IMPROVING UNDERSTANDING OF THE ECOLOGY OF INDO-PACIFIC BOTTLENOSE DOLPHINS (*Tursiops aduncus*) IN ALGOA BAY, SOUTH AFRICA

By

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DEDICATION

TO THE SMARTEST MAN EVER, MY FATHER

*SHAANIKA **D**AVID **NA**FTALI*

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ABSTRACT

Site fidelity and spatial distribution of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) were assesed using mark-recapture from opportunistic photographs collected between June 2008-May 2011 in Algoa Bay, South Africa. Over 10 000 photographs were collected, and assessed, resulting in 2472 photographs being catalogued and analysed. In total, 2002 individual dolphins were photographically identified. The discovery curve does not reach a plateau, indicating a large, open population, as a result, the re-sighting rate over the study period was low. 178 (8.9%) animals were re-sighted, and 32 animals these were seen three times or more. The individual which was re-sighted most often was sighted five times. The residency index averaged 0.05 and reached a maximum at 0.25. 41% of the data were collected in 2009, which skewed the identifications per unit effort (IDsPUE) across years (Kruskal-Wallis Anova, KW= 11.59 n=60, p= 0.009) and seasons (KW= 17.47, n= 60, p=0.007). Due to the relatively higher data collection in 2009, identifications across years (KW=13.29, n=60, P= 0.004) and across seasons (KW=17.81 n=60, P=0.007) also differed significantly. In contrast, there was no significant difference is re-sighting across years (KW = 6.9, n=56, p= 0.8) and seasons (KW=12.26, n=56, p=0.6). The association between the 32 individuals seen three times or more was measured using the Half Weight Index, the index ranged from 0 to 1. A dendrogram revealed two social clusters consisting of 23 and 8 animals each, with one individual having no associations.

Xenobalanus was recorded on all but five surveys over the study period. *Xenobalanus* occurrence did not significantly differ across years (KW=1.49, n=42, p=0.68) and seasons (KW= 6.59, n=43, p=0.36).

Dolphins were mostly sighted in depths of <15 metres all around the bay. Travelling (36%) behaviour was the most recorded, followed by feeding (29 %), socialising (15%), milling (11 %), Slow travel (6%), resting (2%) and fast travelling (1%). Other than milling the spatial distribution of all behaviours were similar to the general spatial distribution of sightings.

The project provides information that can be used for further research and conservation management of *T. aduncus*. Photographs used in this project were opportunistically collected, which has resulted in the underestimation of photo-identified individuals and consequently results of this project.

Keywords: Algoa Bay, association index, Indo-Pacific bottlenose dolphins *(T. aduncus)*, site fidelity, spatial distribution, photographic identification, *Xenobalanus*

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CHAPTER ONE

General introduction

1.1 Ecological and economic significance of dolphins

Apex predators are species that dominate the top level in an ecosystem (Ritchie & Johnson, 2009). They are usually specialised hunters and may regulate populations of smaller predators in an ecosystem (Ritchie & Johnson, 2009). Wallach *et al.* (2015) defined apex predators as self-regulating predators that prevent population eruptions of prey and smaller predators. Thus a drop in a top-level predator population can lead to an increase in lower level predators and increase in primary consumers, which can lead to an imbalanced ecosystem (Daskalov, 2002). Off Adak and Amchitka Islands a decline in sea otter population, which preyed on sea urchins, led to high kelp grazing intensity due to a rising sea urchin population (Estes *et al*., 2004),

As top predators, dolphins are consumers at high trophic levels of aquatic ecosystems (Trites, 2008; Estes, 2009; Young *et al*., 2017). This means contaminants can build up in their bodies through bioaccumulation (Wells *et al*., 2004). This means the health of dolphins can reflect the health status of their ecosystem (Wells *et al*., 2004), and can make them good indicator species of the health and ecological state of the aquatic environment (Amir, 2010; de Wet, 2013; Lane *et al*., 2014). Gomez-Salazar *et al*. (2012) found density estimates of river dolphins (*I. geoffrensis and S. fluviatilis*) in the Amazon river basin to have a negative relationship with a measure of habitat degradation, and Wells *et al*. (2004) developed a health monitoring system by sampling body fluids in dolphins.

