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Using DNA Barcoding to Identify Seafood Fraud in Puerto Rico

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Abstract—**DNA barcoding is a powerful tool that can be effective for identifying unknown seafood samples when morphological characteristics are unreliable. Additionally, DNA barcoding has proven useful for identifying illegal trade such as commercial seafood fraud, and the technique has advanced such that it can be used to identify even highly processed products such as jerky, dog food, and cosmetics. In Puerto Rico, a popular local fried turnover called "*empanadillas de chapín*" are allegedly prepared using other fish or meat products as a substitute for the traditional smooth trunkfish (*Lactophrys triqueter*), known in Spanish as *chapín*. Sharks and rays are commonly sold for local cuisine; however, it is unknown which species of sharks or rays are being consumed. Driven by these unconfirmed reports of substitutions and the consumption of protected shark species, we sought to identify the prevalence of this allegedly common yet unverified type of seafood fraud, using DNA barcoding. Fifteen fish species were identified as substitutes for *chapín* including elasmobranchs and imported freshwater species. Furthermore, this molecular forensic technique also identified nine shark species sold as fillets in local cuisine, of which the majority were misidentified to the consumer. The meat source inside these fried turnovers and shark meat products could be identified even after it was cooked and visually unrecognizable. This study demonstrates, for the first time, that rays are being consumed in Puerto Rico, and confirms the report that a variety of native and imported fish are being substituted for *chapín* in the local cuisine.**

Seafood fraud is defined as a criminal activity and is typically committed to obtain financial benefits from unaware consumers (Reilly 2018). Various activities can be defined as seafood fraud, including mislabeling, substitution, counterfeiting, misbranding, dilution, and adulteration of seafood. Unfortunately, this activity is considerably common and most often occurs at restaurants and smaller markets rather than in large chain grocery stores (Warner et al. 2019). Seafood fraud can be committed at different stages throughout the supply chain. For instance, one of the most common forms of fraud is the substitution of target species for lesser quality species. The lesser quality species may be enhanced by undeclared chemical agents such as sodium tripolyphosphate and the use of carbon monoxide, which are used to increase weight and to maintain or improve fish flesh appearance (Reilly 2018). In 2010, the non-profit organization Oceana conducted seafood fraud studies and found that one-third of 1,500 samples tested were mislabeled, and one in three of the commercial establishments that were visited were found to sell at least one mislabeled seafood product in United States (Warner et al. 2019). Besides substitution, the second most common form of seafood fraud is mislabeling. Intentional mislabeling occurs when sellers or distributors use a different species name or a generic name to hide the geographical origin of illegally harvested species (Reilly 2018). This action is widely used to hide catches of protected/vulnerable species (Muttaqin et al. 2019), while overglazing, overbreeding, and the use of undeclared water-bindings to increase weight (Reilly 2018), lead to misled consumers regarding the nature of fishery products.

Consumers are generally unaware of seafood fraud, especially if is cooked. The appearance, taste, and texture are very similar between fish species, which makes it difficult to identify the species correctly. In addition, fish markets and restaurants often sell these products using generic names (Reilly 2018). For example, a study from Oceana found that businesses labeled fish products generically as "snapper" when the product actually represented 11 different species of snappers and even included other non-snapper fish species such as tilapia (Warner et al. 2019). In a similar way, consumers can unknowingly purchase shark meat when it is advertised as some other non-shark fish species. In southern Brazil, some markets were observed to sell meat under a general name "Cação," which translates to dogfish, and which most consumers do not associate with shark meat (Bernardo et al. 2020). In other cases, there are potential risks to public health, considering the possibility that non-toxic fish are being substituted with toxic fish or farmed/freshwater species from polluted water sources (Reilly 2018). Finally, the mislabeled or substituted seafood products can sometimes be obtained from a protected or critical-status species (O'Bryhim et al. 2017), which poses an ethical dilemma for some consumers who actively seek to avoid consuming unsustainable seafood, such as many sharks and rays.

Elasmobranchs, which are distinguished from bony fishes in that their skeletons are composed of cartilage, are overexploited at dangerous rates worldwide (Steinke et al. 2017). Although international laws exist to protect elasmobranchs, worldwide demand for shark and ray cuisine (e.g., fish meat, fin soup, liver oil, and gill plates), along with traditional and cultural medicinal practices, has increased fishing pressure on at least 1,038 species (Hellberg et al. 2019). Elasmobranchs are often intentionally mislabeled when sold to fish markets and restaurants; this practice has become a more prevalent concern in many developing countries, such as Mozambique, Costa Rica, India, Sri Lanka, and Indonesia (Vannuccini 1999 in Bornatowski et al. 2013). Intentional mislabeling of elasmobranchs in Brazil was found to be used to control and reduce any perceived negative association with the capture, species type, and origin of elasmobranchs (Almerón-Souza et al. 2018). However, molecular techniques have successfully aided in uncovering the mislabeling of shark meat. A recent study found that 43.3% of the total collected samples belonged to shark species listed in some IUCN risk category (Bernardo et al. 2020).

In Puerto Rico, the catch and consumption of elasmobranchs has been suspected for some species, and sometimes directly observed. Specifically, there were allegations by local citizens that rays (e.g., *Hypanus americanus* Hildebrand & Schroeder, 1928) were being harvested with the intention of substituting their meat in place of smooth trunkfish (*Lactophrys triqueter* (Linnaeus, 1758)), or boxfish, known locally in Spanish as *chapín*. Consumers purchase "*empanadillas de chapín*"/smooth trunkfish turnover, a typical local fried dish made with smooth trunkfish meat, and assume they are consuming *chapín*, but instead are eating other species of fish, such as rays, triggerfishes, or even sharks. Boxfish in the Caribbean are highly valued for their flavor and quality of meat (Matsuura 2013). However, in Puerto Rico, fishmongers frequently sell *chapín* to restaurants and occasionally fishers will retain the *chapín* for personal consumption. Although the *chapín* turnovers are a very popular dish, fishers do not often catch significant quantities of it. Consequently, this higher value meat averages approximately five to six U.S. dollars per pound whole, compared to, for example, some snappers which have a value of approximately five U.S. dollars per pound filleted. Furthermore, the impact ofn the fishing of smooth trunkfish and boxfishes in Puerto Rico is still unknown. Nonetheless, as smooth trunkfish become more difficult to find, restaurants are forced to use other fish as a means to satisfy customer demands.

The substitution and mislabeling of elasmobranchs in Puerto Rico may be a result of the fishers' and fishmongers' lack of discrimination between species, fish sizes, and life stages (anonymous, Department of Natural and Environmental Resources of Puerto Rico, DNER-PR, pers. comm.), leading to the introduction of untargeted species and juveniles into the fishery. A lack of education on proper identification of elasmobranchs could be perpetuating the indiscriminate catch of sharks and rays and their resulting presence in the fishery. Worldwide, and locally, rays are very poorly understood due to the lack of research or data limited fisheries (Bräutigam 2015), yet they are one of the most vulnerable taxa among elasmobranchs (Wannell et al. 2020). Presently, there are no management actions in place for these species. According to fishery managers, the lack of regulations is stemming from the perception that rays are not regarded as target species and are consumed unknowingly and undocumented. The Puerto Rico/NMFS Cooperative Fisheries Statistics Program reported landings of rays by commercial fishers from April 2012 to March 2018 (Matos-Caraballo 2018). However, reports of these landings were sporadic since rays were not a taxon of interest on landing forms. Currently in Puerto Rico, sharks are rarely reported in catch data. Although previously considered part of the fishery, sharks do not presently contribute a large portion to Puerto Rico's commercial market (National Marine Fisheries Service, 2019). Another elasmobranch, the nurse shark (*Ginglymostoma cirratum* (Bonnaterre, 1788)), is locally regulated despite a lack of catch data or population estimates. The nurse shark has been protected from fishing, possession, and sale since 2004 (No. 7949-section 8.27-New fishing regulation of Puerto Rico-2010). A recent study found that nurse sharks were sold to local fish markets (Franqui-Rivera 2020), which demonstrates seafood fraud, namely the prohibited take and sale of a protected species. However, to ascertain the prevalence of this fraud, expanded sampling is necessary to better understand the frequency with which nurse sharks are caught and sold for consumption, and how often they are mislabeled as other shark species.

This study used DNA barcoding in a forensics-like methodology to identify the use of rays and a variety of other fish in *chapín* turnovers, as well as the sale of threatened shark species in the local fish markets. These data can serve as a baseline assessment of the presence of rays for consumption, presenting the first data of its kind in Puerto Rico, while also identifying the various shark species that are sold, as well as cases of mislabeling of sharks for other fish species. The results can serve as the foundation to establish management practices for critical fish species and to inform resource managers about the occurrence of mislabeling and substitution in Puerto Rico's seafood industry.

METHODS

Sample collection and initial processing

Chapín turnovers

All samples were collected from local businesses selling smooth trunkfish turnovers in the coastal towns around Puerto Rico. These businesses were randomly chosen throughout these regions based on the known presence of *chapín* turnovers on the menu. The quantity of samples was dependent on the success of sample collection throughout a one-year period (October 2019–October 2020). Turnovers were collected at a total of 63 locations (n = 63 samples; Table 1). The majority of turnovers were bought unfried, however, the meat inside was already pre-cooked. In addition, all information related to the region and specific local business was recorded.

TABLE 1. Region with number of *chapín* turnovers collected per town.

Region	Number of turnovers collected
North	
Cataño	2
Dorado	1
Barceloneta	2
San Juan	1
Loíza	2
South	
Guayanilla	3
Ponce	4
Guayama	3
Arroyo	1
Patilla	5
Santa Isabel	1
East	
Luquillo	5
Fajardo	2
Naguabo	4
Humacao	4
Yabucoa	4
Maunabo	3
West	
Cabo Rojo	8
Mayagüez	1
Lajas	2
Guánica	5

As each sample was processed, three subsamples of meat (~0.25 oz per subsample) were removed from the turnover and analyzed independently to maximize the likelihood of detecting more than one fish species in the turnover. This methodology was implemented due to differences of texture and color observed in the meat within each turnover (Fig. 1), as it was anecdotally known that businesses often include several species to prepare the fish stuffing. These subsamples were deliberately, but randomly, selected according to color and texture to ensure that a diversity of meat was included in the downstream analyses (Fig. 2). All samples were preserved in 95% ethanol and stored at -20° C.

Shark meat

Shark meat samples were collected from local businesses (restaurants, fish markets) that advertised the

FIG. 1. A sample of a fish turnover collected in Luquillo, where the pre-cooked meat represents the three analyzed subsamples (CR 121, CR 122, and CR 123). The flour-based dough has not been fried.

sale of shark turnovers, *pinchos* (shark meat on a stick, similar to *kebobs*), or fillets. A total of 100 samples were collected including 59 fillets, 33 turnovers, and 8 *pinchos* (Table 2). Any additional information offered by the seller or fisher was recorded, such as: city where captured or sold, date and time of purchase, species, and date of capture. An identification of many of the shark fillets was not offered due to seller misinformation. Tissue from each sample (0.25 oz) was removed and preserved in 95% ethanol and stored at -20°C for downstream analyses.

