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Genetic Identification of Octopodidae Species in Southern California Seafood Markets: Species Diversity and Resource Implications

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Capstone Advisory Committee

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Genetic Identification of Octopodidae Species in Southern California Seafood Markets: Species Diversity and Resource Implications

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Abstract

Various species of Octopodidae are commonly found in seafood markets throughout Southern California. Most of the octopus available for purchase is imported, with the majority of imports coming from various Asian nations. Despite the diversity of global octopus species, products are most commonly labeled as simply "octopus," with some distinctions being made in size, e.g., "baby" or "little octopus." In efforts to characterize species diversity, this study genetically tested 59 octopus samples from a variety of seafood markets in Los Angeles, Orange, and San Diego Counties. Universal 16S rRNA primers (ref) and CO1 primers developed by Folmer et al. (1994) were used for PCR amplification and sequencing of mtDNA. In all, 105 sequences were acquired. Seven species were identified with some confidence. *Amphioctopus aegina* was the most prevalent species, while two additional species were undetermined. Little available data exists pertaining to octopus fisheries of the countries of production of the samples. Most available information on octopus fisheries pertains to those of Mediterranean and North African nations, and identifies the *Octopus vulgaris* as the fished species. Characterizing octopus diversity in Southern California seafood markets and assessing labeling and countries of production provides the necessary first step for assessing the possible management implications of these fisheries and seafood supply chain logistics for this group of cephalopods.

Introduction

Octopuses are exclusively marine cephalopod mollusks that form the order Octopoda. They are found worldwide in various benthic and pelagic habitats, but the highest species diversity occurs in shallow water benthic octopuses that form the family Octopodidae, of which there are most likely over 300 species (Jereb et al., 2014). They are generally fast-growing and short-lived, with the average lifespan lasting one to two years (Jereb et al., 2014). Most species breed only once; males die after mating and the female protects her eggs until their hatching and her subsequent death (Hernández-García et al., 2002).

Octopus is an exploited marine resource, with global catch reaching upwards of 350,000 tons per year (Jereb et al., 2014). Octopus is highly-valued as a food commodity and bait, though to a lesser degree on the latter (Jereb et al., 2014). Most octopus catch is thought to be *Octopus vulgaris* from Western Africa and the Mediterranean, and various species from the Western Pacific Ocean (Norman, 2003). Most available information on octopus fisheries refers to those that target *O. vulgaris*, making it a common label for octopus caught around the world, and it is the most studied of all octopod species (Norman, 2003). Octopus fisheries are diverse, ranging from small-scale artisanal fisheries to large commercial practices. Depending on the fishery, octopus are caught through a variety of methods, including traps, trawls, clay/other types of pots, and simply by hand or by spear (Rathjen, 1991).

Despite its lack of any established commercial octopus fishery, the United States has seen increasing market demand for imported octopus (GlobeFish, 2014). Spain is the main provider of US octopus imports, with China and the Philippines occupying top spots as well. In 2010, the US imported 42.7 million dollars worth of octopus, with this number increasing significantly by 2014, reaching 107.8 million dollars. In 2014, over 35 million dollars of octopus imports passed through California alone, with the majority of these products coming into Southern California (NOAA Foreign Trade, 2015). Despite the vast amount of octopus products entering the United States and the evidence for multiple-species fisheries, octopus is commonly only generically labeled without any hint as to what species is being presented. In order to characterize octopus species that make up the market and to better understand fisheries implications, this study aimed to identify octopus samples purchased in seafood markets throughout Southern California. Given the generic labeling of octopus, the study was driven by the question as to how many species exist in the market in Southern California and the trade and fishery implications that might be explored by genetically identifying various octopus samples.

Materials and Methods

Octopus samples were collected from a variety of seafood markets, restaurants, and retailers in Southern California, specifically Los Angeles, Orange, and San Diego Counties. All samples were raw, and were either frozen or previously frozen and thawed, and sold in whole form, chopped, or mixed with other various seafood products in mixed packages (Fig. 1). Fifty-nine different samples were acquired. Of these fifty-nine, forty-one samples contained multiple individuals. For these purchases, the study selected multiple individuals within the sample to test, depending on the number of specimens available. Multi-individual samples ranged from two to eight specimens within the package.

Sample	Market Labeling	Country of Origin/Production
1	Baby Octopus	Vietnam
2	Baby Octopus	N/A
3	Baby Octopus	India
4	Baby Octopus	N/A
5	Octopus	NA
6	Octopus	Philippines
7	Baby Octopus	N/A
8	Octopus	N/A
9	Octopus	N/A
10	Small Octopus	N/A
11	Octopus	N/A
12	Small Octopus	N/A
13	Octopus	New Zealand
14	Baby Octopus	USA
15	Baby Octopus	Thailand
16	Octopus (as part of seafood mix)	China
17	Small Octopus	NA
18	Octopus	NA
19	Small Octopus	China
20	Octopus	China
21	Octopus	NA
22	Small Octopus	China
23	Octopus	China
24	Long Arm Octopus	China
25	Octopus	N/A
26	Octopus	Philippines
27	Baby Octopus	Vietnam
28	Small Octopus	Thailand
29	Small Octopus	China
30	Octopus	NA
31	Baby	Thailand
32	Baby	Vietnam
33	Baby	Vietnam
34	Little	Vietnam
35	Baby	India
36	Baby	Thailand
37	Little	India
38	Octopus	China
39	Baby	Thailand

40	Baby	N/A
41	Baby	Thailand
42	Baby	Vietnam
43	Baby	Thailand
44	Baby	N/A
45	Little	N/A
46	Octopus	N/A
47	Baby	N/A
48	Baby	N/A
49	Octopus	N/A
50	Octopus	China
51	Octopus	N/A
52	Baby	Vietnam
53	Baby	Thailand
54	Octopus	N/A
55	Octopus	N/A
56	Octopus	N/A
57	Octopus	N/A
58	Octopus	N/A
59	Octopus	N/A

Fig. 1. Table showing sample number, describing how each sample was labeled at the location of purchase, and information on the country of production, if available.