Dolphins can undertake migrations, usually in response to changes in the physical, chemical and biological characteristics of aquatic habitats, which causes the distribution and abundance of dolphins to vary over time (Findlay *et al*., 1992; Elwen *et al*., 2009). A change in prey abundance can change dolphin abundance in a given area (O'Donoghue *et al*., 2010; Sprogis *et al*., 2016). Thus, the presence or absence of dolphins in a habitat can be a sign of environmental changes happening in a given location.

Different dolphin species occur in different aquatic environments globally, with most species having an oceanic habitat (Palacios *et al*., 2012; Findlay *et al*., 1992; Forcada, 2008), while some inhabit river systems (Mcguire & Henningsen, 2007).

Dolphins also have a socioeconomic value for the coastal regions they occur in (O'Connor *et al.,* 2009); together with other marine wildlife they are a lucrative and fast-growing tourist attraction (Wilson & Tisdell, 2002) and contribute directly and indirectly to the development of settlements, businesses and to improving livelihoods of communities (Smith *et al.,* 2006; Dicken, 2010). Marine wildlife tourism (MWT) was valued at US$ 2113.1 million in 2008 globally (O'Connor *et al.,* 2009). A review on various Atlantic Islands reported whale watching tourism's total expenditure to be US$133 million in 1998 (Hoyt, 2005b). Scottish whale-watching tourism supports 18000 jobs and was valued at over £2.5 billion annually in 2000 (Woods-Ballard *et al*., 2003). In Africa, MWT happens in over 15 countries around the continent (O'Connor *et al.,* 2009). In 2008, MWT in Namibia, Mozambique, and South Africa was valued at over US$ 3 million, US$ 1 million, and US$ 61 million, respectively (O'Connor *et al.,* 2009; Leeney, 2014). South Africa has by revenue the largest MWT in Africa, contributing 21% of the country's GDP (O'Connor *et al*., 2009).

Despite the ecological and socioeconomic significance of dolphins, large parts of their biology and ecology remain unstudied in African waters (Elwen *et al*., 2011a). The current research aims to add to the existing knowledge of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) in Algoa Bay, South Africa.

1.2 Taxonomy

There is an ongoing debate over the taxonomic classification of the genus *Tursiops* (Ross, 1982; Borsa *et al*., 2012). Two species of bottlenose dolphin, *T. aduncus* (Ehrenberg 1833) and *T. truncatus* (Montagu 1821), have been identified in different regions around the world (Hale *et al*., 2000; Amir, 2010; Borsa *et al*., 2012), including South African waters (Ross, 1982; Ross *et al*., 1989). Wang *et al*. (1999) found the *Tursiops spp* morphotypes off China to be two distinct species (*T. aduncus* and *truncatus*) which are reproductively isolated. *T. truncatus* is generally found offshore (Amir *et al*., 2005) and *T. aduncus* occurs inshore of the 50m isobath over the continental shelf (Findlay *et al*., 1992). There are several external features that distinguish *T. aduncus* and *truncatus* (Borsa *et al*., 2012; Hale *et al*., 2000), such as pigmentation patterns, body size, snout-to-eye length, rostrum length, and the ratio of rostrum to body length (Borsa *et al*., 2012). *Tursiops truncatus* is bigger than *T. aduncus,* although *T. aduncus* exhibits larger appendages (Findlay *et al*., 1992), such as dorsal fin, pectoral fins, and flukes, in relation to the body (Best, 2007; Wang & Yang, 2008). *Tursiops aduncus* exhibits dark spots on the posterior ventral half of the body (Amir *et al*., 2005; Borsa *et al*., 2012)

(Figure 1). The present study will focus on bottlenose dolphins in Algoa Bay off Port Elizabeth, South Africa. Based on results from previous studies in this area (Ross *et al*., 1989; Findlay *et al*., 1992), it is assumed these animals belong to *T. aduncus.* (Figure 1).

Figure 1. Illustration of the external features of *Tursiops aduncus* (Best, 2007).

