

## ARTICLE

# Site Fidelity and Residency of *Tursiops truncatus* off the Aragua Coast, Venezuela-First Records of Long Residency

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## ABSTRACT

This study represents the first comprehensive analysis of the residency patterns of a coastal population of bottlenose dolphin off the coast of Aragua, Venezuela, over a multi-year period. Using photo-identification, the most recent study (2019-2020) identified 56 individuals with the time between encounters from one to 344 days between the first and last sighting. Site Fidelity (SF) and Residence (RES) indices were calculated and Agglomerative Hierarchical Clustering (AHC) modeling was performed, with three patterns of residence obtained: resident (25%), semi-resident (17.86%) and transient (57.14%). These results were contrasted with remodeled data from a previous study (2006-2007), showing similar patterns: resident (24.44%), semi-resident (28.89%) and transient (46.67%). Importantly, two individuals were found to have been resident over the extended period. A breeding female sighted for the first time in 2004 and again in 2020 (16 years) and the other from 2005 to 2020 (15 years).

This region is an important area for marine mammals, known to support a resident reproductive population over many years, as well seabirds, sea turtles, whale sharks and fishermen. We recommend that consideration be given to designating the waters as a Marine Protected Area to safeguard the existing population and provide benefit to the surrounding marine environment.

## 1. Introduction

Although most abundant offshore, the relative ease of watching *T. truncatus* from the coast makes them one of

the best-known species of cetacean <sup>[1]</sup>. Despite this and their function as a coastal habitat umbrella species <sup>[2]</sup>, data on population size, stability, distribution, habitat and gene flow is lacking for many populations of coastal bottlenose

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dolphin<sup>[3]</sup>.

Research to date has shown that individuals within populations of *T. truncatus* may show high levels of variability in their residential patterns - with evidence of some remaining for many years, whilst others show high fidelity but for just a few days or seasonally<sup>[4-6]</sup>.

Previous investigations have identified populations that demonstrate high levels of residency or site fidelity; the Moray Firth (Scotland) supports a 200 strong population of *T. truncatus* with high residency rates and low numbers of transients<sup>[7]</sup>, whilst on the other side of the North Atlantic, genetic studies indicate populations using open waters between New York and Florida (USA) portion the habitat latitudinally and longitudinally, demonstrating residency with seasonal overlap between populations<sup>[8]</sup>. Other highly resident populations have been recorded off Walvis Bay (Namibia) (James, personal communication, 2021), Dusky Bay (New Zealand)<sup>[9]</sup> and Mikura Jima (Japan)<sup>[10]</sup>, although all also experience varying numbers of transient individuals.

In order to make appropriate management and conservation recommendations it is necessary to study separate populations to an individual level in order to better realise home range, residency patterns, site-fidelity patterns and changes in population size and distribution<sup>[11,12]</sup>. The ability to confidently detect trends in abundance over time enables early identification of potential issues<sup>[13]</sup> in order that corrective measures can be taken - shifts in occurrence and abundance may indicate a decline in prey abundance for example or a new anthropogenic pressure<sup>[14]</sup> that requires consideration or mitigation.

The purpose of this study is to better understand the long-term residency status and site-fidelity of a small coastal population of *T. truncatus* that utilise the waters off Bahía de Cata, Aragua, Venezuela in order to assist with the identification of suitable conservation measures.

Anecdotal evidence from fishermen suggests pods of *T. truncatus* have used the Bahía de Cata stretch of coastline for more than 50 years (Jose ‘Cata’, personal communication, 2021), with the first known population study undertaken in 1998<sup>[15]</sup>. In more recent times, photographic identification has been employed during studies as a proven capture-recapture method<sup>[16]</sup> to aid abundance estimates of the population but in the face of limited resources many of these studies have been short-lived or been broken by extended periods of inactivity. This latest study, when combined with the reanalysed results of a previous study, is able for the first time to quantify the long-term residency and site fidelity trends of this population, as well as providing first records of long residency of *T. truncatus* in Venezuelan waters.

## 2. Materials and Methods

### Study Area

The coast of Aragua, Venezuela borders the south Caribbean Sea and extends to ~60 km. The study area (~30 km) covered the stretch of water between Bahía de Turiamo (10° 28’ N, 67° 50’ W, western terminus) and Colombia Port (10° 30’ N, 67° 36’ W, eastern terminus), extending out to approximately three km from the coastline, covering an area of ~92 km<sup>2</sup> (Figure 1). The coastline features rocky cliffs with some sandy beaches<sup>[17]</sup> and is characterised by three main habitat types: internal and external coastal habitats and neritic. Sea surface temperatures remain fairly constant between 25-27 °C, with salinity at 34-36 ppm<sup>[18]</sup>. Tidal regime for the region is ± 24 cm (in a mixed tidal pattern) and the primary weather seasons are dry (November-April) and wet (May-October)<sup>[18]</sup> (Figure 1).