DNA extraction, amplification, and sequencing

Chapín turnovers

Genomic DNA was extracted from the ethanol-preserved samples using the Qiagen DNeasy Blood and Tissue kit (Qiagen, Germany) following the manufacturer's protocol. Modifications were made at the final step where the DNA was eluted using pre-heated (37° C) AE buffer to a volume of 60 µl (Hellberg et al. 2019). Afterwards, a ~110–130 bp region of the mitochondrial gene Cytochrome Oxidase subunit 1 (CO1) was amplified with polymerase chain reaction (PCR) using mini primers: VF2_t1 Forward, FishF2_t1 Forward, and Shark COIMINIR Reverse (Fields et al. 2015). Additionally, to ensure the amplification for the majority of samples, a universal CO1 fish primer pair (FishF2 forward and FishR2 reverse; Table 3) was used to amplify a fragment of approximately 650 bp (Camacho-Oliveira et al. 2020). Reactions had a final volume of 25 µL and included 4–6 µL of DNA template, 0.25 µL of VF2_t1, 0.25 µL of FishF2_t1, 0.50 µL of Shark COIMINIR, 12.5 µL of KAPA RM Taq, and PCR grade water. The thermal cycling conditions were: initial denaturation at 95°C for three minutes, followed by 40 cycles of denaturation at 94°C for one minute, anneal-

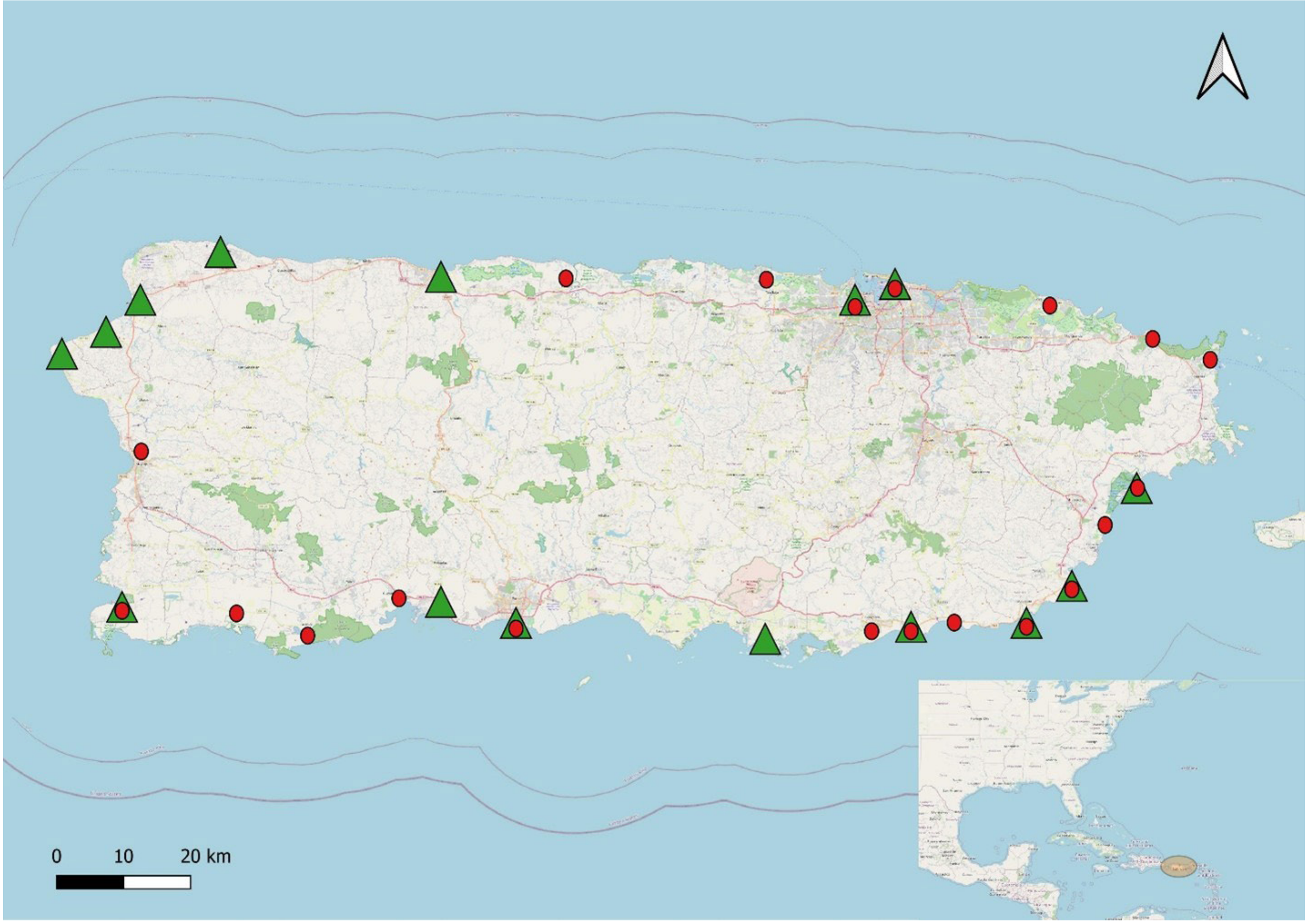

FIG. 2. Map of Puerto Rico with locations of sample collections. Green triangles represent locations where shark samples were acquired (from shark fillets, *pinchos*, and *chapín* turnovers) and red circles represent those where smooth trunkfish (*chapín*) turnovers were collected. This map was created using QGIS v. 3.12.

ing at 52°C for one minute, extension at 72°C for two minutes, and a final extension step at 72°C for five minutes (Hellberg et al. 2019). When performing PCRs with the universal primers, a total volume of 25 μL was used including 4–6μL of DNA template, 0.5 μL FishF2, 0.5 μL FishR2, 12.5 μL of KAPA RM Taq, and PCR grade water. The thermal cycling conditions were an initial denaturation of 95°C for two minutes followed by 35 cycles of denaturation at 95° C for 30 seconds, annealing at 54° C for 30 seconds, extension at 70° C for 40 seconds, and a final extension step at 72° C for five minutes.

The amplicons were then cleaned using ExoSAP-IT (Affymetrix, Santa Clara, CA) to eliminate the remaining dNTPs and unincorporated primers from the PCR products, which were then sequenced using Sanger sequencing at MCLAB (San Francisco, CA). The DNA traces of forward and reverse reactions were checked for errors, end-trimming, and a consensus sequence was created for each sample using Geneious Prime version 2021.2.2. The sequences were checked for homology and identification with BLAST+ 2.12.0. Sequences were compared to reference sequences obtained from GenBank using the Basic Local Alignment Search Tool (BLASTn: https://blast.ncbi.nlm.nih.gov/Blast.cgi) function. Sequence similarity of 97% or higher was used as the threshold for determining the potential species identification. The top BLAST hit was used for identification. Sequence homologies were also checked against the Barcode of Life Database v4.(BOLD) (Ratnasingham and Hebert 2016). The same search criteria were used for both databases.

Shark meat

Genomic DNA was extracted from the ethanol-preserved samples using the Qiagen DNeasy Blood and

TABLE 2. City and number shark meat samples collected in Puerto Rico.

Region	Number of samples
North	
San Juan	3
Arecibo	6
Cataño	8
Isabela	1
South	
Ponce	6
Peñuela	5
Salinas	1
Arroyo	1
East	
Naguabo	39
Maunabo	2
Yabucoa	3
West	
Aguadilla	2
Aguada	5
Rincón	4
Añasco	1
Cabo Rojo	13

Tissue kit (Qiagen, Germany) following the manufacturer's protocol. Modifications were made to the final elution step where the DNA was eluted using pre-heated (37° C) AE buffer to a volume of 150 µL (Hellberg et al. 2019). After extraction, PCR was used to amplify a fragment of approximately 127 bp of CO1 using a specific primer set for *Ginglymostoma cirratum,* allowing for rapid detection of this species without the need for sequencing thereafter. The nurse shark primers were designed using Primer3 version 0.4.0 and tested with nurse shark tissue to confirm specificity. Therefore, a positive PCR amplification as viewed on gel electrophoresis confirmed the presence of *G. cirratum* in that sample. The specific primers were: Forward and Reverse (Table 3). The total volume of each PCR reaction was 25 µL, including 4–6 µL of DNA template, 0.5 µL FishF2, 0.5 µL FishR2, 12.5 µL of KAPA RM Taq, and PCR grade water. The thermal cycling conditions were an initial denaturation of 94°C for two minutes followed by 40 cycles of denaturation at 94°C for 30 seconds, annealing at 48°C for 30 seconds, elongation at 72° C for 30 seconds, and a final extension at 72° C for five minutes. If amplification was not successful, the elasmobranch mini primers and the universal fish primers were used for the shark meat, under the same PCR and thermal cycling conditions. The DNA sequencing procedures, DNA editing, and species identification methods were the same as for the *chapín* turnovers described above. The CITES listing status of each identified species was determined using the IUCN Red List of Threatened Species (http://www.iucnredlist.org/).

RESULTS AND DISCUSSION

Chapín turnovers

Species identification from at least one subsample per turnover was obtained for all samples, except for samples that did not amplify with either primer set we tested (n = 27 subsamples). A total of 15 species were identified from the 62 turnovers (Table 4), including elasmobranchs and bony fish (GenBank Accession numbers OL792174–OL792299; Appendices 1–3). The best match average was 99%, only one turnover subsample had a similarity of 97% with the striped mojarra, *Eugerres plumieri* (Cuvier, 1830) (subsample 13). The identity was confirmed with two additional subsamples analyzed from same turnover that matched the same species. No discrepancies were found in our sequence comparisons between GenBank and BOLD.

Four species of boxfish were identified, three were from the same genus: *Lactophrys triqueter* (Linnaeus, 1758), *L. trigonus* (Linnaeus, 1758), and *L. bicaudalis* (Linnaeus, 1758), as well as *Acanthostracion quadricornis* (Linnaeus, 1758). Eight of the 62 samples contained '*chapín*,' from which four samples were 100% boxfish, while the other four contained boxfish meat mixed with other species (Appendix 1). The only species of ray identified was the Southern stingray (*Hypanus americanus;* n = 7 samples; Table 4). Additionally, one shark species, Shortfin Mako (*Isurus oxyrinchus* Rafinesque, 1810) was found in one sample. The most common meat substitutes were tilapia (*Oreochromis niloticus* (Linnaeus, 1758); n = 40), striped catfish (*Pangasianodon hypophthalmus* (Sauvage, 1878); n = 27), Bocourt's catfish (*Pangasius bocourti* Sauvage, 1880; n = 19), and the queen triggerfish (*Balistes vetul*a Sauvage, 1880; n = 23). Except for *B. vetula* and *H. americanus*, the other fish species are mostly raised in aquaculture and distributed globally. For ex-

TABLE 3. Primer sets used to amplify the CO1 gene in samples from *chapín* turnovers and shark meat.

Primer	Primer Sequence
Mini Primers	VF2_t1 (5'-GTAAAACGACGGCCAGTCAACCAACCACAAAGACATTGGCAC-3') FishF2_t1 (5'-TGTAAAACGACGGCCAGTCGACTAATCATAAAGATATCGGCAC-3') Shark COIMINIR (5'-AAGATTACAAAAGCGTGGGC-3') (Fields et al. 2015)
Universal Fish Primers	FishF2 Forward (5'- TCGACTAATCATAAAGATATCGGCAC-3') FishR2 (5'- ACTTCAGGGTGACCGAAGAATCAGAA-3') (Camacho-Oliveira et al. 2020)
Specific Primers for *G. cirratum*	Forward (5'- TAATAAGAATGAAGGAGGAAGTAGTCAAAA-3') Reverse (5'- AGATTTATAATGTGATTGTAACAGCTCATG-3')

ample, *Pangasianodon hypophthalmus* has a massive production value of $645 million (USD), making it one of the largest single-species farming systems (Phan et al. 2009). However, even though they reproduce in large numbers and have fast growth rates, this species is still in danger due to their continued decline of natural populations according to IUCN (Vidthayanon and Hogan 2011). Thus, the *chapín* turnovers were largely substituted with commercially available fish that could be purchased in large quantities, frozen, from large scale grocery chains. Also, it is more cost effective to buy boxes of tilapia or catfish than to buy local boxfish through a fishmonger, who sells them at a higher price and usually has less stock available. The two other most common substitutes, *B. vetula* and *H. americanus*, are commonly found in Puerto Rico, and their fishery is not regulated.