DNA was extracted using the QIAGEN DNeasy Blood & Tissue Kit from octopus tissue samples up to 25 mg. Manufacturer protocols for animal tissue were followed for the DNA extraction. The mitochondrial genes for 16S rRNA and CO1 were targeted for amplification by PCR using primers from (Palumbi 1996) and Folmer et al. (1994) respectively. PCR reactions consisted of 12.5 μl of GoTaq Green Master Mix (Promega), 10 pmol of each primer (either for 16S or CO1), and approximately 100 ng of sample DNA in a total volume of 25 μL. The thermal cycler protocol for 16S was as follows: 35 cycles of amplification of the target sequence with an initial denaturation at 95°C for 3 minutes, and post-amplification extension at 72°C for 7 minutes. Each cycle consisted of 30 seconds at 95°C, 1 minute at 50°C, and 1 minute at 72°C. The thermal cycler protocol for CO1 consisted of 5 cycles of amplification followed by 30 additional cycles of amplification under different constraints, with initial denaturation for 3 minutes at 94°C, and post-amplification extension for 5 minutes at 72°C. The first 5 cycles of amplification consisted of 30 seconds at 94°C, 45 seconds at 47°C, and 1 minute at 72°C. The following 30 cycles consisted of 30 seconds at 94°C, 45 seconds at 52°C, and 1 minute at 72°C.

Three μL of each PCR product was loaded onto a 2 % agarose gel with gel red to determine the success of the amplification process and then visualized with a UV illuminator. To prepare the PCR product for sequencing, product was cleaned using Sephadex spin column. Resulting DNA was measured using Nanodrop Spectrophotometer ND-1000, and then prepared for sequencing.

Sequencing was performed by Retrogen Inc. (San Diego) using the primers described above to sequence the forward strand of each gene. Sequences were trimmed and identity assessed using BLAST at the National Center for Biotechnology Information. Hits that resulted in a 95 percent match or more were taken as positive matches. All sample sequences were edited and aligned in Mesquite (Maddison and Maddison) with top matches from GenBank for the purpose of creating data matrices to determine the degree of relation among the different sequences. Using TCS (Clement) and Popart (Leigh et al.), PAUP* (Swofford) parsimony networks and/or phylogenetic trees (neighbor-joining) were created and visualized. Outgroups were chosen to root the phylogenetic trees by choosing the next most distant BLAST hit. These outgroups were excluded from the network analyses. Fig Tree (Rambaut) was used to examine phylogenetic trees and Popart networks were used to assess the degree of relation between sequences and their countries of production.

Results

Sample	Top GenBank Match
1B	A. marginatus 95%
2	A. aegina 99%
3A	O. sp. BOLD:ABA1887 99%
4A	A. aegina 99%
4B	A. aegina 100%
5	O. cyanea 99%
6	O. cyanea 99%
7B	O. cyanea 98%
8	O. minor 100%
9A	O. minor 99%
9B	O. minor 99%
10A	A. ovulum 94%
10B	O. ocellatus 98%
11	O. cyanea 99%
12A	A. aegina 99%
12B	A. aegina 99%
13	O. cyanea 99%
14	A. aegina 96%
15	A. aegina 99%
16A	A. marginatus 90%
16B	A. kagoshimensis 97%
17A	A. aegina 99%
17B	A. aegina 85%
18	O. minor 99%
19A	O. minor 98%
19B	O. minor 99%
20A	O. minor 99%
20B	O. minor 99%
21A	O. minor 98%
21B	O. minor 96%
22A	O. minor 99%
22B	O. minor 97%
23A	O. minor 98%
23B	O. minor 99%
24	O. minor 97%
25A	O. minor 99%
25B	O. minor 98%
26	O. cyanea 99%
27A	O. sp. BOLD:ABA1887 98%
27B	A. marginatus 94%
27C	O. sp. BOLD:ABA1887 99%
28A	A. aegina 100%
28C	A. aegina 100%
28D	A. aegina 99%
29A	O. minor 99%
29B	O. minor 99%
30	O. cyanea 96%
31A	A. aegina 99%
31B	A. aegina 99%
32A	A. aegina 99%
32B	A. aegina 99%
34A	A. aegina 99%
34B	A. aegina 99%
35A	O. sp BOLD:ABA 1887 97%
35B	O. sp BOLD:ABA 1887 98%
35C	O. sp BOLD:ABA 1887 99%
36A	A. aegina 100%
36B	A. aegina 100%

37A	A. aegina 99%
37B	A. aegina 99%
37C	A. aegina 100%
38A	O. minor 98%
38B	O. minor 98%
38C	C. minor 99%
38D	C. minor 98%
39A	A. aegina 99%
39B	A. aegina 99%
39C	A. aegina 99%
40A	A. aegina 99%
40B	A. aegina 99%
40C	A. aegina 99%
41A	A. aegina 99%
41B	A. aegina 99%
42A	A. aegina 99%
42B	A. aegina 99%
43A	A. aegina 99%
43B	A. aegina 99%
44A	A. aegina 99%
44B	A. aegina 99%
45A	A. aegina 99%
45B	A. aegina 100%
46A	A. fangsiao 91%
46B	A. aegina 99%
47A	A. aegina 97%
47B	A. fangsiao 92%
48A	A. aegina 96%
48B	A. fangsiao 96%
49A	O. minor 97%
49B	O. fusiformis 98%
50	O. minor 97%

51	O. variabilis 98%
52A	A. aegina 96%
52B	A. aegina 97%
53	A. aegina 98%
54A	O. minor 98%
54B	O. minor 95%
55A	O. minor 98%
55B	O. fusiformis 99%
56A	O. fusiformis 98%
56B	O. fusiformis 96%
57A	O. variabilis 98%
57B	O. fusiformis 97%
58	O. minor 97%
59	O. fusiformis 97%

Fig. 2. Top GenBank match for each sequence obtained in the study.