1.3 Distribution and ecology of the Indo-Pacific bottlenose dolphin *Tursiops aduncus*

1.3.1. Distribution

The Indo-Pacific bottlenose dolphin *T. aduncus* has a patchy distribution in coastal warm-temperate to tropical waters of the Indo-Pacific region (Wang & Yang, 2008). *T. aduncus* populations are found along the southern coast of Australia in the Pacific Ocean, along the west coast of Japan, and along the northern rim of the Indian Ocean to the southern tip of Africa (Afsal *et al*., 2003; Wang & Yang, 2008)(Figure 2). Population is defined as a group of organisms of the same species inhabiting a given location at the same time (Perrin *et al*., 2008). Population structure and distribution of marine mammals can be influenced by oceanographic factors, such as depth, sea surface temperature (SST), salinity, thermocline depth, bottom topography, and frontal convergence (Findlay *et al*., 1992; Forcada, 2008).

The distribution of *T. aduncus* off South Africa stretches from False Bay in the West to the South Africa /Mozambique border in the East (Findlay *et al*., 1992), three subpopulations are defined off South African waters, Ifafa-False bay, Ifafa-Kosi bay and a seasonal subpopulation (Cockcroft *et al.,* 2016), in what appears to be the longest connected distribution of *T. aduncus* (Wang & Yang, 2008). Despite the widespread distribution along most of South Africa's coast, there is still limited knowledge about the species' site fidelity, habitat preference, population connectivity, and individual ranging boundaries (Cockcroft *et al.*, 2016).

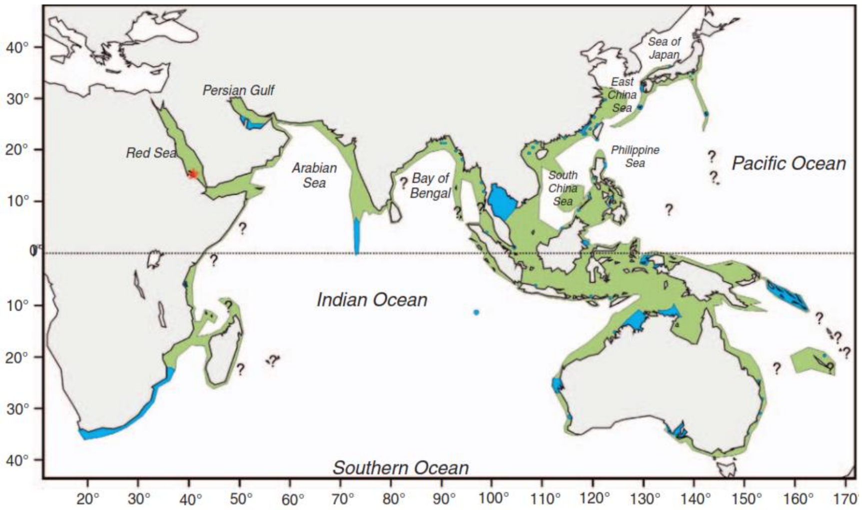


Figure 2. The worldwide distribution range of *T. aduncus*. Assumed distribution in olive green and confirmed records are shown in blue (Wang & Yang, 2008).

1.3.2. Life history

Cetaceans are social animals and often aggregate for several reasons, including, but not limited to, mating and feeding (Sprogis *et al*., 2016). Off Zanzibar, Tanzania *T. aduncus* diet consisted of 50 bony fish species and three squid species(Amir *et al.*, 2005). In South African waters, *T. aduncus* forages inshore on over 90 different fish and cephalopod species (Kaiser, 2012).

Female *T. aduncus* off East Africa attain sexual maturity at 8-9 years and the males at about 16 years (Amir, 2010), while in South African waters females attain sexual maturity at 9-11 years, two to three years before males, with calving occurring year-round, but peaking during the summer months December – February (Cockcroft & Ross, 1990; Best, 2007). *T. aduncus* are long-lived animals with both sexes living to over 40 years (Best, 2007).