We observed a tendency towards the use of multiple fish species to prepare the meat stuffing of the turnovers (Table 4). The fish stuffing could be very diverse when used in the turnovers. For example, one sample collected in the town of Guayanilla contained boxfish combined with tiger shark (*Galeocerdo cuvier* Perón & Lesuer, 1822), and another sample had boxfish combined with queen triggerfish (*Balistes vetula).* Also, the four turnovers that only contained boxfish were made with two different species of boxfish (e.g. *Lactophrys trigonus* and *Acanthostracion quadricornis*). Additionally, some turnovers contained a mix of marine and freshwater species. One turnover collected in the southern city of Ponce contained *Pangasius bocourti, Pangasianodon hypophthalmus*, and *Balistes vetula* in the same turnover while another sample collected in the eastern town of Humacao contained *P. hypophthalmus* and *Scomberomorus cavalla* (Cuvier, 1829). Lastly, there were also samples that contained three different marine fish species in the same turnover, such as one sample collected in San Juan which consisted of *A. quadricornis*, *Cantherhines macrocerus* (Hollard, 1853), and *L. trigonus*.

Shark meat

Of the 100 shark meat samples, 92 were successfully identified, while eight samples were eliminated due to DNA or tissue degradation (GenBank Accession numbers OL792767–OL792789; Appendix 3). The presence of nurse shark DNA was not detected in the samples during the collection period. The study period was very unusual due to the COVID-19 pandemic and local seismic events that negatively impacted the fishing industry, including the closure of several fish markets. The absence of nurse sharks in this sampling time does not rule out illegal fishing, as it has been previously observed to occur (Franqui-Rivera 2020). However, a variety of locally and nationally unregulated sharks were identified from the meat samples (Table 5). Two sharks, the tiger shark (*Galeocerdo cuvie*r) and Caribbean reef shark (*Carcharhinus perezi* (Poey, 1876)), were the most commonly identified species in the collected samples and are considered "Near Threatened" and "Endangered" by CITES (IUCN 2021). These two species represented more than half of the shark meat samples. Eight species identified in this study, the Caribbean reef shark (*Carcharhinus perezi*), blacktip shark (*Carcharhinus limbatus* (J. P. Müller & Henle, 1839)), Atlantic sharpnose shark (*Rhizoprionodon terraenovae* (J. Richardson, 1836)), great hammerhead (*Sphyrna mokarran* (Rüppell, 1837)), tiger shark (*G.*

TABLE 4. Species identified from 62 *chapín* turnovers collected around Puerto Rico. Columns include the number of samples containing only the individual identified species, along with the number of samples containing mixed fish species to which that identified species was found. CITES Listing: NL, Not Listed; Appx. II, Appendix II. IUCN Red List status: LD, Least Concern; NT, Near Threatened; EN, Endangered; VU, Vulnerable.

Common name	Scientific name	CITES Listing	IUCN Red List status	# containing only the identified species	# containing the identified species in a mixed stuffing
Common Dolphinfish	*Coryphaena hippurus*	NL	LC-2010	1	1
Southern Stingray	*Hypanus americanus*	NL	NTA2bd-2019	1	6
Queen Triggerfish	*Balistes vetula*	NL	NT-2011	4	8
Striped Mojarra	*Eugerres plumieri*	NL	LC-2010	0	1
Common Snook	*Centropomus undecimalis*	NL	LC-2019	0	1
Bocourt's catfish	*Pangasius bocourti*	NL	LC-2011	0	10
Striped Catfish	*Pangasianodon hypophthalmus*	NL	EN A2bd+4b-cd-2011	0	19
Wahoo	*Acanthocybium solandri*	NL	LC-2010	1	0
Shortfin Mako	*Isurus oxyrinchus*	Appx. II	EN A2bd-2018	1	0
King Mackerel	*Scomberomorus cavalla*	NL	LC-2010	0	1
Whitespotted Filefish	*Cantherhines macrocerus*	NL	LC-2015	0	1
Spotted Trunkfish	*Lactophrys bicaudalis*	NL	LC-2015	0	2
Tilapia	*Oreochromis niloticus*	NL	LC-2020	13	1
Buffalo Trunkfish	*Lactophrys trigonus*	NL	LC-2011	0	5
Tiger Shark	*Galeocerdo cuvier*	NL	NT A2b-d+3d-2018	0	1
Black Triggerfish	*Melichthys niger*	NL	LC-2011	0	1
Scrawled Cowfish	*Acanthostracion quadricornis*	NL	LC-2011	0	5
Gray Triggerfish	*Balistes capriscus*	NL	VU A2bd-2011	0	1
Smooth Trunkfish	*Lactophrys triqueter*	NL	LC-2011	0	1

cuvier), shortfin mako (*Isurus oxyrinchus*), blacknose shark (*Carcharhinus acronotus* (Poey, 1860)), and silky shark (*Carcharhinus falciformis* (J. P. Müller & Henle, 1839)) are protected under the 'Atlantic Highly Migratory Species,' and a federal permit is required for their capture in federal waters ("50 CFR Part 635," 1999). However, *C. perezi* is protected by a permanent closure in federal waters, therefore, the capture of this species is prohibited (Mena et al. 2007). Unfortunately, seven of these shark species are also in critical population status (IUCN 2021), and could suffer further decline without regulatory enforcement or compatible laws between federals and local waters (Table 5). Furthermore, several of these species such as *Carcharhinus limbatus, Sphyrna mokarran, Carcharhinus acronotus,* and *Carcharhinus falciformis* have recently been reclassified as Vulnerable, Critically Endangered, and Endangered, respectively (Table 5; IUCN 2021).

TABLE 5. Species identified from the 92 shark meat samples collected from around Puerto Rico. CITES Listing: NL, Not Listed; Appx. II, Appendix II. IUCN Red List status: LD, Least Concern; NT, Near Threatened; EN, Endangered; VU, Vulnerable; CR, Critically Endangered (IUCN 2021).

Common Name	Species	CITES Listing	IUCN Red List Status	Number of Samples Containing Species
Atlantic Sharpnose Shark	*Rhizoprionodon terraenovae*	NL	LC-2019	3
Caribbean Reef Shark	*Carcharhinus perezi*	NL	EN A2bcd-2019	20
Tiger Shark	*Galeocerdo cuvier*	NL	NT A2bd+3d-2018	30
Blacktip Shark	*Carcharhinus limbatus*	NL	VU A2bd-2020	5
Great Hammerhead Shark	*Sphyrna mokarran*	Appx. II	CR A2bd-2018	6
Blacknose Shark	*Carcharhinus acronotus*	NL	EN A2bd-2019	2
Silky Shark	*Carcharhinus falciformis*	Appx. II	VU A2bd-2017	5
Striped Catfish	*Pangasianodon hypophthalmus*	NL	EN A2bd+4b-cd-2011	5
Bigeyed Sixgill Shark	*Hexanchus nakamurai*	NL	NT A2d-2019	1
Common Snook	*Centropomus undecimalis*	NL	LC-2019	9
Tilapia	*Oreochromis niloticus*	NL	LC-2020	1
Dusky Smooth-hound Shark	*Mustelus canis*	NL	NT A2bd-2019	5

Mislabeling was also identified with shark meat products purchased from restaurants. The majority of the *pinchos* were mislabeled, where five of the eight samples were substituted with a different species. Instead of shark *pinchos*, the customers would have been served with *pinchos* made of *Pangasianodon hypophthalmus* (n = 5), *Centropomus undecimalis* (n = 9), and *Oreochromis niloticus* (n = 1); this last species (n = 10) was also identified in shark turnovers. The substitution with *Oreochromis niloticus* and *Pangasianodon hypophthalmus* may occur because these two fish are cheaper to purchase in large quantities from supermarkets. The most frequent substitution of shark meat with other fish species in turnovers occurred in the samples from Naguabo, while the most frequent substitution in shark *pinchos* occurred in the samples from Cabo Rojo. In addition, identification of shark fillets was provided in some purchases by the seller (29 of 59 fillets, or 49 %), but of those, only five samples were correctly identified by the seller or fisher. Of the nine shark species detected using DNA barcoding in this study, only two could be correctly identified (*Galeocerdo cuvier* and *Carcharhinus perezi*) by the fisher at the time of sale. Shark identification can be difficult even for some experts since several species share similar characteristics. For this reason, fisheries managers may choose to focus on education and outreach to enhance shark identification among fishers and fishmongers.

Types of seafood fraud identified

Seafood fraud was detected in *chapín* turnovers, *pinchos*, and in the shark turnovers (Tables 4–5; Appendices 1–2). Species substitution and mislabeling were the two types of seafood fraud observed in this study. In most of the turnovers, two different species were identified together in the same turnover and, in some cases, up to three different species were substituted for *chapín*. Aside from falsely representing the item advertised for sale, substitution could be dangerous to human health when substituted species are potentially toxic when consumed. A study performed on samples collected in La Parguera and Jobos Bay, Puerto Rico found that king mackerel (*Scomberomorus cavalla* (Cuvier, 1829)) contained hazardous levels of arsenic and mercury in the muscle tissues (Salgado-Ramírez et al. 2017). Additionally, substituted sharks and rays that contain pollutants (Tiktak et al. 2020) can also be harmful for human consumption.

In Puerto Rico, the economy has been negatively affected by recent disasters such as Hurricanes Irma and María in 2017, strong seismic events between 2019 and 2020, and the global pandemic from 2020 to 2022. Although the prevalence of seafood fraud has not been studied previously on the island, all these events may be causing an increase of seafood fraud locally as businesses may be struggling to maintain their profits. A recent assessment of the seafood industry contacted 139 small-scale commercial fishers to understand the COVID-19 pandemic impacts in Puerto Rico. This assessment identified the top three impacts on the commercial harvest as: 1) a 79% reduction on numbers of fishing trips, 2) a 71% decrease in prices or lack of markets (dealers, buyers, clients), and 3) a 48% reduction in their operational activities due to government restrictions (U.S. Department of Commerce National Oceanic and Atmospheric Administration 2021). These factors could explain why Naguabo and Cabo Rojo–two historic fishing towns with multiple seafood restaurants and fish markets–reflected more prevalent cases of seafood fraud in contrast to other towns, as these areas were attempting to maintain their business during the pandemic. In European countries, an increase in food fraud (including fish and seafood) has also been reported in reaction to COVID-19, due to the increase in demand of seafood, cost of fish, and reduction of global regulatory monitoring (Brooks et al. 2021). Additionally, the report identified a 22% increase in seafood fraud involving adulteration, substitution, dilution, and mislabeling/counterfeiting during the years mentioned.

Fish identification of a carcass or tissue is a difficult task when all morphological characteristics have been removed through tissue preparation for consumption, such as those processing practices used in the seafood industry. The use of DNA barcoding has been shown to be an accurate way to obtain species identification in seafood products (Shokralla et al. 2015; this study) and other studies in the Caribbean and Gulf of Mexico. For example, DNA barcoding was used to analyze fish products in Mexico City and markets located on the Gulf and Caribbean coasts of Mexico, where lower quality or untargeted fish (*Pangasianodon hypophthalmus, C. falciformis, Carcharhinus brevipinna* (Valenciennes, 1839)–spinner shark, and *Hypanus americanus)* were substituted in place of higher-value species (Sarmiento-Camacho and Valdez-Moreno 2018). The application of DNA barcoding led to the identification of a variety of fish species that are being substituted and mislabeled in popular local cuisines in Puerto Rico. Although these samples were highly processed, this technique allowed for confirmation of the unverified reports about fish substitution in *chapín* turnovers, as well as regulated and unregulated shark species being consumed.