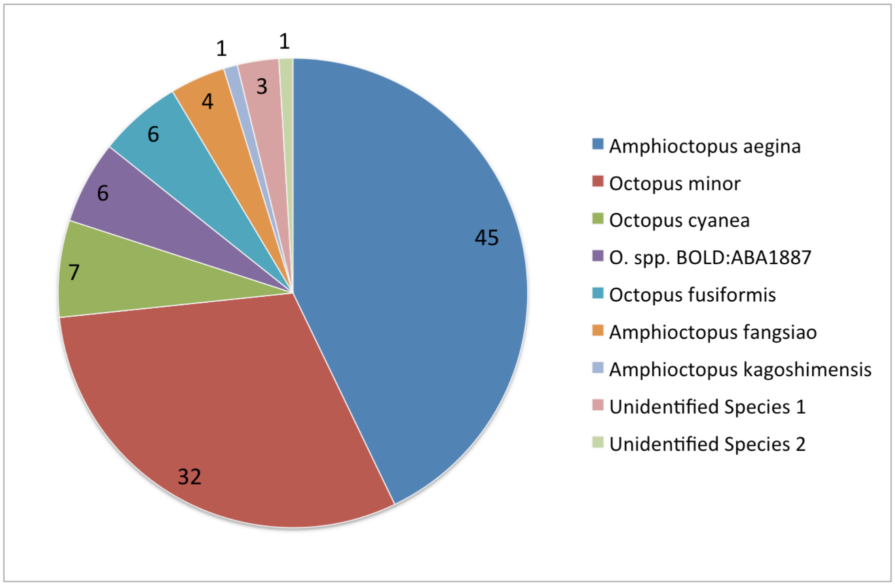

Fig. 3. Number of sequences obtained for each species. Sequences that BLASTED identically but under two synonymous names are included in the count for the currently accepted species name.

DNA was extracted from all of the 59 samples, with varying degrees of success among the samples that contained multiple individuals. In all, the study produced 105 individual sequences spanning the 59 samples. COI proved to be the most effective primer pair for the PCR amplification, with eighty-nine produced using CO1 and the remaining sixteen using 16S when CO1 failed. Six of the 105 sequences resulted in BLAST matches below 95 percent, and phylogenetic trees were created to more accurately determine species identity. Of the forty-one samples that contained multiple individuals, nine samples contained more than one species.

Below are short descriptions on the species identified, ranked in the order of most common to least common in terms of number of sequences obtained in the study.

Identified Species

With high probability: 7

The following species were acquired from sequences that resulted in 95 percent or higher identities with GenBank sequences, and showed high enough degrees of relation among similar sequences in TCS/Popart networks and PAUP*/Fig Tree phylogenetic trees to confirm a species identity.

Amphioctopus aegina **(Gray, 1849)**

Common Name: Marbled Octopus, Sandbird Octopus

Amphioctopus aegina, sometimes listed as *Octopus aegina*, is a moderate-sized species found in coastal waters of continental Asia, from India to China, and also south to Malaysia and Indonesia (Jereb et al., 2014). It is particularly common in Thai waters (Promboom et al., 2011). According to Jereb et al., (2014) this species "forms the basis of large export trawl fisheries" in the Gulf of Thailand, and is one of two species heavily fished in this area of the world (Norman, 2003). Also noted is the fact that it is often labeled with other *Amphioctopus* species as "baby octopus" in seafood markets around the world (Jereb et al. 2014, Norman 2003), and was labeled as "little" or "baby octopus" in markets visited in this study. In places where it is fished, it is often labeled under the name *Octopus dollfusi*, which is arguably a synonym species name (Lü et al., 2013). Norman writes of an *A. aegina* species complex, which contains more than 10 related species, some of them unnamed (Norman, 2003). *A. aegina* is sometimes misidentified as *A. kagoshimensis,* another species found in this study.

Upon making the phylogenetic trees for the sequences resulting in this species, two distinct groups were found (Fig. 4). Taking into consideration the *A. aegina* species complex, it is reasonable to assume cryptic species may be present in the study. Minimum pairwise distance of study sequences and those matched in GenBank is 3%.