Like many other cetaceans, *T. aduncus* may have ectoparasites attached to them (Kane *et al.*, 2008), particularly the hermaphroditic, suspension feeding cirriped *Xenobalanus globicipitus* (hereafter referred to by genus) (Kane *et al.,* 2008). *Xenobalanus* have been reported on over 34 cetacean species (Kane, 2008). The species burrows into the dolphins' skin, mostly on the trailing edges of fins and flukes (Seilacher, 2005). *Xenobalanus* are cosmopolitan barnacle species and have been reported in all oceans, in both coastal and offshore waters (Waerebeek *et al*., 1993; Orams & Schuetze, 1998; Kane *et al.*, 2008; Bearzi & Patonai, 2012), including on *T. aduncus* off South Africa (Best, 2007; de Wet, 2013). *Xenobalanus* abundance is affected by, but not limited to, age, swimming speed, diving depth, and oceanographic conditions (Orams & Schuetze., 1998). There is limited literature on *Xenobalanus* in South African waters.

1.4 Importance of recognising individuals and spatial analyses

A considerable amount of research has been done on cetaceans with the aim to further understand the taxonomy, biology, ecology, and human interactions. Dolphins are impacted by anthropogenic factors, such as marine wildlife watching tourism (Williams *et al*., 2006; Courbis & Timmel, 2009; Christiansen *et al.*, 2010; Elwen *et al*., 2011b), marine traffic (Dolman *et al*., 2006), by-catch from fishing activity i.e. gillnet, shark nets, trawlers and purse seiners (Perrin, 2008; Ambrose, 2010; Amir, 2010), and live capture (Brownell & Reeves, 2008). Increasing concern over human impact has led to the development of different cetacean research methods in an effort to advise conservation management measures for cetaceans (Elwen *et al*., 2011b; Silva, 2012; Hammond *et al*., 2013).

Non-lethal field research methods have been applied to various questions in marine mammal studies (Hunt *et al*., 2013), assisting in gathering information about cetacean abundance, distribution, migrations, population structure, and behaviour. Field research methods, such as acoustic methods (Gridley *et al*., 2012; Read *et al*., 2012), molecular methods (Riccialdelli *et al.*, 2010; Hunt *et al*., 2013), and observations (Würsig & Würsig, 1977) have been used. Among these method observations provides perhaps the easiest way of studying individual animals. Observation can be undertaken from air, land, or sea platforms; using these various platforms, Findlay *et al*. (1992) defined 28 distribution patterns of small odontocetes found in Southern African waters.

Quantifying certain aspects of cetacean ecology, such as diving times (Würsig & Würsig, 1977), habitat ranges (Ballance, 1992), migration routes (Elwen *et al*., 2014) demographic parameters (Kogi *et al.*, 2004) and site fidelity (Baracho-Neto *et al.,* 2012) requires cognizance of individual animals. Hence the development and adaptation of photo-identification as a mark-recapture tool into cetacean research (Würsig & Würsig, 1977; Slooten *et al*., 1992; Markowitz *et al*., 2003; Bolger *et al.*, 2012)

1.4.1 Photographic-identification as mark-recapture tool

Photographic-identification (photo-ID) is a method used to identify individual animals based on distinctive natural markings, such as pigmentation/colour patterns (Best, 1990) and scars (Harzen & Brunnick, 1997). Photo-ID has been used as a monitoring tool for a number of aquatic and terrestrial animals (Stafford & Lloyd, 2011). It has been applied to terrestrial vertebrates, such as Australian skinks *Liopholis slateri* (Treilibs *et al*., 2015), great crested newts *Triturus cristatus* (Drechsler *et al*., 2014), brown hyenas *Parahyaena brunnea* (Wiesel, 2006), cheetahs *Acinonyx jubatus* (Kelly, 2001), tigers *Panthera tigris spp* (Hiby *et al*., 2009) and giraffes *Giraffa camelopardalis tippelskirchi* (Bolger *et al.*, 2012). In the aquatic environment, photo-ID has been used to monitor freshwater armoured catfish *Rineloricaria aequalicuspis* (Dala-Corte *et al*., 2015), green turtles *Chelonia mydas* (Reisser *et al*., 2008; Ciccione *et al*., 2015), white sharks *Carcharodon carcharias,* and basking sharks *Cetorhinus maximus* (Hillman *et al*., 2003; Gore *et al*., 2016), sea otters *Enhydra lutris* (Gilkinson, 2004), sea lions *Phocarctos hookeri* (Mcconkey, 1999), and predominantly cetaceans (Würsig & Würsig , 1977; Meyler *et al*., 2012; Boer *et al*., 2013; Pérez-Jorge *et al*., 2016).

