sea cucumber samples were assigned to each detected genus across the three different neighborhoods. The length of the horizontal bar for each neighborhood indicates the total number of samples (*x*-axis) for which we obtained sequence data. The colored section of each bar indicates how many samples were assigned to each genus (species-level assignments are included in the genus counts here), while the grey sections indicate the count of samples for which we could not conclusively assign taxonomic identity.

At a more detailed level, the genetic tests and store location data indicate relationships between supply sources and stores based on borough and corporate structure. Samples collected from the stores owned by the same company but located in different boroughs exhibited different genera across boroughs. For example, samples collected from BK12,

FL03, and FL07 are from different stores operated by the same parent company, yet they show a variety of genera on the market, thereby suggesting different supply sources or places of harvest. In contrast to this example, which points to borough-specific divergences, other samples point to commonalities in corporate-specific supply chains, which was supported by interviews. For example, MN06, MN07, and BK01 are all owned by the same parent company and exhibited the same genus in tests across the Manhattan and Brooklyn boroughs. (See Supplementary File S2). These countervailing patterns suggest that some retailers may have borough-specific suppliers and others may have corporate-specific suppliers. The genetic tests, store location data, and interviews in this study indicate countervailing patterns in suppliers based on borough and corporate structure. Larger scale studies that deploy both corporate- and borough-specific sampling procedures are needed to further explore these relationships.

All the sequences assigned to species level were to one of three species: *Actinopyga agassizi* (*n* = 8), *Holothuria tubulosa* (n = 3), and *Isostichopus fuscus* (n = 8). The first two of these species are listed as "least concern" by the IUCN [44] but the brown sea cucumber *Isostichopus fuscus* is listed as endangered [43] and is listed in Appendix III of the Convention on International Trade in Endangered Species [45]. A total of 8 out of our 74 analyzed samples were assigned to this species with high confidence (sequence similarity >98% and no hits with >94% similarity to any other reference species), suggesting that it remains abundant on the market despite the recognized vulnerability. Fishing for *Isostichopus fuscus* has been banned from several areas (e.g., the Galápagos Islands [46] but harvest continues to be allowed in other parts of the distribution range. To trace illegally harvested and traded products, there is therefore a need to develop more high-resolution genetic markers that can trace not just the species but also the geographic origin. Such markers that can trace specific fish stocks have been developed for other marine fisheries (e.g., [47]) and would be an important resource for combatting illegal harvest and trade of sea cucumber products and could be utilized to develop a more specific market labeling system that reflects both the species and region of harvest.

The relatively low taxonomic resolution of the currently available markers also limits our ability to identify incongruence between the claimed region of origin and known distribution ranges of particular species. This is compounded by the inability of most retailers to identify species on the market, demonstrated through interviews discussed below. The degraded nature of the DNA in dried seafood limits the length of the sequence fragments that can be screened but future testing that uses multiple mini-barcode loci targeting different genes could improve the resolution (e.g., [48]). The fact that we also found that more than half of our samples did not show sequence similarity >98% with any available reference sequence also suggests that many of the species represented in our samples are missing from current reference databases. Hence, efforts to expand reference data would also improve options for more detailed tracking of the sea cucumber trade in the future.

4.2. Findings from Interviews

In our interviews, we found widespread associations between sea cucumbers and other dried seafood with enhancing human health. Furthermore, retailers had limited knowledge of the dried seafood products they sold. Moreover, retailers claimed their knowledge of the health benefits of consuming dried seafood derives from personal experiences of consumption, social media content, and cultural traditions. Finally, we observed a generational shift in retailers' training corresponding with gender, age, industry experience, and immigration status.