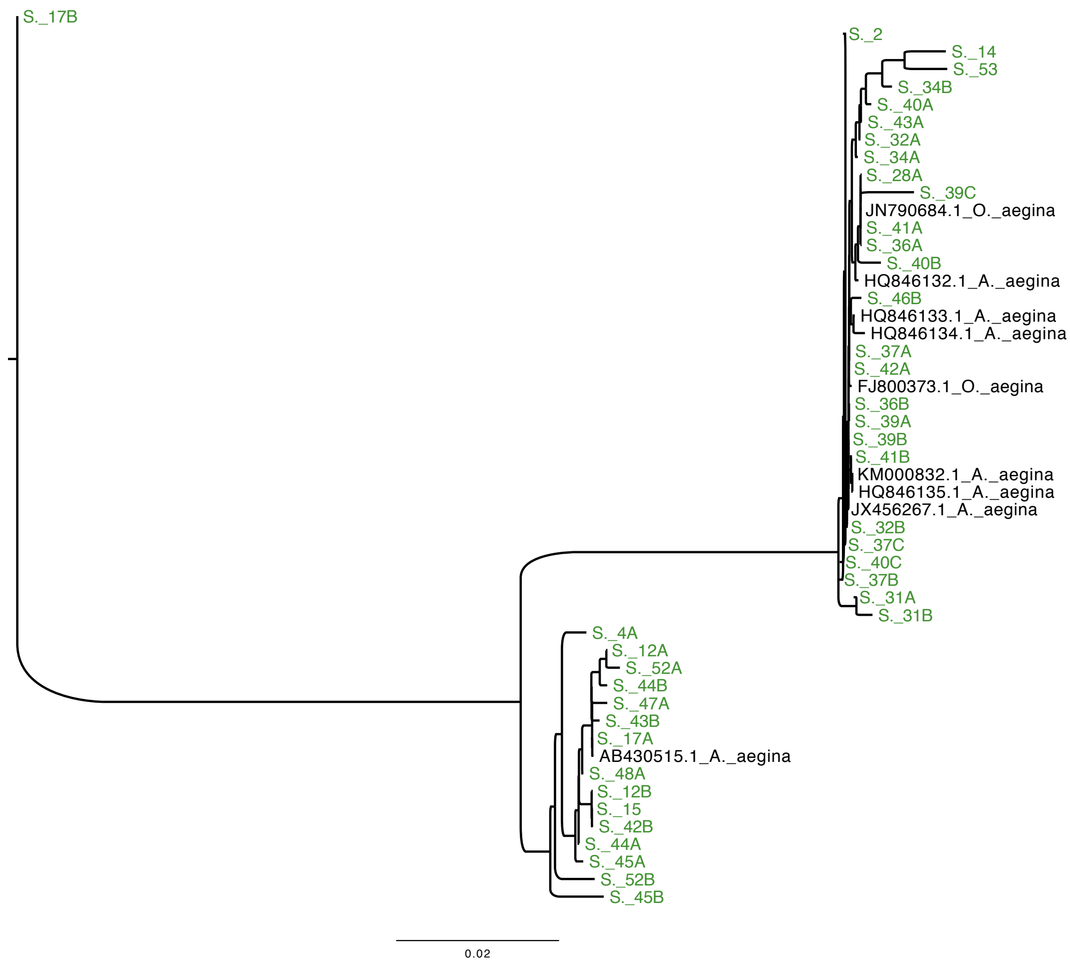

Fig. 4. Evolutionary tree of *A. aegina* GenBank sequences and matching samples from the study (in green), showing distinct clustering in two groups.

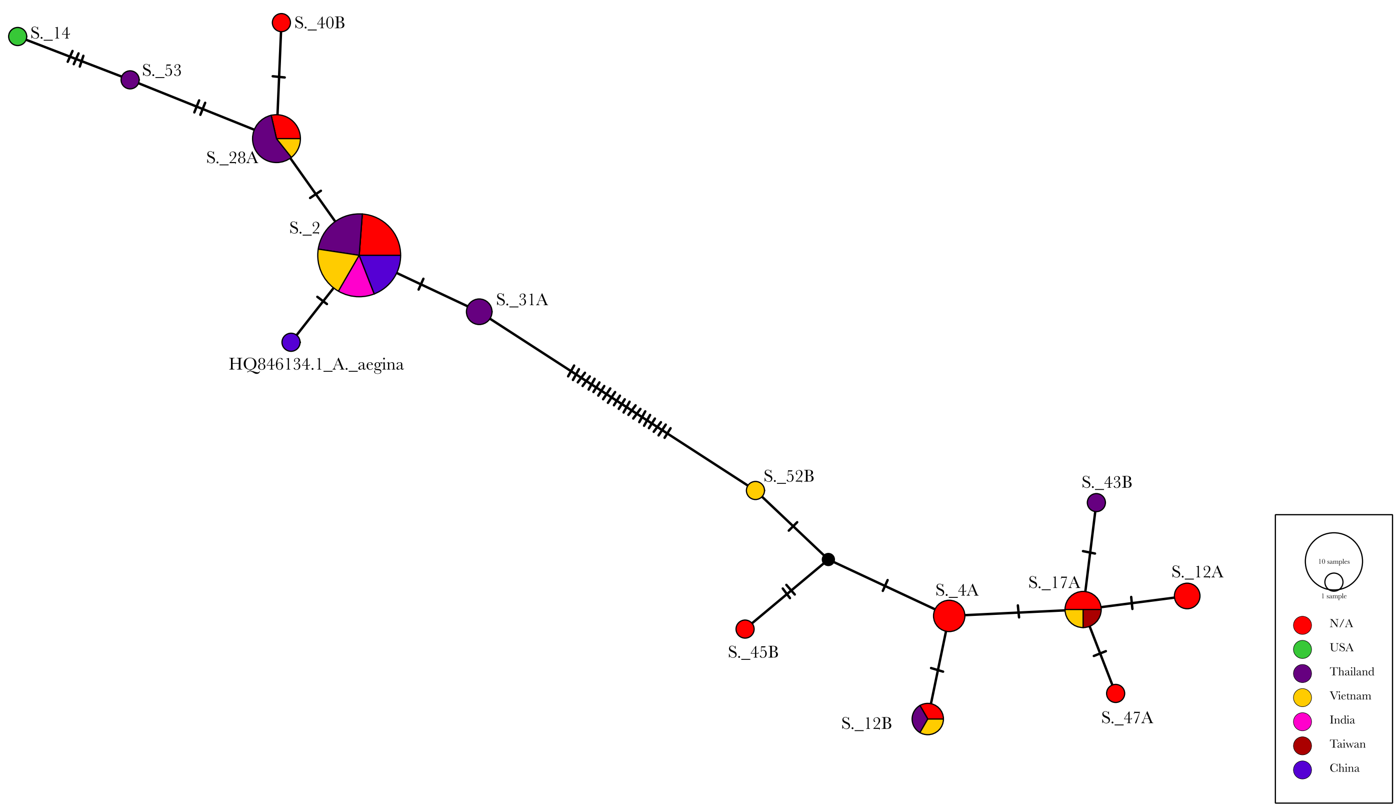

Fig. 5. Further analysis of *A. aegina* GenBank sequences and matching sample sequences (S._#), demonstrated through Popart network. Geographic color-coding suggests that cryptic *Amphioctopus* species share similar ranges (=sympatric).