Unique natural markings on dorsal fins, flukes, and other visible body parts during surfacing makes cetaceans suitable for photo-ID studies (Best, 1990; Würsig & Jefferson, 1990; Hillman *et al.*, 2003). Whales are mostly photo-identified by fluke shape and pigmentation patterns, callosities, and pigmentation patterns appearing on the dorsal part of the body (Best, 1990; Carlson *et al*., 1990; Hillman *et al.*, 2003), while dolphins are mainly identified by the shape of their dorsal fin, nicks on their dorsal fin, and any other visible distinct features occurring dorsally (Würsig & Jefferson, 1990). Photo-ID allows re-sighting of individuals without physical contact, making it a relatively non-invasive and inexpensive research tool (Hammond, 2008; Hunt *et al*., 2013; Treilibs *et al*., 2015). This is important for studying animals that are challenging to tag due to their elusive nature and size (Baumgartner, 2008).

Despite the popularity of photo-ID as a mark-recapture tool (Urian *et al*., 2014), it is not without limitations (Hammond, 2008; Urian *et al*., 2014). Photo-ID mark-recapture may not be ideal as the probability of recapturing (re-photographing) specific individuals is not always guaranteed (Best & Underhill, 1990), natural marks of animals can change over time (Best, 1990; Carlson *et al*., 1990), and natural marks can be similar between individuals, which could lead to incorrect recording and reporting (Hammond, 2008). These can cause uncertainties, bias, and inconsistency in results if data are not carefully handled (Carlson *et al*., 1990). Due to the inability to recapture nomadic individual blue whale (*Balaenoptera musculus*), the highest estimate of individuals off the Gulf of St. Lawrence, Canada, was found to be lower than the total number of photo-identified animals (Hammond *et al*., 1990). Best (1990) defined six natural markings (skin moulding, wounds, white blazes, partial albinism, grey blazes, and callosities) for right whales (*Eubalaena australis*) off South Africa that could be used to identify individuals, but only three of these (white blazes, grey blazes, and callosities) were used for identification of individuals as they appear relatively consistent over time. Awareness and consideration of these limitations in data analysis increases the validity of photo-ID capture-recapture studies (Hammond, 2008).

High-quality pictures are essential in photo-ID studies; this exposes external information on dolphins that could lead to further detailed studies (Bain, 1990; Ritter *et al*., 2015). Unidentified skin disorders were reported on *T. truncatus* in the Sado estuary, Portugal, and through further studies, the cause and microbiology of the disorders could be identified (Harzen & Brunnick, 1997). Through examining photographs, Maldini *et al.* (2010) showed that pox-like lesions affect 80% of the *T. truncatus* population in Monterey Bay, USA, while Akritopoulou (2014) established that in Welsh waters skin lesions were more prevalent in female *T. truncatus* than males and that this dolphin population potentially has pox virus and/or tattoo skin disease lesions.. Elwen & Leeney (2010) monitored an injured Heaviside's dolphin (*Cephalorhynchus heavisidii*), which showed rapid healing of deep wounds from a boat propeller; evidence from photographs shows that most cuts had completely healed after 39 days.

Furthermore, to assess the prevalence of the commensal barnacle *Xenobalanus* in the eastern tropical Pacific ocean, photographs were used (Kane *et al.*, 2008), the photographic evidence of *Xenobalanus* prevalence could potentially also give insight into the movement patterns of *T. aduncus* off South Africa. Previous work has shown that parasites can be used to as a biological-tags (Williams *et al.*, 1992) and the relationship between parasite and host can be used to make inferences about the hosts' ecology and biology as it can provide insight on the host's movement and distribution patterns (Killingley, 1980).