CONCLUSIONS

Through the use of DNA barcoding in a forensic fashion, this study provides evidence of seafood fraud in the form of species substitution and mislabeling among fishmongers and restaurants in Puerto Rico. This is the first time that the possible use of rays as a substitute in *chapín* turnovers was studied and ultimately verified. Nurse shark meat was not detected in any of the shark samples collected. Mislabeling was detected in both types of seafood product sampling and shows the use of imported species, such as *Pangasianodon hypophthalmus,* and species that can be toxic when consumed such as *Scomberomorus cavalla*. The use of mini primers was essential to amplify degraded DNA, which included cooked and damaged tissue allowing for the identification of samples regardless of the amount of degradation. Finally, most species that were detected are in a Near Threatened, Vulnerable, Endangered, and Critically Endangered state. If no regulatory action is taken for the protection of these species, they could potentially become locally extinct. These results will serve as a foundation to encourage development of new regulations and to help the reinforcement of current regulations that are under evaluation to protect species such as Balistidae (triggerfishes), Myliobatidae (eagle and manta rays), and Dasyatidae (stingrays).

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APPENDIX 1. The 189 *chapín* turnover samples from this project with their respective locality, Blast Top identification, percent coverage, percent identity, and GenBank accession number. Every three samples represent a distinct turnover. NA = no amplification. Sequences that are not accessioned in GenBank are found in Appendix 3.

Sample ID	Municipality	Blast result	% Coverage	% Identity	GenBank accession
CR 1	Lajas, La Parguera	*Coryphaena hippurus*	99%	99.11%	OL792289
CR 2	Lajas, La Parguera	*Coryphaena hippurus*	100%	99.84%	OL792290
CR 3	Lajas, La Parguera	*Coryphaena hippurus*	97%	99.36%	OL792291
CR 4	Cabo Rojo, Poblado	NA	-	-	-
CR 5	Cabo Rojo, Poblado	*Hypanus americanus*	100%	99.07%	Appendix 3
CR 6	Cabo Rojo, Poblado	*Hypanus americanus*	100%	99.84%	OL792250
CR 7	Cabo Rojo	NA	-	-	-
CR 8	Cabo Rojo	*Hypanus americanus*	100%	99.84%	OL792251
CR 9	Cabo Rojo	*Hypanus americanus*	100%	99.24%	Appendix 3
CR 10	Cabo Rojo	*Balistes vetula*	99%	99.84%	OL792253
CR 11	Cabo Rojo	*Balistes vetula*	99%	99.70%	OL792254
CR 12	Cabo Rojo	*Balistes vetula*	99%	99.70%	OL792255
CR 13	Cabo Rojo, Joyuda	*Eugerres plumieri*	98%	97.96%	Appendix 3
CR 14	Cabo Rojo, Joyuda	*Eugerres plumieri*	98%	99.85%	OL792297
CR 15	Cabo Rojo, Joyuda	*Centropomus undecimalis*	99%	98.96%	OL792296
CR 16	Cabo Rojo	*Balistes vetula*	99%	99.85%	OL792256
CR 17	Cabo Rojo	*Balistes vetula*	99%	99.70%	OL792257

CR 18	Cabo Rojo	*Balistes vetula*	99%	99.83%	OL792258
CR 19	Cabo Rojo	*Pangasius bocourti*	100%	100%	OL792206
CR 20	Cabo Rojo	*Pangasianodon hypophthalmus*	100%	100%	OL792223
CR 21	Cabo Rojo	*Pangasianodon hypophthalmus*	100%	100%	OL792224
CR 22	Cabo Rojo	NA	-	-	-
CR 23	Cabo Rojo	*Balistes vetula*	99%	100%	OL792259
CR 24	Cabo Rojo	*Balistes vetula*	99%	99.25%	OL792260
CR 25	Mayaguez	*Coryphaena hippurus*	100%	99.82%	OL792292
CR 26	Mayaguez	NA	-	-	-
CR 27	Mayaguez	NA	-	-	-
CR 28	Guanica	*Oreochromis niloticus*	100%	100%	OL792181
CR 29	Guanica	*Oreochromis niloticus*	99%	100%	OL792182
CR 30	Guanica	NA	-	-	-
CR 31	Guanica	*Hypanus americanus*	100%	99.33%	Appendix 3
CR 32	Guanica	*Hypanus americanus*	100%	99.83%	OL792252
CR 33	Guanica	NA	-	-	-
CR 34	Guanica	NA	-	-	-
CR 35	Guanica	*Hypanus americanus*	100%	99.07%	Appendix 3
CR 36	Guanica	*Hypanus americanus*	100%	99.07%	Appendix 3
CR 37	Guanica	NA	-	-	-
CR 38	Guanica	*Hypanus americanus*	100%	99.33%	Appendix 3
CR 39	Guanica	NA	-	-	-
CR 40	Guanica	NA	-	-	-
CR 41	Guanica	*Balistes vetula*	99%	99.67%	OL792261
CR 42	Guanica	*Balistes vetula*	99%	99.84%	OL792262
CR 43	Guayanilla	*Oreochromis niloticus*	99%	100%	OL792183
CR 44	Guayanilla	*Oreochromis niloticus*	99%	100%	Appendix 3
CR 45	Guayanilla	*Oreochromis niloticus*	100%	99.69%	Appendix 3
CR 46	Guayanilla	*Lactophrys trigonus*	100%	99.83%	OL792281
CR 47	Guayanilla	*Galeocerdo cuvier*	100%	99.84%	OL792288
CR 48	Guayanilla	*Lactophrys trigonus*	99%	99.84%	OL792282
CR 49	Guayanilla	*Oreochromis niloticus*	100%	100%	Appendix 3
CR 50	Guayanilla	NA	-	-	-
CR 51	Guayanilla	*Baliste vetula*	99%	99.84%	OL792263
CR 52	Ponce	*Pangasianodon hypophthalmus*	100%	100%	OL792225
CR 53	Ponce	NA	-	-	-
CR 54	Ponce	NA	-	-	-
CR 55	Ponce	*Pangasius bocourti*	100%	100%	OL792208
CR 56	Ponce	*Pangasianodon hypophthalmus*	100%	100%	OL792226
CR 57	Ponce	*Balistes vetula*	100%	100%	OL792264
CR 58	Ponce	*Balistes vetula*	100%	100%	OL792265

CR 59	Ponce	*Melichthys niger*	98%	99.67%	OL792278
CR 60	Ponce	*Melichthys niger*	98%	99.84%	OL792279
CR 61	Ponce	*Oreochromis niloticus*	96%	100%	Appendix 3
CR 62	Ponce	*Oreochromis niloticus*	96%	100%	Appendix 3
CR 63	Ponce	*Oreochromis niloticus*	99%	100%	OL792184
CR 64	Cataño	*Oreochromis niloticus*	81%	99.78%	Appendix 3
CR 65	Cataño	*Oreochromis niloticus*	100%	100%	OL792185
CR 66	Cataño	*Oreochromis niloticus*	99%	100%	OL792186
CR 67	Cataño	*Pangasianodon hypophthalmus*	100%	100%	OL792227
CR 68	Cataño	*Pangasius bocourti*	100%	100%	OL792209
CR 69	Cataño	*Pangasianodon hypophthalmus*	100%	100%	OL792228
CR 70	Dorado	*Pangasius bocourti*	99%	100%	OL792210
CR 71	Dorado	*Pangasianodon hypophthalmus*	100%	100%	OL792229
CR 72	Dorado	*Pangasius bocourti*	100%	100%	OL792211
CR 73	Barceloneta	*Hypanus americanus*	100%	98.68%	Appendix 3
CR 74	Barceloneta	*Hypanus americanus*	100%	98.68%	Appendix 3
CR 75	Barceloneta	*Hypanus americanus*	100%	98.68%	Appendix 3
CR 76	Naguabo	NA	-	-	-
CR 77	Naguabo	*Acanthostracion quadricornis*	99%	99.83%	OL792174
CR 78	Naguabo	*Balistes vetula*	99%	99.84%	OL792266
CR 79	Barceloneta	*Balistes vetula*	99%	99.84%	OL792267
CR 80	Barceloneta	*Balistes capriscus*	98%	100%	OL792276
CR 81	Barceloneta	*Balistes capriscus*	98%	100%	OL792277
CR 82	Humacao	*Lactophrys triqueter*	99%	99.53%	OL792280
CR 83	Humacao	*Balistes vetula*	99%	100%	OL792268
CR 84	Humacao	*Balistes vetula*	99%	99.84%	OL792269
CR 85	Humacao	*Acanthocybium solandri*	96%	100%	Appendix 3
CR 86	Humacao	*Acanthocybium solandri*	96%	100%	Appendix 3
CR 87	Humacao	*Acanthocybium solandri*	96%	100%	Appendix 3
CR 88	Yabucoa	*Oreochromis niloticus*	96%	100%	Appendix 3
CR 89	Yabucoa	*Oreochromis niloticus*	100%	100%	OL792187
CR 90	Yabucoa	*Oreochromis niloticus*	96%	100%	Appendix 3
CR 91	Yabucoa	*Pangasianodon hypophthalmus*	100%	100%	OL792230
CR 92	Yabucoa	*Pangasianodon hypophthalmus*	100%	100%	OL792231
CR 93	Yabucoa	*Pangasius bocourti*	99%	99.68%	OL792207
CR 94	Maunabo	*Oreochromis niloticus*	99%	98.28%	OL792188
CR 95	Maunabo	*Oreochromis niloticus*	100%	99.83%	OL792189
CR 96	Maunabo	*Oreochromis niloticus*	100%	99.84%	OL792190
CR 97	Maunabo	*Oreochromis niloticus*	96%	100%	Appendix 3
CR 98	Maunabo	*Oreochromis niloticus*	99%	99.35%	OL792191
CR 99	Maunabo	*Oreochromis niloticus*	100%	100%	Appendix 3