### Data Collection and Photo-Identification

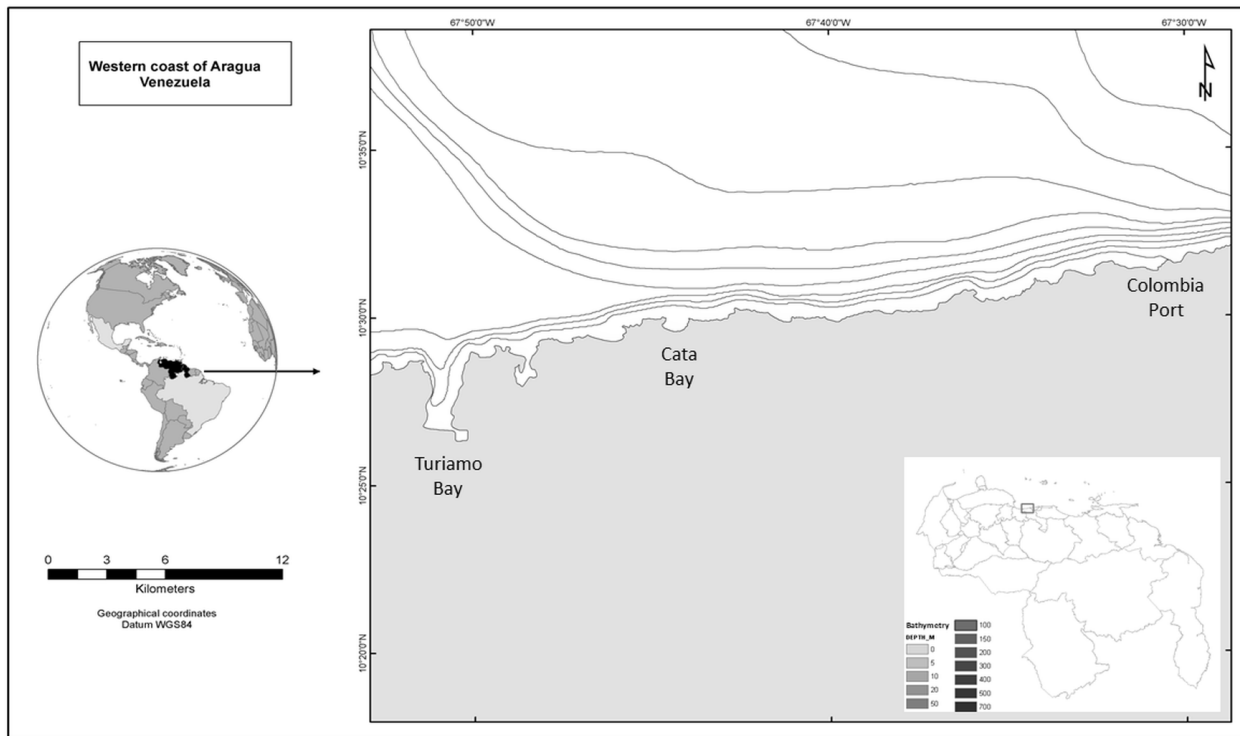
Six field sessions were conducted each consisting of five boat surveys (Jun 2019, Aug 2019, Oct 2019, Nov 2019, Mar 2020 and May 2020). Surveys were not conducted between the months of Dec 2019 and Feb 2020 when the coastline experiences a swell season, with a sea state of four or greater on the Douglas Scale.

All boat surveys sessions were carried out under Scientific Hunting Permit from the Ministry of the Environment granted by the National Office of Biological Diversity, Venezuela. Each survey was completed in one day, lasted approximately ~3.5 hours, undertaken when sea state was below three on the Douglas Scale and conducted along a predefined ~30 km line transect.

A 9m long 45 HP outboard-powered “peñero” (skiff/panang) was used to survey the transect at a speed of ~seven knots with four observers aboard (bow, starboard, port and the skipper, who has undertaken observer training, at the stern. Visibility extended to a minimum distance of 1.5 km for all surveys.

When dolphins were sighted, the vessel approached at reduced power (maximum 0.5 knots) in order to reduce the impact of its presence on the dolphins’ behaviour, maintaining a position roughly parallel to direction of travel. If stationary, feeding, socializing or resting, a distance of approximately 20 m was maintained.

Date, start and end times, geographic coordinates, visibility, Douglas, Beaufort, wind direction, pod size, pod composition, behaviour, other species present and boats viewable from the transect line were recorded every 30 minutes, as well as supplementary bioacoustics



**Figure 1.** Study area: western coast of Aragua, Venezuela.

recordings. Once in closer proximity to the dolphins, the bow observer photographed individuals using a Digital Rebel XT Reflex SRL Canon camera with a Canon 18-200 or 35-300 mm zoom lens, set to 'Large' file size.