Based on interviews, retailers conveyed sea cucumber and other dried seafood as having both general and specific health benefits. Most commonly, retailers discussed these commodities as protecting health (保健). Consuming sea cucumber, retailers suggested, contributes to maintaining health and protecting the body by supplementing essential elements. Retailers claimed that consuming sea cucumber and fish maw bolsters collagen in the body (Numerous interviews). Collagen, a component of human bones, muscles,

tendons, skin, and cartilage, was frequently discussed as the part of sea cucumber that most enhances human health. Furthermore, some retailers associated sea cucumbers with enhancing male virility and masculinity more broadly (Interviews 48, 50, 57, 60, and 62). In contrast, retailers associated consuming fish maw with enhancing female fertility and skin beautification. Additionally, interviewees claimed these items can enhance kidney functions, lower blood pressure, and strengthen the body (健体). According to retailers, the health benefits of consuming sea cucumber and other dried Sea cucumbers, moreover, were described as lowering cholesterol, enhancing kidney functions, and preventing cancer (Interviews 48, 51, 55, and 60). Retailers suggested that consuming sea cucumber supports human health throughout the aging process, frequently using the term *yanglao* (养老), which refers to caring for the body as it ages.

When asked about how consumption affects human bodies, retailers often relied on their personal experiences of consumption to discuss health benefits. Retailers and consumers alike stated that fish maw provides health benefits, citing that it contains nutrients such as protein, collagen, and calcium (Interviews 15, 21, 29, 30). A retailer also stated that "fish maw provides protection for the stomach" (Interview 10). Another retailer with 20 years of experience and accumulated knowledge through training with a Chinese medicine practitioner (中医师) noted that dried seafood "helps with facial complexion and provides calcium for bone structure" (Interview 27). Based on our interviews, retailers widely describe their dried seafood products as beneficial to human health and beauty.

While retailers conveyed abundant benefits to human health of consuming sea cucumber, they exhibited limited knowledge regarding the importing process and origins of dried seafood, which poses a challenge to cross-referencing our genetic analyses. Numerous retailers claimed they did not know the origin of the seafood commodities they sold (Interviews 3, 9, 12, 20, and 30). Some retailers claimed higher-level managers maintained this information (Interviews 5, 9, and 15). An employee with over four years of experience conveyed that not only were they unaware of the country of origin of their dried seafood supply but they also did not keep track of the supply of particular products. Instead, they replenished supply whenever goods were low in stock and simply reproduced the place of origin communicated by their wholesalers on their market labels (Interview 3). This points to the possibility for future genetic sampling procedures to consider not only retail markets but also wholesalers. Furthermore, this indicates that retailers operate with limited knowledge of the origins of their products. Many retailers, however, claimed a timeless Chinese culture of consumption that dates to dynastic rule, with some interviewees claiming that emperors favored rare seafood dishes (Interview 32, 42, and 55). Within NYC diasporic communities, banquets are a key site for serving sea cucumbers. Banquets hold social significance because they affirm relationships with gift-oriented reciprocity [49]. Yet, recent work suggests that rather than a timeless cultural tradition, such consumption practices are relatively recent and linked to bourgeoning middle-class tastes [50].

Dried seafood consumption was not only associated with health but also with social status, as it symbolizes wealth in diasporic communities and gendered conceptions of beauty and bodily enhancement. While sea cucumber was associated with male enhancement, fish maw was widely associated with women's health and beauty. Female retailers from multiple stores claimed that they consume fish maw for the purposes of beautification (Interviews 4, 5, 8, and 12). One such retailer claimed that fish maw "is for good health." When asked about how she knew about these health benefits, she responded by saying "you can feel it; the body reacts positively to it" (Interview 3). Another retailer stated that consuming dried seafood improved her beauty and health, claiming that she appears to be aging slower because she consumes these goods every day in small portions. She referred to her personal experience, noting that "her arms seem to hurt less, and her skin is smoother" (Interview 5). Another retailer noted that she felt "less tired" and her "body hurt less." She also recommended, while speaking to a female interviewer, that "we [women] should preserve our beauty because it will be harder when we are older" (Interview 9). Numerous female retailers reported feeling physical enhancement of their appearance after

consuming dried seafood. Importantly, they also talked to their customers about these experiences. Therefore, the affective communication of consumption experiences reinforces gendered and classed social dynamics of the urban dried seafood market.

Retailers referred to social media, personal experiences, or traditional cultural beliefs as sources of knowledge regarding dried seafood products. Within these neighborhoods, ideas about particular health benefits circulate through word of mouth and digital mediums. One retailer, for instance, claimed that she knew that dried seafood like sea cucumber and fish maw "makes skin beautiful" because she learned about this on the Internet (Interview 12). Another retailer said that these items have "health benefits, specifically from high levels of collagen. You can search it up on the Internet" (Interview 29). Retailers expressed confidence in the information they provided to their customers based on their own experiences of consumption, media representations, and the cultural milieu of dried seafood in their communities.