***Octopus minor* (Sasaki, 1920)**

Common Name: Whiparm Octopus

Octopus minor is a small to moderate species, distinguished by its elongate body form with long, slender arms (Jereb et al., 2014). It is found from Russian waters north of Japan, around the Japanese islands, and potentially as far south as Hong Kong. Jereb et al. (2014) state that this species is important commercially in Japan. This species is sometimes called *Callistoctopus minor*.

This species was fully labeled in one sample in the study. A frozen package containing one specimen was labeled “Longarm octopus.” This was the only sample to have any label that included a common name, albeit one that is not mentioned by Jereb et al. (2014) Not to be confused with the Atlantic or Lilliput longarm octopus, *Macrotritopus defilippi (citation)*.

Two sequences from the study yielded the species *Octopus variabilis* (Sasaki, 1929), but based on Jereb et al. (2014), this species is a junior synonym of *O. minor*.

***Octopus cyanea* (Gray, 1849)**

Common Name: Big Blue Octopus

This a large, muscular species found through the Indo-Pacific, from West Africa to the Hawaiian Islands. Throughout its range, it is fished for both subsistence and commercial purposes (Jereb et al., 2014). It is fished with spears and lures (Jereb et al., 2014), and trawls in certain parts of its range, particularly the Philippines (Seafood Watch, 2011).

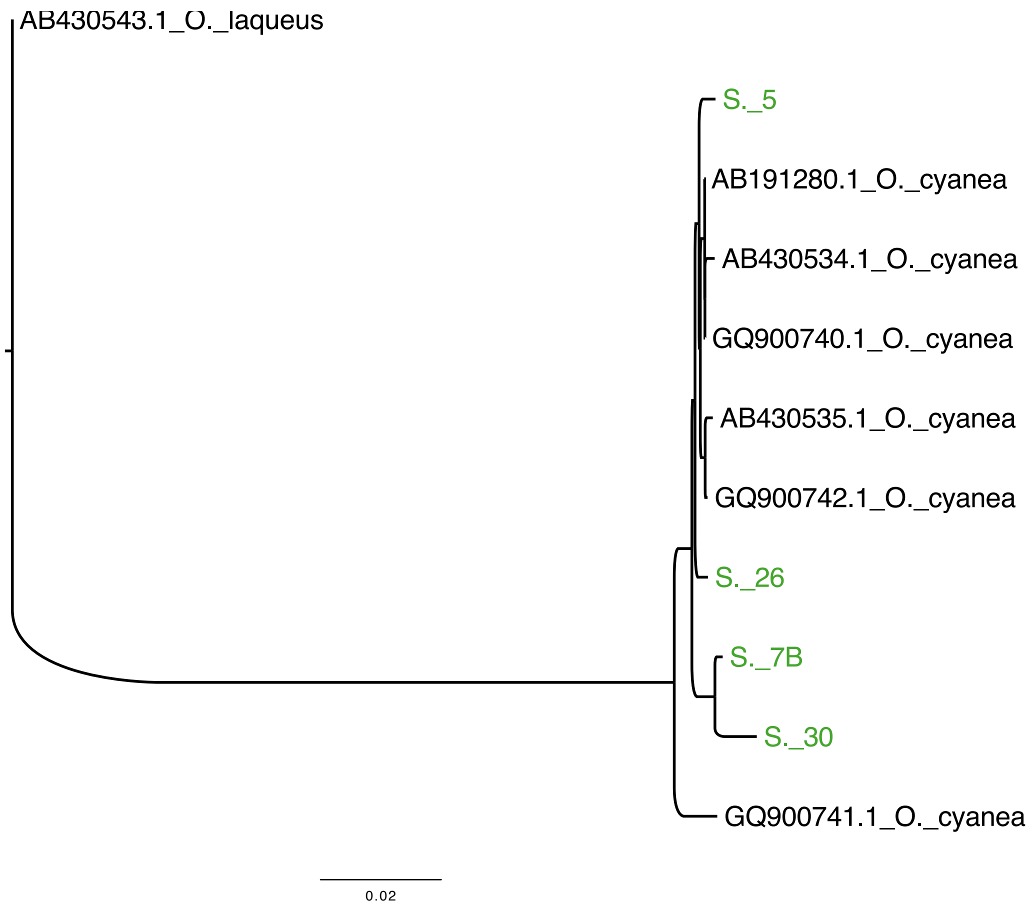

Fig. 6. Evolutionary tree showing clustering of study samples with GenBank sequences of *O. cyanea*.