CR 100	Yabucoa	*Oreochromis niloticus*	99%	99.84%	OL792192
CR 101	Yabucoa	*Oreochromis niloticus*	100%	98.46%	OL792193
CR 102	Yabucoa	*Oreochromis niloticus*	96%	100%	Appendix 3
CR 103	Naguabo	*Oreochromis niloticus*	100%	99.68%	OL792194
CR 104	Naguabo	*Oreochromis niloticus*	100%	99.84%	OL792195
CR 105	Naguabo	*Oreochromis niloticus*	100%	100%	OL792196
CR 106	Naguabo	*Isurus oxyrinchus*	97%	98.47%	Appendix 3
CR 107	Naguabo	*Isurus oxyrinchus*	97%	98.50%	Appendix 3
CR 108	Naguabo	*Isurus oxyrinchus*	97%	98.66%	Appendix 3
CR 109	Naguabo	*Oreochromis niloticus*	100%	100%	OL792197
CR 110	Naguabo	*Oreochromis niloticus*	100%	100%	OL792198
CR 111	Naguabo	*Oreochromis niloticus*	100%	100%	OL792199
CR 112	Yabucoa	*Lactophrys trigonus*	99%	100%	OL792283
CR 113	Yabucoa	*Acanthostracion quadricornis*	94%	99.59%	OL792175
CR 114	Yabucoa	*Acanthostracion quadricornis*	98%	100%	OL792176
CR 115	Luquillo	*Pangasius bocourti*	100%	99.38%	Appendix 3
CR 116	Luquillo	*Pangasianodon hypophthalmus*	100%	100%	OL792232
CR 117	Luquillo	*Pangasius bocourti*	99%	99.68%	OL792212
CR 118	Luquillo	*Pangasius bocourti*	99%	99.84%	OL792213
CR 119	Luquillo	NA	-	-	-
CR 120	Luquillo	*Pangasianodon hypophthalmus*	100%	100%	OL792233
CR 121	Luquillo	*Pangasianodon hypophthalmus*	99%	100%	OL792234
CR 122	Luquillo	NA	-	-	-
CR 123	Luquillo	NA	-	-	-
CR 124	Luquillo	NA	-	-	-
CR 125	Luquillo	NA	-	-	-
CR 126	Luquillo	*Pangasianodon hypophthalmus*	100%	100%	OL792235
CR 127	Humacao	*Scomberomorus cavalla*	100%	100%	OL792298
CR 128	Humacao	*Scomberomorus cavalla*	100%	99.84%	OL792299
CR 129	Humacao	*Pangasianodon hypophthalmus*	100%	100%	OL792236
CR 130	Fajardo	*Pangasius bocourti*	99%	100%	OL792214
CR 131	Fajardo	*Pangasianodon hypophthalmus*	99%	100%	OL792237
CR 132	Fajardo	*Pangasianodon hypophthalmus*	100%	100%	OL792238
CR 133	Loiza/Carolina	*Oreochromis niloticus*	100%	100%	OL792200
CR 134	Loiza/Carolina	*Oreochromis niloticus*	96%	100%	OL792239
CR 135	Loiza/Carolina	*Oreochromis niloticus*	100%	100%	OL792201
CR 136	Luquillo	*Oreochromis niloticus*	100%	100%	OL792202
CR 137	Luquillo	*Oreochromis niloticus*	96%	99.45%	Appendix 3
CR 138	Luquillo	*Oreochromis niloticus*	100%	100%	Appendix 3
CR 139	Loiza	NA	-	-	-
CR 140	Loiza	NA	-	-	-

CR 141	Loiza	NA	-	-	-
CR 142	Fajardo	NA	-	-	-
CR 143	Fajardo	*Pangasianodon hypophthalmus*	100%	100%	Appendix 3
CR 144	Fajardo	*Pangasianodon hypophthalmus*	100%	100%	OL792240
CR 145	Lajas, La Parguera	*Hypanus americanus*	90%	98.88%	Appendix 3
CR 146	Lajas, La Parguera	*Hypanus americanus*	100%	99.25%	Appendix 3
CR 147	Lajas, La Parguera	NA	-	-	-
CR 148	San Juan	*Acanthostracion quadricornis*	98%	99.84%	OL792177
CR 149	San Juan	*Cantherhines macrocerus*	90%	99.17%	Appendix 3
CR 150	San Juan	*Lactophrys trigonus*	99%	99.84%	OL792284
CR 151	Cabo Rojo	*Lactophrys trigonus*	99%	100%	OL792285
CR 152	Cabo Rojo	*Lactophrys trigonus*	99%	99.84%	OL792286
CR 153	Cabo Rojo	*Lactophrys bicaudalis*	100%	99.84%	OL792293
CR 154	Maunabo	*Pangasianodon hypophthalmus*	100%	99.85%	OL792241
CR 155	Maunabo	*Pangasius bocourti*	100%	100%	OL792215
CR 156	Maunabo	*Pangasianodon hypophthalmus*	100%	100%	OL792242
CR 157	Patilla	*Oreochromis niloticus*	99%	100%	OL792203
CR 158	Patilla	*Oreochromis niloticus*	100%	98.57%	OL792204
CR 159	Patilla	*Oreochromis niloticus*	99%	100%	OL792205
CR 160	Guayama	NA	-	-	-
CR 161	Guayama	*Pangasianodon hypophthalmus*	99%	100%	OL792243
CR 162	Guayama	*Pangasius bocourti*	100%	99.84%	OL792216
CR 163	Patilla	*Balistes vetula*	99%	100%	OL792270
CR 164	Patilla	*Balistes vetula*	99%	99.85%	OL792271
CR 165	Patilla	*Balistes vetula*	99%	99.84%	OL792272
CR 166	Guayama	*Acanthostracion quadricornis*	98%	99.51%	OL792178
CR 167	Guayama	*Acanthostracion quadricornis*	98%	99.35%	OL792179
CR 168	Guayama	*Lactophrys trigonus*	99%	99.84%	OL792287
CR 169	Patilla	*Balistes vetula*	99%	99.84%	OL792273
CR 170	Patilla	*Balistes vetula*	99%	100%	OL792274
CR 171	Patilla	*Balistes vetula*	100%	99.84%	OL792275
CR 172	Guayama	*Lactophrys bicaudalis*	95%	99.85%	OL792294
CR 173	Guayama	*Lactophrys bicaudalis*	98%	99.85%	OL792295
CR 174	Guayama	*Acanthostracion quadricornis*	100%	98.20%	OL792180
CR 175	Arroyo	*Pangasianodon hypophthalmus*	100%	100%	OL792244
CR 176	Arroyo	*Pangasius bocourti*	89%	98.07%	Appendix 3
CR 177	Arroyo	*Pangasianodon hypophthalmus*	99%	100%	OL792245
CR 178	Patilla	NA	-	-	-
CR 179	Patilla	*Pangasius bocourti*	100%	100%	OL792217
CR 180	Patilla	*Pangasius bocourti*	100%	99.84%	OL792218
CR 181	Patilla	*Pangasianodon hypophthalmus*	100%	100%	OL792246

CR 182	Patilla	*Pangasianodon hypophthalmus*	100%	100%	OL792247
CR 183	Patilla	*Pangasius bocourti*	100%	100%	OL792219
CR 184	Humacao	*Pangasianodon hypophthalmus*	100%	100%	OL792248
CR 185	Humacao	NA	-	-	-
CR 186	Humacao	*Pangasius bocourti*	100%	99.84%	OL792220
CR 187	Santa Isabel	*Pangasius bocourti*	100%	100%	OL792221
CR 188	Santa Isabel	*Pangasianodon hypophthalmus*	99%	100%	OL792249
CR 189	Santa Isabel	*Pangasius bocourti*	99%	100%	OL792222

APPENDIX 2. Shark meat samples by municipality they were collected, source of tissue, percent coverage, percent identity, and GenBank accession number. NA = no amplification. Sequences that are not accessioned in GenBank are found in Appendix 3.

Sample ID	Municipality	Blast result	Source of Sample	% Coverage	% Identity	GenBank accession
NS 1	San Juan	*Rhizoprionodon terraenovae*	Fillet	96%	98.35%	Appendix 3
NS 2	Arecibo	*Carcharhinus perezi*	Fillet	100%	100%	Appendix 3
NS 3	Arecibo	*Mustelus* sp.	Fillet	97%	98.32%	Appendix 3
NS 4	Naguabo	*Carcharhinus perezi*	Fillet	99%	99.28%	Appendix 3
NS 5	Naguabo	*Carcharhinus perezi*	Fillet	97%	98.99%	Appendix 3
NS 6	Aguadilla	*Galeocerdo cuvier*	Fillet	99%	100%	Appendix 3
NS 7	Arecibo	*Carcharhinus perezi*	Fillet	96%	98.32%	Appendix 3
NS 8	Cataño	*Galeocerdo cuvier*	Fillet	89%	99.25%	Appendix 3
NS 9	Cataño	*Galeocerdo cuvier*	Fillet	97%	98.99%	Appendix 3
NS 10	Ponce	*Mustelus* sp.	Fillet	97%	98.64%	Appendix 3
NS 11	Cabo Rojo	*Carcharhinus perezi*	Fillet	97%	97.99%	Appendix 3
NS 12	Cataño	*Galeocerdo cuvier*	Fillet	90%	100%	Appendix 3
NS 13	Ponce	*Mustelus* sp.	Fillet	97%	98.32%	Appendix 3
NS 14	Maunabo	*Carcharhinus perezi*	Fillet	100%	100%	Appendix 3
NS 15	Naguabo	*Carcharhinus perezi*	Pincho	100%	100%	Appendix 3
NS 16	Naguabo	*Carcharhinus limbatus*	Fillet	100%	99.29%	Appendix 3
NS 17	Naguabo	*Sphyrna mokarran*	Fillet	97%	98.32%	Appendix 3
NS 18	Arroyo	*Carcharhinus perezi*	Fillet	100%	98.99%	Appendix 3
NS 19	Aguada	*Galeocerdo cuvier*	Fillet	90%	100%	Appendix 3
NS 20	Isabela	*Carcharhinus perezi*	Fillet	97%	98.99%	Appendix 3
NS 21	Cataño	*Galeocerdo cuvier*	Fillet	90%	100%	Appendix 3
NS 22	Penuelas	*Galeocerdo cuvier*	Fillet	90%	100%	Appendix 3
NS 23	Aguadilla	*Rhizoprionodon terraenovae*	Fillet	98%	98.46%	Appendix 3
NS 24	Yabucoa	*Carcharhinus limbatus*	Fillet	97%	98.66%	Appendix 3
NS 25	Naguabo	*Carcharhinus acronotus*	Fillet	93%	100%	Appendix 3
NS 26	Cataño	*Galeocerdo cuvier*	Fillet	97%	98.99%	Appendix 3
NS 27	Naguabo	*Carcharhinus limbatus*	Fillet	97%	100%	Appendix 3
NS 28	Naguabo	*Galeocerdo cuvier*	Fillet	97%	98.66%	Appendix 3