Following a survey, photographs were sorted using Irfanview 4.57 and reviewed independently by three processors to minimize potential for individual error. Photographs were then selected that enabled accurate identification of each adult individual (dorsal fin in focus, parallel to the plane of the photo, well-defined fin edge or other natural, permanent marks, e.g. scars, notches, and deformations<sup>[19,21]</sup>). Non-adults and individuals classified as unmarked (i.e. no edge marks on dorsal or distinguishing features) were excluded. Darwin 2.22 was used to compile a catalogue of identifiable individuals, with a matching query performed on each new individual upon entry to prevent duplication. Individuals were assigned a category of distinctiveness, relative to the number, depth and extent of markings, ranging from D1 to D3 where D1 = slightly distinctive, D2 = distinctive and D3 = very distinctive<sup>[19,22,24]</sup> (Figure 2). Finally, once identification was completed, an individual was assigned an alpha-numeric ID code (T####).

### Daily Encounter Ratio and Pod Size

In order to estimate frequency of observation the Daily Encounter Ratio (DER) of *Tursiops truncatus*

was calculated as 'number of sightings / search effort'<sup>[25]</sup>. A pod was defined as all dolphins within a 100 m radius<sup>[26]</sup> in apparent association, moving in the same direction although not necessarily involved in the same activity<sup>[27]</sup>. Pod size was calculated by each observer independently counting the number of animals present until a consensus was reached; these field-estimated sizes were later corrected if photo-identification provided more accurate information. Pod composition was recorded for all encounters, i.e. number of calves ( $\leq$  half the length of the accompanying adult and in very close proximity), juveniles ( $>$  half the length of the accompanying adult) and adults.

### Site Fidelity and Residency

Site fidelity was defined as the reutilisation of an area by an individual<sup>[28]</sup>. An index to quantify site fidelity for each individual was calculated, being the ratio between the number of recaptures and the number of days sampled, as a proportion;<sup>[28,29]</sup> with a value of one indicating that the individual was sighted in every survey and a value of zero indicating that it was sighted once (no recaptures).

Residency was defined as the tendency of an individual to remain or return to the study area<sup>[30]</sup>. A residency index was calculated as being the number of days elapsed from the first sighting to the last as a proportion of the total number of days in the sampling period<sup>[30,32]</sup>.



**Figure 2.** Different marking levels in dorsal fin: D1: Slightly distinctive (few notches along the trailing edge). D2: Distinctive (moderated notches) and D3: Very distinctive (multiple and large notches, deep nicks, cuts along the trailing edge or leading edge and disfigurements).

Depending upon residency pattern; prolonged residence, intermediate/seasonal residence or short residence, individuals were categorised as Resident, Semi-resident or Transient. Analysis using Agglomerative Hierarchical Clustering (a bottom-up clustering methodology, with each observation starting as an individual cluster, with pairs of clusters then merging based on similarity as one moves up the hierarchy until all clusters have been combined into one) <sup>[28]</sup> for site fidelity and residency indices was undertaken to enable discrimination between classes, these analysis were performed using PAST software. Squared Euclidean distance was selected as the most appropriate measure of dissimilarity with Ward's method selected as the linkage criteria <sup>[33]</sup>. Automatic truncation was based upon the entropy criterion. To verify the validity of the resulting dendrogram, the cophenetic correlation coefficient (CCC) <sup>[34]</sup> was calculated; with the dendrogram most accurately representing the structure of the data when the value approaches one <sup>[28]</sup>.

### 3. Results

#### Survey Effort

A total of 30 boat surveys (103 hours) were conducted across six sessions between June 2019 and May 2020. Bottlenose dolphins were sighted in 15 field surveys (ten hours of observation time) with a total of 16 encounters.

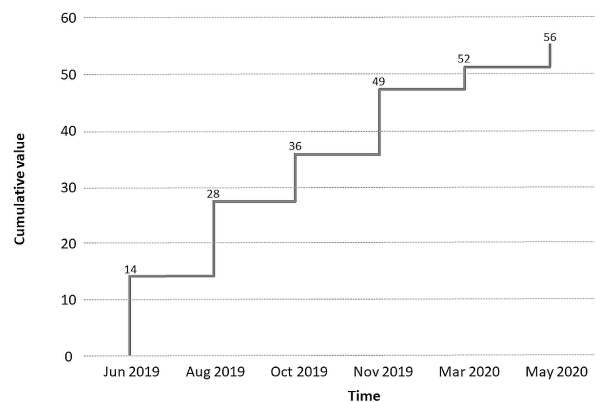
#### Daily Encounter Ratio and Pod Size

Pod size ranged from two to 37 individuals ( $X = 16.50$ ,  $SD = 10$ ,  $SE = 3.00$ ) with a daily encounter ratio of 5.64 individuals ( $SD = 4.00$ ) per survey day. Pod composition revealed an average of 2.50 calves ( $SD = 2.57$ ), 2.83 juveniles ( $SD = 2.58$ ) and 11.25 adults ( $SD = 6.30$ ).