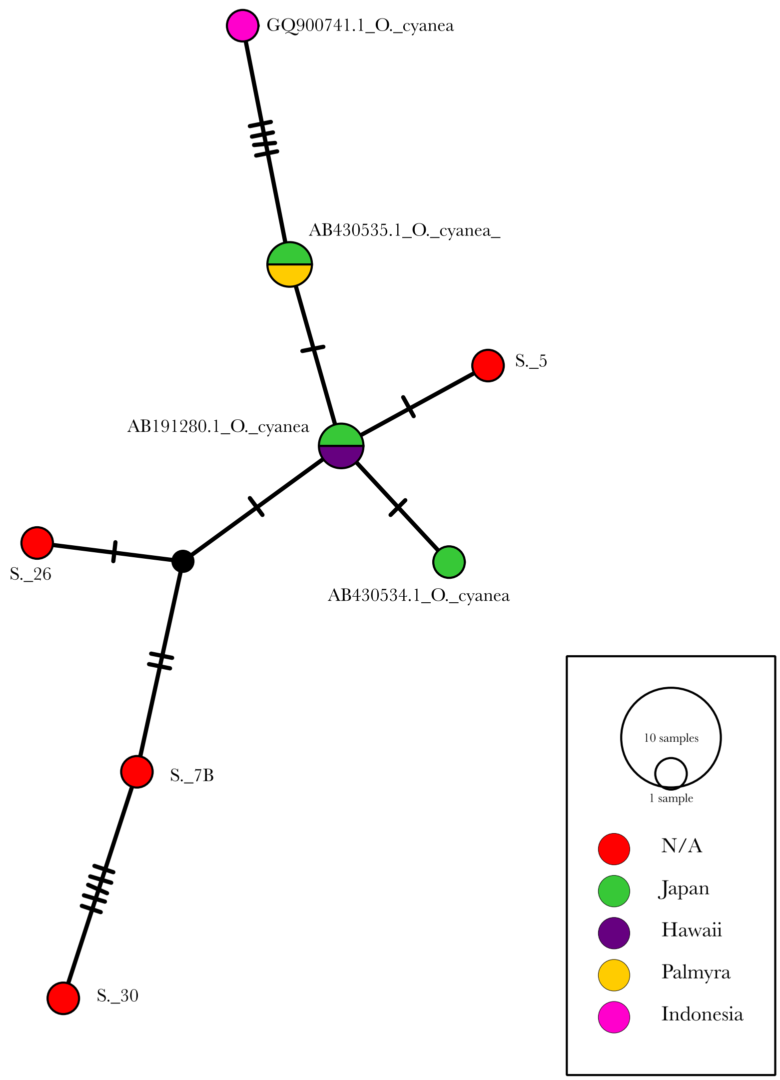

Fig. 7. Phylogenetic network showing degree of relation among *O. cyanea* haplotypes from the study and GenBank sequences.

Octopodidae sp. BOLD:ABA 1887

Common Name: none

A yet unclassified species, *O*. sp. was described in a paper by researchers from the University of Kerala in India (Appukuttan Nair and Vijayamma, 2014). Coincidentally enough, samples that resulted in this species were labeled as "Product of India."

***Octopus fusiformis* (Brock, 1887)**

Common name: none

Like *O. minor*, this is species exhibits long arms and a slim body (Lü et al., 2013) Not mentioned by Jereb et al. (2014) in their report, little is known on this species.

***Amphioctopus fangsiao* (d'Orbigny, 1839-1841)**

Common Name: Gold-spot octopus

This is a small to moderate-sized species found from the south coast of Hokkaido, Japan, south to Taiwan and Hong Kong. It is fished on a large scale, mostly as bycatch in trawl fisheries operating along the coast (Jereb et al., 2014).

One sequence from the study BLASTes as *O. ocellatus*. However, according to Jereb et al. (2014), *O. ocellatus* is a synonym of *A. fangsiao*, along with the names *O. areolatus* and *O. membranaceous*.

***Amphioctopus kagoshimensis* (Ortmann, 1888)**

Common name: none

Sometimes misidentified as *O. aegina*, this small, robust species is found from

Southern Japan south to Taiwan. In terms of fisheries importance, *A. kagoshimensis* is sometimes caught as bycatch in coastal Japanese trawls (Jereb et al., 2014).

Without Certainty: 2

Though some sequences for the following specimens resulted in 95 percent matches with GenBank sequences, TCS networks and PAUP* phylogenetic trees did not yield conclusive enough results to declare a single species found. The following are organized into two groups based on top matches, with descriptions of the multiple species that the specimens may belong to.

Undetermined Species 1:

Top Matches: *Amphioctopus marginatus* (Taki, 1964), *Amphioctopus arenicola* (Huffard and Hochberg, 2005), *Amphioctopus aegina* (Gray, 1849)

Three sequences resulted in identical matches with the above three species. Phylogenetic analysis did not resolve ambiguities (Fig. 7), evidence that there are one or two species of unknown identity.

A. marginatus

Common Name: Veined Octopus, Coconut Octopus

A moderate-sized species. *A. marginatus* is found from the tropical Indian Ocean to Japan, reaching south to Northeastern Australia (Jereb et al., 2014). It is commercially important and harvested with pots, trawls, and lines. This species is well-known for its peculiar defensive behaviors, in which it will carry coconut or bivalve shells to be used as shelter.

Amphioctopus arenicola

Common name: none

Described from a type specimen collected off Oahu in the Hawaiian Islands, little is known about this small species, and it appears to have no significance to fisheries (Jereb et al., 2014).