NS 29	Rincon	*Carcharhinus acronotus*	Fillet	91%	98.61%	Appendix 3
NS 30	Cabo Rojo	*Galeocerdo cuvier*	Fillet	96%	98.35%	Appendix 3
NS 31	Cabo Rojo	NA	Fillet	-	-	-
NS 32	Cabo Rojo	NA	Fillet	-	-	-
NS 33	Ponce	*Carcharhinus falciformis*	Fillet	96%	100%	Appendix 3
NS 34	Rincon	*Galeocerdo cuvier*	Fillet	96%	98.22%	Appendix 3
NS 35	Penuelas	*Galeocerdo cuvier*	Fillet	100%	98.15%	Appendix 3
NS 36	Ponce	*Mustelus canis*	Fillet	99%	99.11%	Appendix 3
NS 37	Naguabo	NA	Fillet	-	-	-
NS 38	Naguabo	*Galeocerdo cuvier*	Pincho	81%	100%	Appendix 3
NS 39	Cabo Rojo	*Pangasianodon hypophthalmus*	Pincho	100%	99.85%	OL792767
NS 40	Cabo Rojo	*Pangasianodon hypophthalmus*	Pincho	100%	100%	OL792768
NS 41	Cabo Rojo	*Pangasianodon hypophthalmus*	Pincho	100%	100%	OL792769
NS 42	Cabo Rojo	*Galeocerdo cuvier*	Fillet	99%	100%	Appendix 3
NS 43	Ponce	*Mustelus* sp.	Fillet	100%	99.11%	Appendix 3
NS 44	Aguada	*Sphyrna mokarran*	Turnover	99%	98.27%	Appendix 3
NS 45	Aguada	*Galeocerdo cuvier*	Turnover	100%	99.85%	OL792773
NS 46	Cataño	*Galeocerdo cuvier*	Turnover	98%	100%	Appendix 3
NS 47	San Juan	*Carcharhinus perezi*	Fillet	100%	99.11%	Appendix 3
NS 48	Cabo Rojo	*Galeocerdo cuvier*	Pincho	96%	98.20%	Appendix 3
NS 49	Cabo Rojo	*Pangasianodon hypophthalmus*	Pincho	99%	100%	OL792770
NS 50	Aguada	*Sphyrna mokarran*	Turnover	100%	100%	Appendix 3
NS 51	Aguada	*Sphyrna mokarran*	Turnover	100%	100%	Appendix 3
NS 52	Anasco	*Sphyrna mokarran*	Turnover	97%	98.62%	Appendix 3
NS 53	Ponce	*Carcharhinus falciformis*	Fillet	98%	98.40%	Appendix 3
NS 54	Maunabo	*Galeocerdo cuvier*	Fillet	96%	98.18%	Appendix 3
NS 55	Arecibo	*Hexanchus nakamurai*	Fillet	96%	99.08%	Appendix 3
NS 56	Naguabo	*Carcharhinus perezi*	Fillet	96%	99.07%	Appendix 3
NS 57	San Juan	*Carcharhinus perezi*	Turnover	99%	100%	Appendix 3
NS 58	Rincon	*Carcharhinus falciformis*	Fillet	97%	100%	Appendix 3
NS 59	Cataño	*Galeocerdo cuvier*	Fillet	85%	100%	Appendix 3
NS 60	Naguabo	*Carcharhinus perezi*	Fillet	99%	98.52%	Appendix 3
NS 61	Naguabo	*Centropomus undecimalis*	Turnover	97%	99.85%	OL792780
NS 62	Naguabo	*Centropomus undecimalis*	Turnover	99%	99.85%	OL792781
NS 63	Naguabo	*Oreochromis niloticus*	Turnover	99%	99.85%	OL792772
NS 64	Naguabo	NA	Turnover	-	-	-
NS 65	Naguabo	*Centropomus undecimalis*	Turnover	98%	99.85%	OL792782
NS 66	Naguabo	*Centropomus undecimalis*	Turnover	98%	99.85%	OL792783
NS 67	Naguabo	*Centropomus undecimalis*	Turnover	98%	99.85%	OL792784
NS 68	Naguabo	*Centropomus undecimalis*	Turnover	98%	99.85%	OL792785
NS 69	Naguabo	*Centropomus undecimalis*	Turnover	98%	99.85%	OL792786

NS 70	Naguabo	NA	Turnover	-	-	-
NS 71	Naguabo	*Centropomus undecimalis*	Turnover	97%	99.85%	OL792787
NS 72	Naguabo	*Centropomus undecimalis*	Turnover	98%	100%	OL792788
NS 73	Cabo Rojo	*Pangasianodon hypophthalmus*	Pincho	99%	100%	OL792771
NS 74	Naguabo	*Carcharhinus perezi*	Fillet	91%	98.32%	Appendix 3
NS 75	Naguabo	*Galeocerdo cuvier*	Fillet	100%	99.85%	OL792774
NS 76	Penuelas	*Carcharhinus limbatus*	Fillet	97%	97.72%	Appendix 3
NS 77	Cabo Rojo	*Rhizoprionodon terraenovae*	Fillet	96%	98.46%	Appendix 3
NS 78	Arecibo	*Galeocerdo cuvier*	Fillet	88%	98.25%	Appendix 3
NS 79	Penuelas	*Carcharhinus limbatus*	Fillet	97%	98.32%	Appendix 3
NS 80	Salinas	*Sphyrna mokarran*	Fillet	97%	97.69%	Appendix 3
NS 81	Naguabo	*Galeocerdo cuvier*	Fillet	98%	98.20%	Appendix 3
NS 82	Yabucoa	*Carcharhinus perezi*	Turnover	97%	98.69%	Appendix 3
NS 83	Yabucoa	*Carcharhinus perezi*	Turnover	97%	97.69%	Appendix 3
NS 84	Cataño	*Galeocerdo cuvier*	Fillet	96%	98.25%	Appendix 3
NS 85	Cabo Rojo	*Carcharhinus falciformis*	Fillet	97%	97.40%	Appendix 3
NS 86	Naguabo	*Galeocerdo cuvier*	Turnover	98%	100%	Appendix 3
NS 87	Naguabo	*Galeocerdo cuvier*	Turnover	96%	97.22%	Appendix 3
NS 88	Naguabo	NA	Turnover	-	-	-
NS 89	Naguabo	*Carcharhinus perezi*	Turnover	100%	98.15%	Appendix 3
NS 90	Naguabo	*Carcharhinus perezi*	Turnover	99%	99.07%	Appendix 3
NS 91	Naguabo	*Carcharhinus perezi*	Turnover	98%	98.35%	Appendix 3
NS 92	Naguabo	*Carcharhinus perezi*	Turnover	97%	98.18%	Appendix 3
NS 93	Naguabo	NA	Turnover	-	-	-
NS 94	Naguabo	*Galeocerdo cuvier*	Turnover	100%	99.85%	OL792775
NS 95	Naguabo	*Galeocerdo cuvier*	Turnover	100%	99.56%	OL792776
NS 96	Naguabo	NA	Turnover	-	-	-
NS 97	Naguabo	*Galeocerdo cuvier*	Turnover	100%	99.85%	OL792777
NS 98	Penuelas	*Carcharhinus falciformis*	Fillet	99%	99.40%	OL792789
NS 99	Rincon	*Galeocerdo cuvier*	Fillet	100%	99.85%	OL792778
NS 100	Arecibo	*Galeocerdo cuvier*	Fillet	100%	99.55%	OL792779

APPENDIX 3. Sequences of the mitochondrial gene Cytochrome Oxidase subunit 1 (CO1) (~110–130 bp) which are too short to meet the criteria for being accessioned in GenBank. CR samples are from chapín turnovers (see Appendix 1), and NS samples are from shark meat samples (see Appendix 2). Sample ID; collection locality; species; CO1 sequence.

CR 5; Cabo Rojo, Poblado; *Hypanus americanus*; TGGTCTTAGCCTATTAATCCGGACAGAATTAAGTCAAC-CAGGCGCATTACTAGGGGATGACCAAATCTACAACGTAATCGTTACCGCCCACGCCTTTGTAAT. CR 9; Cabo Rojo; *Hypanus americanus*; TGGTCTTAGCCTATTAATCCGGACAGAATTAAGTCAACCAGGCGCATTACTAGG-GGATGACCAAATCTACAACGTAATCGTTACCGCCCACGCCTTTGTAAT. CR 13; Cabo Rojo, Joyuda; *Eugerres plumieri*; GGCCCTCAGCCTGCTGATCCGGGCGGAACTAAGCCAGCCCGGATCCTTACTCGGAGACGAC-CAAATTTATAATGTGATCGTCACCGCCCACGTTTTTGTAAT. CR 31; Guanica; *Hypanus americanus*; TGGTCT-TAGCCTATTAATCCGGACAGAATTAAGTCAACCAGGCGCATTACTAGGGGATGACCAAATCTACAACGTAATC-GTTACCGCCCACGCCTTTGTAAT. CR 35; Guanica; *Hypanus americanus*; TGGTCTTAGCCTATTAATCCGGA-CAGAATTAAGTCAACCAGGCGCATTACTAGGGGATGACCAAATCTACAACGTAATCGTTACCGCCCACG-