#### Photo-identification

A total of 3,011 photographs were taken however only

those that had the potential to meet the selection criteria were processed. Of these, a total of 120 photographs were chosen for classification resulting in 56 marked individuals being identified and recorded in the catalogue. The cumulative curve of new individuals did not plateau prior to the end of the study period and presented a mean identification rate of 0.78 individuals per field survey (Figure 3), with 84.31% ( $\pm 6.34$ ) of adults observed in a pod identifiable (i.e. 15.69% of adult individuals were unmarked).



**Figure 3.** Cumulative curve of new photo-identified individuals.

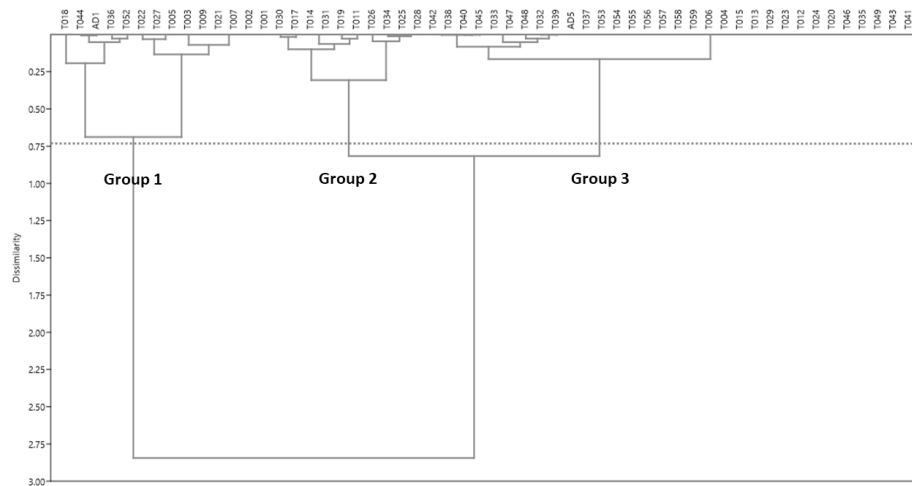
#### Site Fidelity and Residency

Of the 56 individuals identified, half of these were sighted more than once (maximum of eight sightings recorded) with permanence extending from one to 344 days. Average site fidelity index was 0.104 ( $SD = 0.081$ ), ranging from 0.038 to 0.308, and average residency index was 0.271 ( $SD = 0.371$ ) ranging from 0.003 to 0.997.

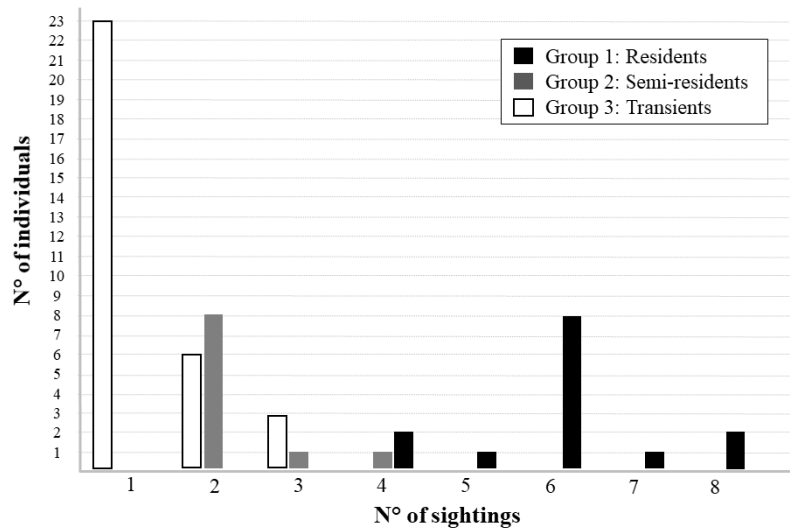
The dissimilarity threshold was set at 0.74 and three clusters were reliably identified (Figure 4). The first cluster included 14 individuals (25.00% of all photo-identified individuals), with four to eight sightings (Figure 5), a permanence of 198 to 344 days and high index values [site fidelity index of 0.231 ( $\pm 0.044$ ) and residency index of

0.868 ( $\pm 0.179$ ), with individuals categorised as resident. A second cluster comprised ten individuals (17.86% of all identified individuals), with two to four sightings, a permanence of 52 to 146 days and medium index values [site fidelity index of 0.088 ( $\pm 0.025$ ) and residency index of 0.157 ( $\pm 0.094$ )], with these individuals categorised as

semi-resident. A third cluster of 32 individuals was also identified (57.14% of all identified individuals), with one to three sightings, a permanence of one to 17 days and low index values [site fidelity index of 0.053 ( $\pm 0.025$ ) and residency index of 0.009 ( $\pm 0.015$ ) (Table 1)], with individuals categorised as transient.



**Figure 4.** Dendrogram of the agglomerative hierarchical clustering analysis. Group 1 are Resident individuals, Group 2 Semi-resident and Group 3 Transient. Dashed line represents the dissimilarity threshold.