Photo-ID has been used as a tool to understand group structure, site fidelity, movement patterns and population size of cetaceans (Würsig & Jefferson, 1990; Hunt *et al.*, 2013; Urian *et al.*, 2014). In the coastal and estuarine waters off Bunbury, Australia, seasonal fluctuations in abundance were seen in *T. aduncus* populations, with overall estimates higher in summer than in winter (Sprogis *et al*., 2016). The influx during summer was thought to be sex-specific, but values were similar for both sexes, hence the observed trend was most likely due to the breeding pattern and prey availability (Sprogis *et al*., 2016). In the Eastern Ionian Sea, a decline was observed in individual common dolphins (*Delphinus sp*.), while no indication of decline in individual *T. truncatus* was observed over a period of ten years (Bearzi *et al*., 2005). *T. truncatus* off southern New Jersey, USA, was found to prefer coastal waters to estuarine waters, a relatively high seasonal level of intra and interannual site fidelity was observed, and it was found that the study area was a corridor for transient individuals (Toth *et al*., 2011). Photo-ID efforts off Walvis Bay, Namibia, have led to successful identification of over 70 *T. truncatus;* in addition, Heaviside's dolphins showed high site fidelity and sightings are more common in summer than any other time of year (Elwen *et al*., 2011b). Best (1990) showed that the population increase of southern right whales (*E. australis*) off South Africa could be attributed to early sexual maturity or high adult survival rate as he identified 245 individual whales using aerial photographs.

The ability to identify individual dolphins also enables ecologist to measure how often two individuals co-occur, using the association index (Ginsberg & Young, 1992). Dolphins are social animals and often associate for feeding, mating, and protection purposes (Tayler & Saayman, 1972), and specific individuals are often found to have close relations with each other as they are often seen in the same pods, these relationships are influenced by population density, sex, kinship, age, ecological and anthropogenic factors (Wells *et al*., 1980; Wells *et al*., 1987; Wiszniewski *et al.*, 2009). Strong association in *Tursiops spp.* has been attributed to male - male bonds (Connor *et al.*, 1992; Quintana-Rizzo & Wells, 2001), mother–offspring groups (Wells *et al*., 1987; Smolker *et al.*, 1992; Quintana-Rizzo & Wells, 2001) and adult only groups (Hawkins & Gartside, 2008), while relatively weak associations have resulted from large populations living in fission-fusion societies (Chilvers & Corkeron, 2002; Quintana-Rizzo, 2006; Antonio *et al*., 2009), thus association indexes can be used to further profile individual dolphins in a given study area, the higher the site fidelity the more detailed the profile is like to be.

Site fidelity and habitat preference studies are ecologically important and vital to management and conservation of wildlife (Brown *et al*., 2016). Re-sighting rates help in determining if animals are resident or transient/migratory as well as determining their home ranges (Gubbins, 2002a; Gubbins, 2002b).

1.4.2 Computer-aided image matching, cataloguing, and analysis for photo-ID research

Since the development of photo-ID as a tool to monitor cetaceans (Würsig & Würsig, 1977), researchers have looked for ways to improve photo-ID research methods. The transition from film-based images to digital images improved the accuracy and efficiency of photo-ID research (Markowitz *et al*., 2003); however, despite the rise of digital images in photo-ID research, there is still room for improvement. Thus the development of computer-assisted matching programs can reduce error and increase efficiency in the process of analysing and matching of digital images (Urian *et al*., 2014). Software applications such as *ACDSee* (Mizroch, 2007; Sprogis *et al*., 2016), *Darwin* (Wilkin, 1999), *Finscan* (Hillman *et al*., 2003), *Fluke Matcher* (Kniest *et al*., 2010) and *Finbase* (Melancon *et al.*, 2011) have been used to manage photo-ID catalogues for mark-recapture studies. These software programs allow the researcher to make the final choice with the matching of images, but helps to minimise subjectivity in the matching process (Urian *et al*., 2014). Reisinger & Karczmarski (2010) and Melly *et al.*, (2017) report *T. aduncus* group sizes of over 500 individuals for Algoa Bay. These large group sizes have led to the decision to use computer programs (*ACDsee* and *Finbase*) to conveniently manage the photo-ID catalogue for this project.