CCTTTGTAAT. CR 36; Guanica; *Hypanus americanus*; TGGTCTTAGCCTATTAATCCGGACAGAATTAAGTCAAC-
CAGGCGCATTACTAGGGGATGACCAAATCTACAACGTAATCGTTACCGCCCACGCCTTTGTAAT. CR 38; Guani-
ca; *Hypanus americanus*; TGGTCTTAGCCTATTAATCCGGACAGAATTAAGTCAACCAGGCGCATTACTAGGG-
GATGACCAAATCTACAACGTAATCGTTACCGCCCACGCCTTTGTAAT. CR 44; Guayanilla; *Oreochromis niloticus*;
TGCACTAAGCCTCCTAATTCGGGCAGAACTAAGCCAGCCCGGCTCTCTTCTCGGAGACGACCAAATCTATA-
ATGTAATTGTTACAGCACATGCTTTCGTAAT. CR 45; Guayanilla; *Oreochromis niloticus*; TGCACTAAGCCTCCTA-
ATTCGGGCAGAACTAAGCCAGCCCGGCTCTCTTCTCGGAGACGACCAAATCTATAATGTAATTGTTACAGCA-
CATGCTTTCGTAAT. CR 49; Guayanilla; *Oreochromis niloticus*; TGCACTAAGCCTCCTAATTCGGGCAGAACTA-
AGCCAGCCCGGCTCTCTTCTCGGAGACGACCAAATCTATAATGTAATTGTTACAGCACATGCTTTCGTAAT. CR
61; Ponce; *Oreochromis niloticus*; TGCACTAAGCCTCCTAATTCGGGCAGAACTAAGCCAGCCCGGCTCTCTTCTC-
GGAGACGACCAAATCTATAATGTAATTGTTACAGCACATGCTTTCGTAAT. CR 62; Ponce; *Oreochromis niloticus*;
TGCACTAAGCCTCCTAATTCGGGCAGAACTAAGCCAGCCCGGCTCTCTTCTCGGAGACGACCAAATCTATA-
ATGTAATTGTTACAGCACATGCTTTCGTAAT. CR 64; Cataño; *Oreochromis niloticus*; TGCACTAAGCCTCCTAAT-
TCGGGCAGAACTAAGCCAGCCCGGCTCTCTTCTCGGAGACGACCAAATCTATAATGTAATTGTTACAGCA-
CATGCTTTCGTAAT. CR 73; Barceloneta; *Hypanus americanus*; TGGTCTTAGCCTATTAATCCGGACAGAATTA-
AGTCAACCAGGCGCATTACTAGGGGATGACCAAATCTACAACGTAATCGTTACCGCCCACGCCTTTGTAAT.
CR 74; Barceloneta; *Hypanus americanus*; TGGTCTTAGCCTATTAATCCGGACAGAATTAAGTCAACCAGGCGCAT-
TACTAGGGGATGACCAAATCTACAACGTAATCGTTACCGCCCACGCCTTTGTAAT. CR 75; Barceloneta; *Hypanus
americanus*; TGGTCTTAGCCTATTAATCCGGACAGAATTAAGTCAACCAGGCGCATTACTAGGGGATGAC-
CAAATCTACAACGTAATCGTTACCGCCCACGCCTTTGTAAT. CR 85; Humacao; *Acanthocybium solandri*; AGCCT-
TAAGCCTGCTCATCCGAGCTGAGCTAAGCCAACCAGGTGCCCTTCTTGGGGACGACCAGATCTACAATGTA-
ATTGTTACGGCTCACGCCTTCGTAAT. CR 86; Humacao; *Acanthocybium solandri*; AGCCTTAAGCCTGCTCATC-
CGAGCTGAGCTAAGCCAACCAGGTGCCCTTCTTGGGGACGACCAGATCTACAATGTAATTGTTACGGCTCAC-
GCCTTCGTAAT. CR 87; Humacao; *Acanthocybium solandri*; AGCCTTAAGCCTGCTCATCCGAGCTGAGCTAAGC-
CAACCAGGTGCCCTTCTTGGGGACGACCAGATCTACAATGTAATTGTTACGGCTCACGCCTTCGTAAT. CR 88;
Yabucoa; *Oreochromis niloticus*; TGCACTAAGCCTCCTAATTCGGGCAGAACTAAGCCAGCCCGGCTCTCTTCTC-
GGAGACGACCAAATCTATAATGTAATTGTTACAGCACATGCTTTCGTAAT. CR 90; Yabucoa; *Oreochromis niloti-
cus*; TGCACTAAGCCTCCTAATTCGGGCAGAACTAAGCCAGCCCGGCTCTCTTCTCGGAGACGACCAAATC-
TATAATGTAATTGTTACAGCACATGCTTTCGTAAT. CR 97; Maunabo; *Oreochromis niloticus*; TGCACTAAG-
CCTCCTAATTCGGGCAGAACTAAGCCAGCCCGGCTCTCTTCTCGGAGACGACCAAATCTATAATGTAATTGT-
TACAGCACATGCTTTCGTAAT. CR 99; Maunabo; *Oreochromis niloticus*; TGCACTAAGCCTCCTAATTCGGG-
CAGAACTAAGCCAGCCCGGCTCTCTTCTCGGAGACGACCAAATCTATAATGTAATTGTTACAGCACAT-
GCTTTCGTAAT. CR 102; Yabucoa; *Oreochromis niloticus*; TGCACTAAGCCTCCTAATTCGGGCAGAACTAAGC-
CAGCCCGGCTCTCTTCTCGGAGACGACCAAATCTATAATGTAATTGTTACAGCACATGCTTTCGTAAT. CR 106;
Naguabo; *Isurus oxyrinchus*; AGCCCTAAGCCTTTTAATTCGTGCCGAACTGGGTCAGCCTGGTTCCCTCCTAGGG-
GATGATCAGATTTATAATGTTATTGTAACCGCCCACGCTTTTGTAAT. CR 107; Naguabo; *Isurus oxyrinchus*; AGC-
CCTAAGCCTTTTAATTCGTGCCGAACTGGGTCAGCCTGGTTCCCTCCTAGGGGATGATCAGATTTATAATGT-
TATTGTAACCGCCCACGCTTTTGTAAT. CR 108; Naguabo; *Isurus oxyrinchus*; AGCCCTAAGCCTTTTAATTCGTG-
CCGAACTGGGTCAGCCTGGTTCCCTCCTAGGGGATGATCAGATTTATAATGTTATTGTAACCGCCCAC-
GCTTTTGTAAT. CR 115; Luquillo; *Pangasius bocourti*; GGCCCTCAGCCTCCTAATTCGGGCAGAGCTAGC-
CCAACCCGGCGCCCTTCTAGGCGACGACCAAATTTATAATGTTATTGTCACTGCCCATGCCTTCGTAAT. CR
137; Luquillo; *Oreochromis niloticus*; TGCACTAAGCCTCCTAATTCGGGCAGAACTAAGCCAGCCCG-
GCTCTCTTCTCGGAGACGACCAAATCTATAATGTAATTGTTACAGCACATGCTTTCGTAAT. CR 138; Luquillo;
Oreochromis niloticus; TGCACTAAGCCTCCTAATTCGGGCAGAACTAAGCCAGCCCGGCTCTCTTCTCGGAGAC-
GACCAAATCTATAATGTAATTGTTACAGCACATGCTTTCGTAAT. CR 143; Fajardo; *Pangasianodon hypophthal-
mus*; ATAATTGGAGGCTTTGGAAACTGACTTGTCCCCTTAATAATTGGAGCGCCTGATATGGCATTCCCTC-
GAATAAATAATATGAGTTTTTGATTACTTCCGCCTTCCTTCCTACTATTGCTTGCCTCCTCTGGAGTAGAAG-
CAGGGGCAGGAACAGGATGAACTGTATATCCACCCCTTGCTGGAAACCTCGCACATGCCGGGGCTTCTG-
TAGATTTAACTATTTTCTCCCTTCATCTTGCAGGGGTATCATCCATTCTAGGAGCCATTAATTTTATTACAAC-
CATTATTAACATAAAACCACCAGCAATTTCACAATATCAAACACCTTTATTTGTATGGGCTGTCTTAATTA-
CAGCTGTTCTTCTATTATTATCTCTACCAGTACTGGCTGCCGGCATTACTATACTCCTAACAGATCGAAACCTA-
AATAC. CR 145; Lajas, La Parguera; *Hypanus americanus*; TGGTCTTAGCCTATTAATCCGGACAGAATTAAGT-
CAACCAGGCGCATTACTAGGGGATGACCAAATCTACAACGTAATCGTTACCGCCCACGCCTTTGTAAT. CR 146;
Lajas, La Parguera; *Hypanus americanus*; TGGTCTTAGCCTATTAATCCGGACAGAATTAAGTCAACCAGGCGCAT-
TACTAGGGGATGACCAAATCTACAACGTAATCGTTACCGCCCACGCCTTTGTAAT. CR 149; San Juan; *Canther-
hines macrocerus*; TGCTCTAAGCCTTTTAATTCGGGCCGAGCTAAGCCAACCCGGCGCTCTCCTTGGAGACGAC-
CAGATCTATAATGTGATCGTTACGGCCCACGCTTTCGTAAT. CR 176; Arroyo; *Pangasius bocourti*; GGCCCTCAG-
CCTCCTAATTCGGGCAGAGCTAGCCCAACCCGGCGCCCTTCTAGGCGACGACCAAATTTATAATGTTATTGT-

CACTGCCCATGCCTTCGTAAT. NS 1; San Juan; *Rhizoprionodon terraenovae*; GGAACAGCCCTAAGTCTCCTAATTCGAGCCGAACTCGGTCAACCTGGATCTCTCTTAGGAGATGATCAGATTTATAATGTGATCGTAACTGCCC. NS 2; Arecibo; *Carcharhinus perezi*; GGAACAGCCCTAAGCCTCCTAATTCGAGCTGAGCTTGGGCAACCTGGATCACTTTTAGGAGATGATCAGATTTACAATGTAATCGTAACCGCCC. NS 3; Arecibo; *Mustelus* sp.; GGGACAGCTCTAAGCCTTCTAATTCGAGCCGAACTTGGGCAGCCAGGATCACTCTTAGGTGATGATCAGATTTACAATGTGATCGTAACCGCCC. NS 4; Naguabo; *Carcharhinus perezi*; GGAACAGCCCTAAGCCTCCTAATTCGAGCTGAGCTTGGGCAACCTGGATCACTTTTAGGAGATGATCAGATTTACAATGTAATCGTAACCGCCC. NS 5; Naguabo; *Carcharhinus perezi*; GGAACAGCCCTAAGCCTCCTAATTCGAGCTGAGCTTGGGCAACCTGGATCACTTTTAGGAGATGATCAGATTTACAATGTAATCGTAACCGCCC. NS 6; Aguadilla; *Galeocerdo cuvier*; GGAACAGCTCTAAGTCTTCTAATTCGAGCTGAACTCGGACAACCAGGATCACTCTTAGGGGACGATCAAATCTATAATGTAATCGTAACTGCCC. NS 7; Arecibo; *Carcharhinus perezi*; GGAACAGCCCTAAGCCTCCTAATTCGAGCTGAGCTTGGGCAACCTGGATCACTTTTAGGAGATGATCAGATTTACAATGTAATCGTAACCGCCC. NS 8; Cataño; *Galeocerdo cuvier*; GGAACAGCTCTAAGTCTTCTAATTCGAGCTGAACTCGGACAACCAGGATCACTCTTAGGGGACGATCAAATCTATAATGTAATCGTAACTGCCC. NS 9; Cataño; *Galeocerdo cuvier*; GGAACAGCTCTAAGTCTTCTAATTCGAGCTGAACTCGGACAACCAGGATCACTCTTAGGGGACGATCAAATCTATAATGTAATCGTAACTGCCC. NS 10; Ponce; *Mustelus* sp.; GGGACAGCTCTAAGCCTTCTAATTCGAGCCGAACTTGGGCAGCCAGGATCACTCTTAGGTGATGATCAGATTTACAATGTGATCGTAACCGCCC. NS 11; Cabo Rojo; *Carcharhinus perezi*; GGAACAGCCCTAAGCCTCCTAATTCGAGCTGAGCTTGGGCAACCTGGATCACTTTTAGGAGATGATCAGATTTACAATGTAATCGTAACCGCCC. NS 12; Cataño; *Galeocerdo cuvier*; GGAACAGCTCTAAGTCTTCTAATTCGAGCTGAACTCGGACAACCAGGATCACTCTTAGGGGACGATCAAATCTATAATGTAATCGTAACTGCCC. NS 13; Ponce; *Mustelus* sp.; GGGACAGCTCTAAGCCTTCTAATTCGAGCCGAACTTGGGCAGCCAGGATCACTCTTAGGTGATGATCAGATTTACAATGTGATCGTAACCGCCC. NS 14; Maunabo; *Carcharhinus perezi*; GGAACAGCCCTAAGCCTCCTAATTCGAGCTGAGCTTGGGCAACCTGGATCACTTTTAGGAGATGATCAGATTTACAATGTAATCGTAACCGCCC. NS 15; Naguabo; *Carcharhinus perezi*; GGAACAGCCCTAAGCCTCCTAATTCGAGCTGAGCTTGGGCAACCTGGATCACTTTTAGGAGATGATCAGATTTACAATGTAATCGTAACCGCCC. NS 16; Naguabo; *Carcharhinus limbatus*; GGAACAGCCCTAAGTCTCCTAATTCGAGCTGAACTTGGGCAACCTGGATCACTTTTAGGGGATGATCAGATTTATAATGTAATCGTAACCGCCC. NS 17; Naguabo; *Sphyrna mokarran*; GGAACAGCCCTAAGTCTTTTAATTCGAGCTGAACTTGGGCAACCAGGATCCCTTTTAGGAGATGATCAGATTTACAATGTAATTGTAACCGCCC. NS 18; Arroyo; *Carcharhinus perezi*; GGAACAGCCCTAAGCCTCCTAATTCGAGCTGAGCTTGGGCAACCTGGATCACTTTTAGGAGATGATCAGATTTACAATGTAATCGTAACCGCCC. NS 19; Aguada; *Galeocerdo cuvier*; GGAACAGCTCTAAGTCTTCTAATTCGAGCTGAACTCGGACAACCAGGATCACTCTTAGGGGACGATCAAATCTATAATGTAATCGTAACTGCCC. NS 20; Isabela; *Carcharhinus perezi*; GGAACAGCCCTAAGCCTCCTAATTCGAGCTGAGCTTGGGCAACCTGGATCACTTTTAGGAGATGATCAGATTTACAATGTAATCGTAACCGCCC. NS 21; Cataño; *Galeocerdo cuvier*; GGAACAGCTCTAAGTCTTCTAATTCGAGCTGAACTCGGACAACCAGGATCACTCTTAGGGGACGATCAAATCTATAATGTAATCGTAACTGCCC. NS 22; Penuelas; *Galeocerdo cuvier*; GGAACAGCTCTAAGTCTTCTAATTCGAGCTGAACTCGGACAACCAGGATCACTCTTAGGGGACGATCAAATCTATAATGTAATCGTAACTGCCC. NS 23; Aguadilla; *Rhizoprionodon terraenovae*; GGAACAGCCCTAAGTCTCCTAATTCGAGCCGAACTCGGTCAACCTGGATCTCTCTTAGGAGATGATCAGATTTATAATGTGATCGTAACTGCCC. NS 24; Yabucoa; *Carcharhinus limbatus*; GGAACAGCCCTAAGTCTCCTAATTCGAGCTGAACTTGGGCAACCTGGATCACTTTTAGGGGATGATCAGATTTATAATGTAATCGTAACCGCCC. NS 25; Naguabo; *Carcharhinus acronotus*; GGAACAGCCCTAAGTCTTCTAATTCGAGCTGAACTTGGGCAACCTGGATCACTTTTAGGAGATGATCAGATCTACAATGTAATCGTAACCGCCC. NS 26; Cataño; *Galeocerdo cuvier*; GGAACAGCTCTAAGTCTTCTAATTCGAGCTGAACTCGGACAACCAGGATCACTCTTAGGGGACGATCAAATCTATAATGTAATCGTAACTGCCC. NS 27; Naguabo; *Carcharhinus limbatus*; GGAACAGCCCTAAGTCTCCTAATTCGAGCTGAACTTGGGCAACCTGGATCACTTTTAGGGGATGATCAGATTTATAATGTAATCGTAACCGCCC. NS 28; Naguabo; *Galeocerdo cuvier*; GGAACAGCTCTAAGTCTTCTAATTCGAGCTGAACTCGGACAACCAGGATCACTCTTAGGGGACGATCAAATCTATAATGTAATCGTAACTGCCC. NS 29; Rincon; *Carcharhinus acronotus*; GGAACAGCCCTAAGTCTTCTAATTCGAGCTGAACTTGGGCAACCTGGATCACTTTTAGGAGATGATCAGATCTACAATGTAATCGTAACCGCCC. NS 30; Cabo Rojo; *Galeocerdo cuvier*; GGAACAGCTCTAAGTCTTCTAATTCGAGCTGAACTCGGACAACCAGGATCACTCTTAGGGGACGATCAAATCTATAATGTAATCGTAACTGCCC. NS 33; Ponce; *Carcharhinus falciformis*; GGAACAGCCCTAAGTCTTCTAATTCGAGCTGAGCTTGGACAACCTGGATCACTTTTAGGGGATGATCAGATTTACAATGTAATCGTAACCGCCC. NS 34; Rincon; *Galeocerdo cuvier*; GGAACAGCTCTAAGTCTTCTAATTCGAGCTGAACTCGGACAACCAGGATCACTCTTAGGGGACGATCAAATCTATAATGTAATCGTAACTGCCC. NS 35; Penuelas; *Galeocerdo cuvier*; GGAACAGCTCTAAGTCTTCTAATTCGAGCTGAACTCGGACAACCAGGATCACTCTTAGGGGACGATCAAATCTATAATGTAATCGTAACTGCCC. NS 36; Ponce; *Mustelus canis*; GGGACAGCTCTAAGCCTTCTAATTCGAGCCGAACTTGGGCAGCCAGGATCACTCTTAGGTGATGATCAGATTTACAATGTGATCGTAACCGCCC. NS 38; Naguabo; *Galeocerdo cuvier*; GGAACAGCTCTAAGTCTTCTAATTCGAGCTGAACTCGGACAACCAGGATCACTCTTAGGGGACGATCAAATCTATAATGTAATCG-