**Figure 5.** Sighting frequency by agglomerative hierarchical clusters.

**Table 1.** N° of individuals, N° of sightings, Site fidelity mean ( $\pm$ SD), Residence mean ( $\pm$ SD) and Category (% of the individuals).

N° of individuals	N° of sightings	N° of days	Site fidelity Mean ( $\pm$ SD)	Residence Mean ( $\pm$ SD)	Category (% of individuals)
14	4 - 8	198-344	0.231 ( $\pm 0.044$ )	0.868 ( $\pm 0.179$ )	Resident (25.00)
10	2 - 4	52-146	0.088 ( $\pm 0.025$ )	0.157 ( $\pm 0.094$ )	Semi-resident (17.86)
32	1 - 3	1-17	0.053 ( $\pm 0.025$ )	0.009 ( $\pm 0.015$ )	Transient (57.14)



## Reanalysis of Data for the Period 2006-2007

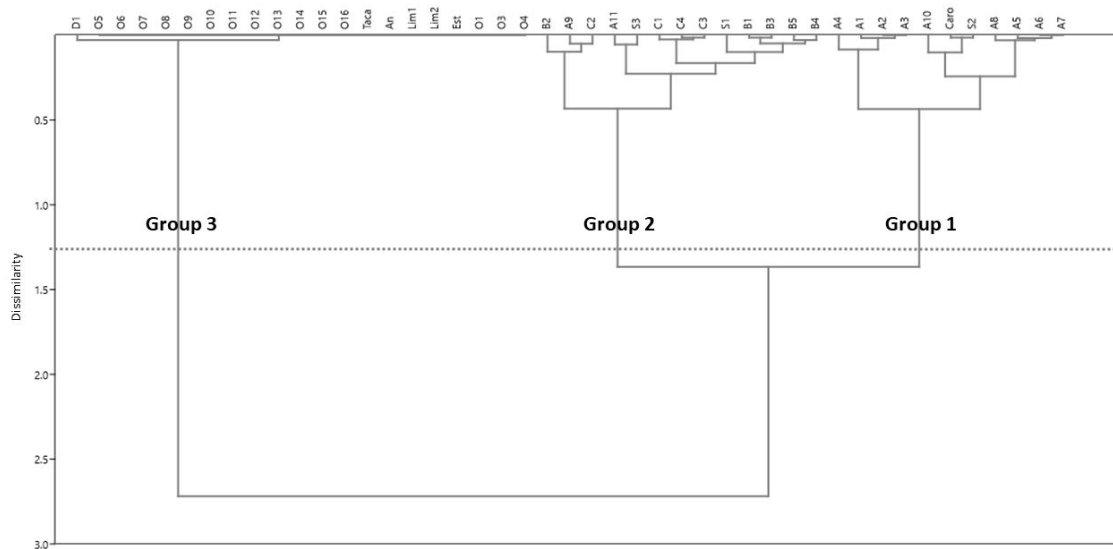
A residency analysis was previously conducted<sup>[35]</sup> using the (modified) method of Möller et al.<sup>[28]</sup> without the use of AHC. This study involved 49 boat surveys that allowed identification of 45 individuals. This data was remodeled using the same AHC methodology as the current study in order to allow for direct comparison.

Reanalysis showed the presence of three defined clusters (dissimilarity threshold was set at 1.25) (Figure 6). The first cluster included 11 individuals (24.44% of all photo-identified individuals), with six to 18 sightings, a permanence of 273 to 346 days and high index values [site fidelity index of 0.202 (SD = 0.112) and residency index of 0.960 (SD = 0.068)] with individuals categorised as resident. A second cluster included 13 individuals (28.89% of identified individuals), with two to nine sightings, a permanence of 92 to 210 days and medium index values [site fidelity index of 0.102 (SD = 0.049) and residency index of 0.470 (SD = 0.110)], with individuals categorised as semi-resident. A third cluster of 21 individuals (46.67%

of identified individuals) with one to two sightings, a permanence of one to eight days and low index values [site fidelity index of 0.021 (SD = 0.004) and residency index of 0.004 (SD = 0.004)], with individuals categorised as transient (Table 2).

## First Records of Long Term Residency

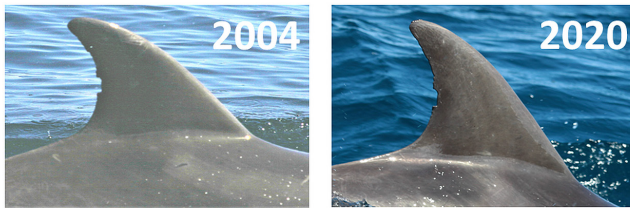
During the November 2019 field session, individuals AD1 and AD5 were re-identified from surveys conducted in 2004<sup>[35]</sup>. The former was sighted six times as part of the current study and had a recorded stay of 198 days; the latter was sighted only once. These individuals were first photo-identified during our study from 2004-2008; AD1 is a female that was sighted 31 times (high frequency resident) from May 2004 to December 2008 (Figure 7) and AD5 was sighted 16 times (medium frequency resident) from July 2005 to December 2008 (Figure 8). Both belonged to the most sighted cluster. Considering the time elapsed between the first sightings and this study, AD1 has shown minimum site fidelity of 16 years and AD5 of 15 years.