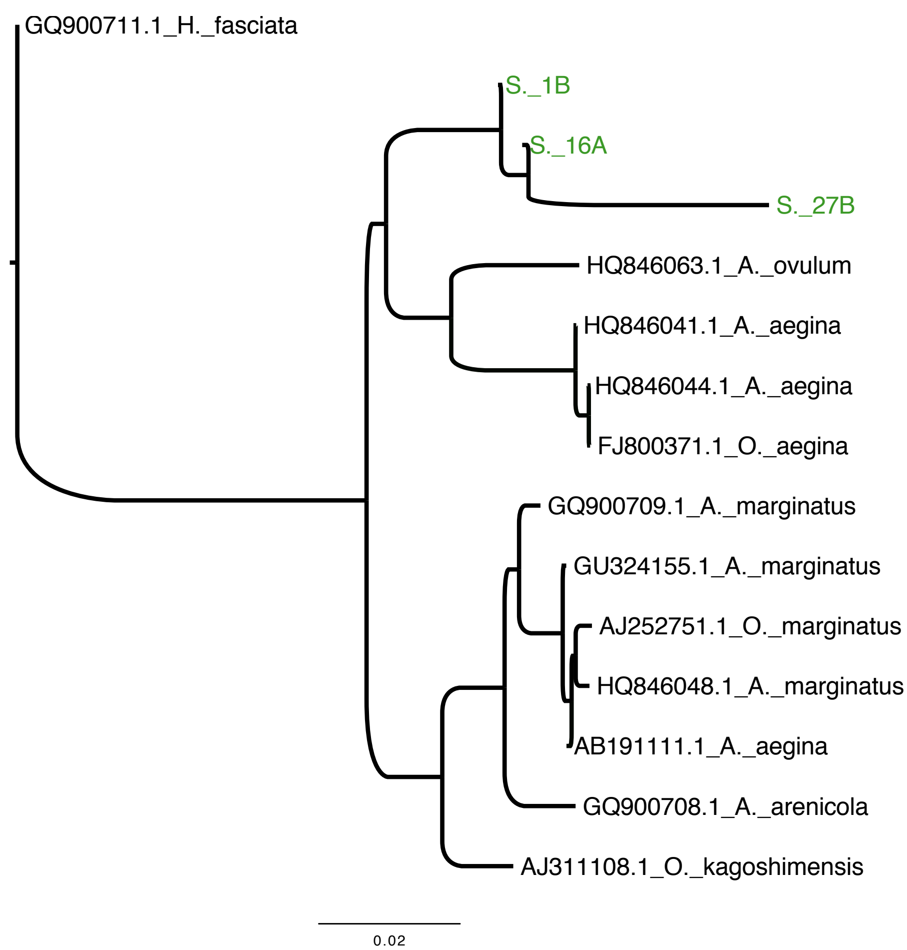

Fig. 8. Evolutionary tree showing clustering of study samples on separate branches than those of top GenBank sequences. Minimum pairwise distance between study sequences

and those of GenBank is 4%.

Undetermined Species 2:

Top Matches: *Amphioctopus ovulum* (Sasaki, 1917), *Amphioctopus aegina* (Gray, 1849)

This one sequence resulted in species ambiguity among *A. ovulum* and *A. aegina*. Both species were matched at 94 percent, and phylogenetic tree analysis did not yield conclusive results. The sequence matches for both species come from the same study, by Dai et al. (2012), that barcoded cephalopod species from Chinese waters.

Little information exists on *O. ovulum*. Most of the available information comes only from the type specimen discovered in a fish market in Japan. The range of this species is unknown, and it is only distinguished from other *Amphioctopus* species on the basis of its small eggs (Jereb et al., 2014).

Discussion

Octopus Taxonomy

According to Jereb et al. (2014), "the single largest impediment to accurate catch statistics is the historically poor state of octopus taxonomy and the limited identification tools available." They continue, stating that as a result very few species are recognized in catch statistics worldwide, and scientific understanding of many aspects of the remaining species is very much lacking. Norman and Hochberg (2005) estimated that the number of benthic octopus species in the world is likely to be greater than 300, and a large number of them have yet to be formally described. They estimate that more than 100 of these benthic species are probably caught in worldwide fisheries, and stress that despite this, only four species are listed in global summary statistics. These include the common octopus (*Octopus vulgaris),* the Mexican four-eyed octopus (*Octopus maya*), the horned octopus (*Eledone cirrhosa*) and the musky octopus (*Eledone moschata*). The rest are simply left as "undescribed octopus" (Jereb et al., 2014).

Interestingly, the greatest diversity of octopus species is found in the tropical Indo-West Pacific, particularly the Indo-Malayan archipelago (Jereb et al., 2014). Coupled with this is that fact that "the rate at which species are being discovered is significantly higher than the rate at which they are being described" (Norman and Hochberg 2005). With the majority of octopus production occurring in the area of the world with the greatest octopod diversity, it is worthwhile to further analyze these fisheries and their catches to not only provide accurate catch records, but to also increase taxonomic understanding of octopod species. Currently, GenBank contains CO1 sequences for roughly 80 octopus species. Seeing as some sequences obtained in the study did not yield conclusive results, or are evidence that multiple species are listed under one single species name, it is worthwhile to continue to describe octopus taxonomy and further review available sequences on GenBank.

Of the species that have been described, there are still taxonomic misunderstandings and ambiguities that need to be resolved. According to Jereb et al. (2014), *A. fangsiao* is "sometimes listed in fisheries statistics under the synonym names *O. ocellatus* and *O. areolatus*, or the unresolved name *O. membranaceus*." *O. minor* also presents taxonomic difficulties, as they claim that this species name is most likely being applied to a host of long-armed species that inhabit the cooler coastal waters of Russia and the northern areas of Japan, south to warmer Chinese waters. For this reason, the report stresses that "*O. minor* is in urgent need of review."

Interestingly, all *O. minor* specimens bought in the study (those that included country of production labeling at least) came from China. Given the uncertainty of where exactly the specimens were fished, exact assumptions cannot be made, but this could perhaps be further evidence of the above claims, or evidence that *O. minor* does in fact extend into Chinese waters, assuming that the specimens were fished in these areas. This finding also lends an air of urgency to reviewing available GenBank sequences of *O. minor*, in order to better understand which species may be misidentified as *O. minor*.