TAACTGCCC. NS 42; Cabo Rojo; *Galeocerdo cuvier*; GGAACAGCTCTAAGTCTTCTAATTCGAGCTGAACTCGGACAACCAGGATCACTCTTAGGGGACGATCAAATCTATAATGTAATCGTAACTGCCC. NS 43; Ponce; *Mustelus* sp.; GGGACAGCTCTAAGCCTTCTAATTCGAGCCGAACTTGGGCAGCCAGGATCACTCTTAGGTGATGATCAGATTTACAATGTGATCGTAACCGCCC. NS 44; Aguada; *Sphyrna mokarran*; GGAACAGCCCTAAGTCTTTTAATTCGAGCTGAACTTGGGCAACCAGGATCCCTTTTAGGAGATGATCAGATTTACAATGTAATTGTAACCGCCC. NS 46; Cataño; *Galeocerdo cuvier*; GGAACAGCTCTAAGTCTTCTAATTCGAGCTGAACTCGGACAACCAGGATCACTCTTAGGGGACGATCAAATCTATAATGTAATCGTAACTGCCC. NS 47; San Juan; *Carcharhinus perezi*; GGAACAGCCCTAAGCCTCCTAATTCGAGCTGAGCTTGGGCAACCTGGATCACTTTTAGGAGATGATCAGATTTACAATGTAATCGTAACCGCCC. NS 48; Cabo Rojo; *Galeocerdo cuvier*; GGAACAGCTCTAAGTCTTCTAATTCGAGCTGAACTCGGACAACCAGGATCACTCTTAGGGGACGATCAAATCTATAATGTAATCGTAACTGCCC. NS 50; Aguada; *Sphyrna mokarran*; GGAACAGCCCTAAGTCTTTTAATTCGAGCTGAACTTGGGCAACCAGGATCCCTTTTAGGAGATGATCAGATTTACAATGTAATTGTAACCGCCC. NS 51; Aguada; *Sphyrna mokarran*; GGAACAGCCCTAAGTCTTTTAATTCGAGCTGAACTTGGGCAACCAGGATCCCTTTTAGGAGATGATCAGATTTACAATGTAATTGTAACCGCCC. NS 52; Añasco; *Sphyrna mokarran*; GGAACAGCCCTAAGTCTTTTAATTCGAGCTGAACTTGGGCAACCAGGATCCCTTTTAGGAGATGATCAGATTTACAATGTAATTGTAACCGCCC. NS 53; Ponce; *Carcharhinus falciformis*; GGAACAGCCCTAAGTCTTCTAATTCGAGCTGAGCTTGGACAACCTGGATCACTTTTAGGGGATGATCAGATTTACAATGTAATCGTAACCGCCC. NS 54; Maunabo; *Galeocerdo cuvier*; GGAACAGCTCTAAGTCTTCTAATTCGAGCTGAACTCGGACAACCAGGATCACTCTTAGGGGACGATCAAATCTATAATGTAATCGTAACTGCCC. NS 55; Arecibo; *Hexanchus nakamurai*; GGTACAGCCCTAAGTTTACTCATCCGAACGGAATTAAGTCAACCCGGAACACTTTTAGGGGACGATCAGATTTATAATGTAATTGTTACCGCCC. NS 56; Naguabo; *Carcharhinus perezi*; GGAACAGCCCTAAGCCTCCTAATTCGAGCTGAGCTTGGGCAACCTGGATCACTTTTAGGAGATGATCAGATTTACAATGTAATCGTAACCGCCC. NS 57; San Juan; *Carcharhinus perezi*; GGAACAGCCCTAAGCCTCCTAATTCGAGCTGAGCTTGGGCAACCTGGATCACTTTTAGGAGATGATCAGATTTACAATGTAATCGTAACCGCCC. NS 58; Rincon; *Carcharhinus falciformis*; GGAACAGCCCTAAGTCTTCTAATTCGAGCTGAGCTTGGACAACCTGGATCACTTTTAGGGGATGATCAGATTTACAATGTAATCGTAACCGCCC. NS 59; Cataño; *Galeocerdo cuvier*; GGAACAGCTCTAAGTCTTCTAATTCGAGCTGAACTCGGACAACCAGGATCACTCTTAGGGGACGATCAAATCTATAATGTAATCGTAACTGCCC. NS 60; Naguabo; *Carcharhinus perezi*; GGAACAGCCCTAAGCCTCCTAATTCGAGCTGAGCTTGGGCAACCTGGATCACTTTTAGGAGATGATCAGATTTACAATGTAATCGTAACCGCCC. NS 74; Naguabo; *Carcharhinus perezi*; GGAACAGCCCTAAGCCTCCTAATTCGAGCTGAGCTTGGGCAACCTGGATCACTTTTAGGAGATGATCAGATTTACAATGTAATCGTAACCGCCC. NS 76; Penuelas; *Carcharhinus limbatus*; GGAACAGCCCTAAGTCTCCTAATTCGAGCTGAACTTGGACAACCTGGATCTCTTTTAGGAGATGATCAGATTTATAATGTAATCGTAACCGCCC. NS 77; Cabo Rojo; *Rhizoprionodon terraenovae*; GGAACAGCCCTAAGTCTCCTAATTCGAGCCGAACTCGGTCAACCTGGATCTCTCTTAGGAGATGATCAGATTTATAATGTGATCGTAACTGCCC. NS 78; Arecibo; *Galeocerdo cuvier*; GGAACAGCTCTAAGTCTTCTAATTCGAGCTGAACTCGGACAACCAGGATCACTCTTAGGGGACGATCAAATCTATAATGTAATCGTAACTGCCC. NS 79; Penuelas; *Carcharhinus limbatus*; GGAACAGCCCTAAGTCTCCTAATTCGAGCTGAACTTGGACAACCTGGATCTCTTTTAGGAGATGATCAGATTTATAATGTAATCGTAACCGCCC. NS 80; Salinas; *Sphyrna mokarran*; GGAACAGCCCTAAGTCTTTTAATTCGAGCTGAACTTGGGCAACCAGGATCCCTTTTAGGAGATGATCAGATTTACAATGTAATTGTAACCGCCC. NS 81; Naguabo; *Galeocerdo cuvier*; GGAACAGCTCTAAGTCTTCTAATTCGAGCTGAACTCGGACAACCAGGATCACTCTTAGGGGACGATCAAATCTATAATGTAATCGTAACTGCCC. NS 82; Yabucoa; *Carcharhinus perezi*; GGAACAGCCCTAAGCCTCCTAATTCGAGCTGAGCTTGGGCAACCTGGATCACTTTTAGGAGATGATCAGATTTACAATGTAATCGTAACCGCCC. NS 83; Yabucoa; *Carcharhinus perezi*; GGAACAGCCCTAAGCCTCCTAATTCGAGCTGAGCTTGGGCAACCTGGATCACTTTTAGGAGATGATCAGATTTACAATGTAATCGTAACCGCCC. NS 84; Cataño; *Galeocerdo cuvier*; GGAACAGCTCTAAGTCTTCTAATTCGAGCTGAACTCGGACAACCAGGATCACTCTTAGGGGACGATCAAATCTATAATGTAATCGTAACTGCCC. NS 85; Cabo Rojo; *Carcharhinus falciformis*; GGAACAGCCCTAAGTCTTCTAATTCGAGCTGAGCTTGGACAACCTGGATCACTTTTAGGGGATGATCAGATTTACAATGTAATCGTAACCGCCC. NS 86; Naguabo; *Galeocerdo cuvier*; GGAACAGCTCTAAGTCTTCTAATTCGAGCTGAACTCGGACAACCAGGATCACTCTTAGGGGACGATCAAATCTATAATGTAATCGTAACTGCCC. NS 87; Naguabo; *Galeocerdo cuvier*; GGAACAGCTCTAAGTCTTCTAATTCGAGCTGAACTCGGACAACCAGGATCACTCTTAGGGGACGATCAAATCTATAATGTAATCGTAACTGCCC. NS 89; Naguabo; *Carcharhinus perezi*; GGAACAGCCCTAAGCCTCCTAATTCGAGCTGAGCTTGGGCAACCTGGATCACTTTTAGGAGATGATCAGATTTACAATGTAATCGTAACCGCCC. NS 90; Naguabo; *Carcharhinus perezi*; GGAACAGCCCTAAGCCTCCTAATTCGAGCTGAGCTTGGGCAACCTGGATCACTTTTAGGAGATGATCAGATTTACAATGTAATCGTAACCGCCC. NS 91; Naguabo; *Carcharhinus perezi*; GGAACAGCCCTAAGCCTCCTAATTCGAGCTGAGCTTGGGCAACCTGGATCACTTTTAGGAGATGATCAGATTTACAATGTAATCGTAACCGCCC. NS 92; Naguabo; *Carcharhinus perezi*; GGAACAGCCCTAAGCCTCCTAATTCGAGCTGAGCTTGGGCAACCTGGATCACTTTTAGGAGATGATCAGATTTACAATGTAATCGTAACCGCCC.