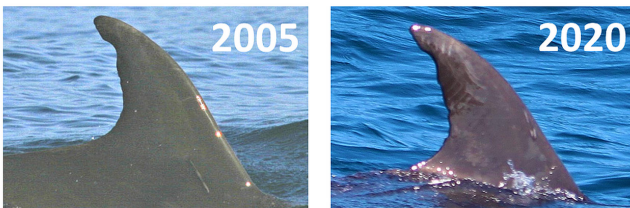
**Figure 6.** Dendrogram of the agglomerative hierarchical clustering analysis from data period 2006-2007. Group 1 are Resident individuals, Group 2 Semi-resident and Group 3 Transient. The dashed line represents the dissimilarity threshold.

**Table 2.** N° of individuals, N° of sightings, Site fidelity mean ( $\pm$ SD), Residence mean ( $\pm$ SD) and Category (% of the individuals) for the period 2006-2007.

N° of individuals	N° of sightings	N° of Days	Site fidelity Mean ( $\pm$ SD)	Residence Mean ( $\pm$ SD)	Category (% of individuals)
11	6 - 18	273-346	0.202 ( $\pm$ 0.112)	0.960 ( $\pm$ 0.068)	Resident (24.44)
13	2 - 9	92-210	0.102 ( $\pm$ 0.049)	0.470 ( $\pm$ 0.110)	Semi-resident (28.89)
21	1 - 2	1-8	0.021 ( $\pm$ 0.004)	0.004 ( $\pm$ 0.004)	Transient (46.67)



**Figure 7.** Individual AD1, a female photo-identified 31 times between May 2004 and December 2008 (left) and re-identified 6 times between November 2019 and May 2020 (right).



**Figure 8.** Individual AD5, photo-identified 16 times between July 2005 and December 2008 (left) and re-identified once between November 2019 to May 2020 (right).

#### 4. Discussion

This study presents for the first time an updated and re-evaluated assessment of the residency and site fidelity of bottlenose dolphin along the western Aragua coast of Venezuela, reinforcing historical assessments and providing first records of extended residency and site fidelity.

The accumulation curve of photo-identified individuals (Figure 3) did not reach the asymptote and it is anticipated that additional new individuals will continue to be photo-identified in any future study. This expectation is reinforced by the high proportion of transient individuals recorded (46.67% for the period 2006-2007 and 49.23% for this current study) to date. In each month sampled, between one and seven new individuals were photo-identified, the latter being a pod of adults travelling west through the study area, as well as another sighting of two individuals travelling east. The remaining transients were recorded associating with the resident pods. This confirms the openness of the habitat, with individuals crossing the area from both the western and eastern ends. To date, the offshore ecotype (with a longer, more streamlined body and shorter fins) has not been observed.

A mosaic of three residential patterns of *Tursiops truncatus* is confirmed: 1) year round residency; 2) seasonal or intermittent semi-residency; and 3) transient.

These residential patterns have been previously reported for this species in other regions with continental and insular coastal habitat [5,28,44,46,36,43].

Approximately a quarter of the sampled population showed long-term year-round residency and we hypothesise that there are two resident pods which together constitute at least 33 individuals. These pods are easily differentiated, with the most frequently sighted pod displaying lighter pigmentation than the other. These two pods exhibit characteristics similar to those reported in other sheltered coastal populations of *T. truncatus* i.e. a small population with long annual residence, no migratory movements and reduced dispersal [26,47,50]. Such site fidelity and residency has also been recorded in other coastal species such as *Tursiops aduncus* and *Sousa chinensis*, as well as pelagic species including *Steno bredanensis*, *Pseudorca crassidens* and female *Physeter macrocephalus* [27,48,51,53].

In both our previous and current studies we monitored the behaviours of two pods of breeding females whose prolonged stay is believed to be due to the presence of (1) a refuge, (2) an annual prey source and 3) low human impact. Bahía de Turiamo (Figure 1), the location of a former naval base, provides a 35 km<sup>2</sup> refuge sheltered from currents and winds, with access prohibited to all commercial and private traffic. In the early morning, a few adults of the most sighted pod depart eastward from this bay and, in the absence of trade winds and opposing currents, travel ~ eight km east where they begin to explore the western end of a known year-round prey source (possibly due to a small upwelling, although further investigation is required to confirm this) typically occupying an area of ~24 km<sup>2</sup> (centre of prey source: ~15 km from the shelter) and providing approximately 20 species of fish and a cephalopod species along the year [54]. After an early exploration by the first adults, the rest of the pod joins with them and the pod feeds together, finishing its feeding activity in the midday hours to then engage in socialising and rest. They then travel slowly back westwards; when the trade winds (and consequently the swell) generally align with the direction of travel, reducing the energy demand, with the journey almost appearing 'restful'.