Based on key characteristics of retailers, including age and industry experience, we found a generational shift in retailers' training. In our interviews, we found that retailers 50 years and above were more likely to have received formal training in TCM, whereas retailers between the ages of 30 to 50 tended not to have training in TCM. This points to a generational shift in training for dried seafood retailers. Many younger retailers had less experience and were introduced to the trade by relatives. A retailer in Brooklyn, for instance, stated "I have been working here for 2 years. I was introduced by a relative" (Interview 5). In contrast, a retailer in their 50s informed us that they have been working in the industry for 6 years in the United States and 20 years in China (Interview 1).

Retailers above 50 years of age tended to have more formal training in pharmacology and TCM, as well as decades of experience participating in the dried seafood trade compared to retailers in their 30s and 40s. A retailer in their 70s has worked in the herbal medicine industry since they were 16, acquiring over 50 years of experience. They learned about the trade in China as an apprentice for their "Master" (师傅) teacher. Moreover, they stated that they need to know the uses and benefits of dried seafood since they own a pharmacy and sell other products related to health (Interview 8). A retailer in their 50s with 20 to 30 years of experience was able to cite specific nutrients in a given product and estimate average weekly sales. The interviewee stated that they gained knowledge about dried seafood products from TCM school (Interview 2). A retailer in his mid-50s with 20 years of experience claimed to be able to accurately differentiate between different types of sea cucumber, fish maw, and the specific health benefits of each type. The interviewee claimed that they gained their knowledge from a Chinese medicine practitioner (Interview 27). Based on these interviews, retailers above 50 years of age typically claimed greater industry experience, formal education in TCM, and training in how to identify different types of dried seafood for specific health benefits.

In contrast, retailers 30 to 50 years of age did not consider it necessary to receive specialized training and, therefore, did not as readily seek out training. When asked about their backgrounds, many retailers within this age range told us that they had no formal training and that they learned everything through working on the retail floor (Interviews 5, 11, and 16). Younger retailers tended to rely on their personal experiences with dried seafood products to answer questions about health benefits, whereas older retailers referred to the training that they received in China and with TCM practitioners (Interviews 3, 9, 15, 20, 29, and 30). This indicates a generational shift in the forms of knowledge and training in NYC dried seafood markets. These findings point to the need for more robust retailer training, as well as the potential for utilizing genetic sequencing techniques and visual identification to foster retailer knowledge and support more sustainable urban seafood markets.

5. Conclusions

The results indicate that endangered species on the market coupled with varying degrees of retailer training and geographic market labeling negatively bear on marine bio-

diversity. Therefore, there is a need for developing genetic markers that can trace geographic origin to determine if species were harvested legally. Additionally, more robust market labeling, training, genetic research, public outreach, and green supply chains [51] are required to advance One Health in urban seafood markets. In this regard, these findings have relevance, not merely for NYC, but cities and regions elsewhere as dried seafood markets and the fisheries that supply them span the globe. Advancing a global approach to One Health in urban seafood markets requires multifaceted attention to the social dynamics and socio-ecological relationships embedded in urbanized commodity formations including but not limited to marine fisheries, trade networks, and market practices.

These results provide a foundation for reorienting market practices and future research. Because the results show widespread market mislabeling and a high number of endangered species relative to the sample size, there is a strong need for scaling up research on dried seafood markets in NYC. As there is a high number of endangered and at-risk species on the market in NYC, a city with a highly regulated seafood industry, it is likely that other cities, especially those with less robust regulatory mechanisms, also contribute significantly to biodiversity loss at sea. Supporting evidence is corroborated by extant work [19,24,52,53]. In this regard, further studies are needed on cities with key roles in the circulation and consumption of seafood commodities like Hong Kong, Singapore, and Taipei, for instance, as these cities have the highest trade volumes globally. Finally, it is imperative to scale up multidisciplinary genetic and social studies of dried seafood markets with attention to supply chains and corporate structures. Such studies can further shed light on the genetic makeup of the market, as well as potential commonalities and differences across cities and regions.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/su16093589/s1.

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