1.4.3 Application of Geographic Information Systems (GIS) in marine mammal research

Geographical information systems (GIS) use spatial data to visualize, analyse, and interpret data to understand relationship patterns and trends (Weng, 2010). Spatial data are data that have a spatial component, e.g. data connected to a specific location (such as a survey track) on earth (Longley *et al*., 2005). GIS integrates four components to produce maps, tables and answer spatial questions: an input component, a storage and retrieval component, an analysis component, and an output component (Weng, 2010). GIS is widely used in cetacean research and has particularly been used to map and quantify spatio-temporal trends (Moses & Finn, 1993; Nelson *et al*., 2009), such as movement patterns (Andrews *et al.*, 2008), site fidelity (Mcguire & Henningsen, 2007; Brown *et al*., 2016), and distribution (Moses & Finn, 1993; Melly *et al.,* 2017). For the purpose of the present study, GIS is used to examine and observe spatial trends and occurrence of *T. aduncus* by investigating the site fidelity and habitat preference of individual dolphins (Nelson *et al*., 2009; Melly *et al.,* 2017).

1.5 Problem identification

Tursiops aduncus populations have been studied extensively globally and in a number of locations, such as Australia (Sprogis *et al*., 2016), Japan (Kogi *et al*., 2004), China *(*Wang *et al.,* 1999), the Persian Gulf (Boer *et al.,* 2002), India (Boer *et al.,* 2002), Tanzania (Amir *et al.,* 2005), and South Africa (Ross, 1977). There is a commendable amount of literature on *T. aduncus*, particularly their distributions, but the specific home ranges of specific populations within their respective distribution ranges are not well understood (Wang & Yang, 2008). Even with the largest *T. aduncus* population estimate (Reisinger & Karczmarski, 2010) and perhaps the longest continuous distribution of *T. aduncus* in the world (Wang & Yang, 2008), movement of dolphins off South Africa's coastline requires further research (Cockcroft *et al.,* 2016).

Creating photographic identification catalogues for different locations within the distribution ranges of the species, analysing the details of images, and matching those catalogues to quantify site fidelity, association index, habitat preference of individual dolphins, and to assess the prevalence of external features such as *Xenobalanus*, can improve our knowledge about home ranges of different *T. aduncus* populations across their distribution ranges and their movement within and between habitats (Möller *et al.,* 2002).

The abundance of *T. aduncus* has been noticed to be higher off the East Coast during the Sardine Run (O'Donoghue *et al*., 2009 & 2010). This apparent relatively higher abundance of dolphins in the Eastern Cape (EC) and KwaZulu-Natal (KZN) coastlines during the winter months suggests that *T. aduncus* are moving between habitats along the South African coast (Natoli *et al*., 2008; O'Donoghue, 2009; Reisinger & Karczmarski, 2010), potentially moving from south coast habitats, such as Plettenberg Bay, to or through Algoa Bay and northwards to EC and KZN waters (Ross, 1984; Melly, 2011).

Algoa Bay potentially is an important habitat for both resident and transient *T. aduncus*, it is likely a rest/transit point for animals travelling to and from the sardine run off EC and KZN. *T. truncatus* research from distinct study sites off the United States of America and Mexico found that individual dolphins' home ranges can vary from ≤200 km to over 900 km (Hwang *et al*., 2014), similarly *T. truncatus* from the United Kingdom and Irish study sites were re-sighted over distances between 487 km to 1277 km (Robinson *et al*., 2012). *T. aduncus* could potentially have similar home range sizes, highlighting the possibility that Algoa Bay has both resident and transient *T. aduncus* from other habitats off the South African coastline.

Site fidelity is the tendency of an individual to return to an area they previously occupied (Baird *et al.*, 2008), thus, residency is a consequence of site fidelity and is essentially how long an individual remains in an area over an extended period of time (Baird *et al.*, 2008; Chapman *et al*., 2011). Site fidelity of cetaceans depends on physical, biological, and anthropogenic factors, such as depth, prey availability, and water quality (Baird *et al.*, 2008; Fury & Harrison, 2008; Bertulli *et al*., 2015). Similarly, habitat preference, which is defined as the unequal use of some resources (physical and biological) over others (Krausman, 1999), also depends on physical, biological and anthropogenic factors (Krausman, 1999; Heithaus & Dill, 2002; Martin & da Silva, 2004). Site fidelity and habitat preference studies are crucial for understanding the general ecology of a species (Krausman, 1999; Freitas *et al*., 2008).