During this study, three encounters were observed of the two merged pods performing this activity. It was noted that the prey source was also utilised by fishermen from at least four coastal villages with, at its busiest, upto 26 - 30 artisanal boats being recorded within the study area (Cobarrubia-Russo, unpublished work). In addition to *T. truncatus*, the area has previously been recorded as supporting resident and visiting *Stenella frontalis*,

with sightings of up to ten pods (mean pod size = 34.34 individuals, SD = 31.93, Min = 2, Max = 120<sup>[49]</sup>). The area is also known to support other species with occasional sightings of *Delphinus* sp., *Stenella longirostris*, *Balaenoptera* sp and *Ziphiidae* sp.<sup>[35,49]</sup> recorded, as well as sightings of juvenile *Rhincodon typus* in recent years (Cobarrubia-Russo, unpublished work).

Given this scenario and the apparent abundance of prey, it is theorised that non-resident *T. truncatus* with a range north (offshore ecotype) or neighbouring (coastal ecotype) to the study area could also use the habitat within the study area, albeit less frequently, and show semi-residency.

The resident *T. truncatus* population off Aragua is notably small<sup>[55]</sup> compared to offshore populations, although in-line with expectations for a coastal population<sup>[56]</sup>. Despite good provision of prey and shelter, local bathymetry could be an important factor in limiting the size of this population. Coastal ecotypes of *T. truncatus* typically live in marine lagoons, inlets, bays, estuaries and open coasts, at a depth range of one to 40 m. Range limits are often demarcated by physiographic features that increase depth such as channels or submarine canyons<sup>[26,39,42,57,58]</sup>. As has been previously recorded along the Ligurian coast,<sup>[59]</sup> this study found individuals predominantly remained between the 50-100 m isobaths with only occasional incursions into waters exceeding the 200 m isobath in Aragua (max. 400m isobath in the Ligurian Sea)<sup>[60,61]</sup>.

Transient individuals accounted for almost half of the dolphins identified (46.67% present study, 49.23% 2006-2007), a percentage similar to that reported in the Istanbul Strait (Turkey) and the Adelaide Coast (Australia)<sup>[28, 46]</sup>. Despite the dramatic contrast between the Istanbul Strait and Aragua in terms of latitude, seasonality and maritime usage, a surprising similarity was noted between the coastal and semi-enclosed habitat of the Strait of Istanbul and the open oceanic coast of Aragua (and the entire central coast of Venezuela), in that the latter - having a very pronounced continental slope resulting in the 100 m isobath being located very close to the shoreline - effectively mimics a narrow corridor of depths between 0 m and 100 m, with the Caribbean pelagic basin effectively restricting the range of *T. truncatus* latitudinally.

Additional survey effort is required to provide greater resolution as to the pattern of usage, in particular to aid identification of semi-resident individuals that, over time, join the pod and become resident, and those individuals that maintain semi-resident or seasonal residency and the patterns of this behaviour. This could, for example, assist with identification and abundance estimates of males that

may only utilise the area during mating season (November to January) and, as such, display high site fidelity over a short period in time. Observed previously within this region,<sup>[35]</sup> a similar scenario has also been reported by Giacomo and Ott<sup>[62]</sup> within the Tramandaí estuary of southern Brazil.

On-going survey effort maintained throughout the year and across multiple years is essential to more fully understanding habitat use, site fidelity and residency<sup>[63]</sup> as these will vary by season. To illustrate this point, a short but intensive photo-identification study undertaken from January to June 2019 [56 field surveys, Effort: 109 h, Transect = 22 km not including Bahía de Turiamo, photo-ID efficiency = 24%] considered indices of residency, site fidelity and assiduity. Of the 54 individuals photo-identified, just 7.41% were categorised as resident (one of them AD1), 20.37% semi-residents and the majority as transients at 72.22%,<sup>[64]</sup> contrasting sharply with the results of both this study and the study of 2006 - 2007.

*T. truncatus* can show a wide range of variability in residency and site fidelity<sup>[22,40,43,46,56,58,62,65,66]</sup>. Prolonged residency and high site fidelity in the species has previously been reported; Sarasota Bay (USA) where five generations have been studied to date<sup>[67]</sup> and residency periods of 15 to 37 years recorded; Pequeña Bahama (USA) where residency of 17 years has been documented<sup>[42]</sup>; and within Latin America the Tramandaí estuary (Brazil) with residency of 18 years confirmed<sup>[62]</sup>.

Across the duration of 2004 to 2020, changes in population composition and mean number of dolphins present have been regularly recorded with the resighting of only two adult individuals confirmed over an extended period. Long term residency of *T. truncatus* has not previously been documented within Venezuelan waters, making the established residency of AD1 and AD5 at 16 and 15 years respectively important first records.