As Norman and Hochberg state, "as these animals receive a higher profile in fisheries, biodiversity and behavioral studies, the need for thorough and detailed taxonomy is higher than ever before." Future detailed studies building off of this one could help clear up gray areas of octopus taxonomy. The potential of 16S and CO1 mitochondrial genes to be used as molecular markers in order to identify and resolve octopus taxonomy ambiguities is strong (Lü et al., 2013).

Fisheries Management

The majority of available information for octopus fisheries around the world seems to focus heavily on those that target *Octopus vulgaris*, specifically those fisheries in Mediterranean and Eastern Atlantic countries. Most readily available octopus fisheries statistics simply refer to *O. vulgaris*, used almost as a kind of blanket term for octopus fisheries. Despite *O. vulgaris*' omnipresence in literature and fisheries statistics, none of the sequences from this study yielded this species. This study reaffirms the assertions made in Jereb et al.'s (2014) report on commercially important cephalopod species, which states that members of the genus *Amphioctopus* and the *Octopus minor* group are among the most common species caught in Asian fisheries. According to the report, Asia claimed the most octopus production in 2010, with landings exceeding 215,500 tons, with most of this catch comprised of unidentified octopus species. In the Gulf of Thailand alone, over 10,000 tons of octopus were landed in 2010. Total Southeast Asian production of octopus, including Japan, totaled over 200,000 tons in the same year.

Despite the sheer size of worldwide, especially Asian, octopus fisheries, few accurate data exist. It is not uncommon for countries with octopus fisheries to have little to no direct management, and catch statistics are slim at best. When the information is available, it is oftentimes based mostly on export data estimates (Jereb et al., 2014). Furthermore, octopus bycatch by fisheries targeting other species is often unreported, and estimates have shown that this unreported catch could perhaps add an extra third to a nation's octopus production. Given these catch statistic irregularities, Jereb et al. (2014) suggest that "global catch data for octopuses should be considered a very rough estimate of total harvest, and likely to be a considerable underestimate." With growing fisheries in many Eastern and Southeast Asian countries, there is much potential to understand their landings and fisheries dynamics, especially given the diversity of octopods in the region and the unidentified species often landed.

Resource Sustainability

Octopus has generally been considered a sustainable resource, especially when compared to the current and past situations of global fish stocks. However, Jereb et al. (2014) stress that the idea of sustainable octopus fisheries is not strengthened by detailed information on the “biology, distributions, stock assessments, and/or impacts of fisheries on stocks or reproductive cycles.” In fact, some stocks have been labeled overfished. The Food and Agriculture Organization’s *General Situation of World Fish Stocks* claims that *O. vulgaris* in Italy and Spain are overfished, along with various octopus species in Morocco, Senegal, and Mauritania (FAO, 2011). Chotiyaputta et al. (2002) claim that octopus resources in the Gulf of Thailand have been fully exploited since 1989.

Further assessments could shed light on possible management concerns and overexploited stocks. Jereb et al.’s (2014) comments about octopus bycatch raise questions about resource sustainability. Another emerging concern is potentially harmful fishing methods. The use of trawls as a means to catch octopus has drawn the attention of seafood sustainability groups, who cite the destructive nature of trawls as a reason to explore alternative catch methods. Monterey Bay Aquarium’s Seafood Watch advisory team warns against the destructive trawl fishery of *O. cyanea* in the Philippines and *O. vulgaris* in Spain, to name a few (Seafood Watch 2011, 2014). Given *A. aegina’s* wide market presence, and claims that the species is fished through trawls, further review on the scale of the fishery and the potential side effects of the trawls in question could be investigated for sustainability reports that widen the scope to more species than just *O. cyanea* and *O. vulgaris*.

Seafood Labeling

Under the Country of Origin Labeling law, is it required that seafood retailers include labeling for the country of origin/production for the products being sold (7CFR1.60.133). Twenty-eight of the fifty-nine samples acquired in this study did not include country of production labeling, directly violating this law. In order to better understand the species composition of octopus in American seafood markets, it is necessary to look at the country of production information, but the lack of available required information not only makes researching these fisheries more difficult, but perhaps suggest a laissez-faire attitude when it comes to cephalopod seafood labeling. Seeing as there are at least seven different octopus species in Southern California seafood markets, it would be beneficial to provide more accurate labeling in regards to the trade dynamics of these products.

Furthermore, a question of accuracy in relation to octopus physiology is raised. All but one of the samples that were labeled "baby octopus" were actually smaller species, such as *A. aegina* and *A. marginatus*. The one outlier was an *O. cyanea* specimen that was labeled "baby octopus." Norman and Jereb et al. (2014) describe this labeling, but the question is left open of whether these smaller species are purposefully labeled as "baby octopus" for commercial purposes or if those operating the fisheries and/or seafood markets are under the assumption that they are fishing and selling immature individuals.

Conclusion

Multiple octopus species are present in Southern California seafood markets. Most of these products originate from Asian countries, and this area of the world sees the most octopus production. However, little is known about the fisheries dynamics of the countries and the various octopus species that are being caught. As this area of the world has the greatest octopod diversity, it is worthwhile to further investigate these fisheries for catch statistics and species composition purposes. Such studies could benefit the areas of octopus taxonomy, fisheries management, resource sustainability, and seafood labeling. This study provides parallel information to Jereb et al.'s 2014 report and reaffirms the need for more attention to be given to Asian octopus fisheries statistics and octopod taxonomy.

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