AD1 is a reproductive adult female, recorded in close association with a calf in January 2007. Previous analysis of social structure and social networks placed this individual as one of two matriarchs within the most frequently sighted resident pod, with AD1 always with the bulk of. Although group structure can be fairly fluid, we consider that it is therefore likely to be the same pod that was observed in both studies (Cobarrubia-Russo, unpublished work).

Whilst the available habitat is restricted latitudinally, neighbouring stretches of coastline support populations of *S. frontalis* and *T. truncatus* among other species. With female lifespan of *T. truncatus* estimated at circa 50 years and male lifespan slightly shorter at 40-50 years<sup>[58, 68]</sup>, for AD1 to have invested at least 16 of life within the study



area should be considered significant and indicative of good quality habitat. In addition, fishermen aged 45 to 50 years old have known dolphins since childhood, so this population may have a much longer presence.

Extent of residency for AD1 prior to the first record in 2014 is of course unknown. A conservative estimate would put the minimum age of this individual at 21 (as of 2020); on the basis that AD1 appeared fully grown in 2004. When discerning by eye, this would put the minimum age in 2004 at five years. It should be noted however that a smaller second growth spurt has been recorded in other coastal populations<sup>[69]</sup> and a minimum age of eight in order to consider an individual an adult<sup>[70]</sup> would not be unreasonable. This would conservatively place the time of birth in or prior to 1999, if not earlier. With this in mind, residency from birth, with AD1 as a second generation member of the pod, is a highly possible scenario and continued monitoring of this individual and pod should be maintained to bring additional meaning to the data already collected and develop understanding.

It is noteworthy that only one record was obtained of AD5 in this most recent study, despite frequent sightings between 2005 and 2008. One possible explanation is that the individual is male and has extended or changed home range. A large individual home range, extending beyond the boundaries of the study area, may also explain the apparent variation in timing between sightings of resident dolphins<sup>[5]</sup> with individuals of *T. truncatus* known to cover large distances of up to 45 km for 12 to 24 h<sup>[71,72]</sup>.

The western coast of Aragua presents a certain level of protection from anthropogenic disturbance, a highly protected refuge (Bahía de Turiamo) and a source of annual prey, this “core” as per Toth et al.<sup>[73]</sup> has been used for an extended period by *T. truncatus* and until recently by pods of *Stenella frontalis*. Nuclei such as these exist discretely along the coast, in much the same way as human population centres that are connected by transit routes. Resident individuals from these cores may partially merge to form “communities”<sup>[50]</sup> defined as regional societies of dolphins that share ranges and social associates, but show genetic exchange with other social units, which can be considered essentially equivalent to populations, with an explicit biological basis<sup>[17]</sup>.

Nucleus areas that provide refuge and food sources require identification and characterisation in order to better understand habitat use. From a conservation and management perspective, quantitative information on site fidelity, residency, habitat use, movement patterns, and abundance trends of species and discreet populations utilising an area is necessary in order to ensure that appropriate protection and management can be

implemented.

The ‘success’ of any MPA depends largely upon their location within the population home range and should include these “nuclei”<sup>[74]</sup>. In light of the findings of this study, it is suggested that the coast of Aragua is a good candidate for a MPA<sup>[75]</sup>. Such a designation could be achieved by extending the boundary of Henri Pittier National Park to include the marine waters that currently form the northern boundary, along its existing length. Inclusion of this coastal habitat into the National Park, and implementation of appropriate management structures, in conjunction with the fishermen whose livelihoods depend upon these waters, would be highly beneficial in providing the necessary protection for a habitat that hosts not only a resident population of *T. truncatus* but also other species of conservation interest such as whale sharks, sea turtles, endemic and migratory birds marine crocodiles and other cetacean species.

## 5. Conclusions

The data presented here demonstrate that a mosaic of residential patterns persists in the study area: resident, semi-resident and transient. The proportions of which are relatively constant over time, indicating that this locality offers 1) refuge, 2) food and 3) low human impact, which may support resident dolphins belonging to breeding groups. This fact forces more weight to be given to habitat management for protectionist purposes.

Monitoring of these resident groups is crucial both for scientific and conservation purposes, and as indicators of climate change in terms of presence vs. temperature, prey availability, anthropogenic pressure, etc. As well as the management to extend the northern border (coast) of the Henry Pittier National Park up to a certain isobath to declare this locality a Marine Protected Area in order to safeguard the landscape and consequently its biodiversity.

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## Authors’ Contribution

C-R S conceived and designed the study, collected and analysed the data, prepared figures and reviewed all manuscripts drafts. S I collected data, wrote and reviewed all the manuscripts. G-A M collected data and reviewed

all the manuscripts. M-L A. wrote and reviewed all the manuscripts. All authors have read and agreed to the version of the manuscript submitted.

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