The group size of Indo-Pacific bottlenose dolphins *T. aduncus* in Algoa Bay averages 57.8 individuals (Melly, 2011), and varies from 1 to over 500 individuals (Reisinger & Karczmarski, 2010; Melly *et al*., 2017). Pods in Algoa Bay are mainly sighted at water depths of < 15 metres (Ross *et al*., 1987; Melly *et al*., 2017), but the residency, association patterns, and habitat preference of individuals in these pods are still not well understood. The re-sighting of a *T. aduncus* in Plettenberg Bay (210 km west of Algoa Bay) after it was initially sighted in Algoa Bay (Ross, 1984), suggest that *T.aduncus* potentially have large home ranges too. While molecular studies have shown a difference in the three supposed subpopulations: either side of Ifafa, KwaZulu-Natal Province, and a third 'migratory' or transient subpopulation (Goodwin *et al.,* 1996), The literature points out the need for further long term research to better understand the movement, site fidelity, habitat use and preference by individual *T. aduncus* in their population range in South African waters (Cockcroft *et al.,* 2016). Research on *T. aduncus* along the South Africa coastline is important to understand the ecological and ecosystem processes that enables *T. aduncus* to flourish. Developing photographic identification catalogues from geographically distinct locations off South Africa's coastline, such as

Plettenberg Bay, Algoa Bay, the Wild Coast and KZN coast and matching these catalogues can potentially improve our understanding of their home range, site fidelity, and habitat preference of South Africa's widespread *T. aduncus* population.

Thus knowledge of site fidelity, associations and habitat preference of wildlife and prevalence of *Xenobalanus* is vital in informing and implementing conservation and natural resource management strategies (Brown *et al.*, 2016). This is particularly important for the formation of marine mammal protected areas (Hoyt, 2005a). Photographic identification and geographical information systems (GIS) provide valuable tools for ensuring accurate presentation of these measures (Würsig & Jefferson, 1990; Pulcini *et al.*, 2010).

1.5.2 Research aim

This project aims to create a photo-ID catalogue of all identifiable *T. aduncus* from images taken in Algoa Bay during boat-based surveys between 2008-11. Using this catalogue, the intention is to investigate the spatial trends of individual *T. aduncus* in Algoa Bay with the aim to measure and quantify their site fidelity, measure the social network(s), habitat preference, and prevalence of *Xenobalanus* using photo-ID as a mark-recapture tool.

1.5.3 Research objectives and hypotheses

Five objectives with associated research questions and hypotheses were formulated in order to achieve the above-mentioned aim.

Objective one: To identify all identifiable dolphins from photographs taken in Algoa Bay between 2008 and 2011 and produce a photo-ID catalogue.

Objective two: Determine the site fidelity of *T. aduncus* in Algoa Bay

Research question: Are *T. aduncus* in Algoa Bay resident or transient.

Research hypothesis: *T. aduncus* in Algoa Bay show a high level of site fidelity.

Objective three: Measure the association index of individuals re-sighted ≥3 times

Research question: do individual *T. aduncus* in Algoa Bay have individual associations with other individuals, therefore forming social groups?

Research hypothesis: *T. aduncus* do have associates, forming social clusters activities

Objective four: Assess the prevalence of *X. globicipitus*

Research question: does the prevalence of *X. globicipitus* vary over time

Research hypothesis: the presence of *X. globicipitus* varies across seasons

Objective five: Asses the spatial distribution and infer habitat use of identified resident *T. aduncus* in Algoa Bay

Research question: What habitats within Algoa Bay do these *T. aduncus* prefer, and what behaviour do they exhibit in their preferred habitats?

Research hypothesis: *T. aduncus* prefer certain habitats over others in Algoa Bay for different behavioural activities

CHAPTER TWO

Research methods and tools

2.1 Study area (Algoa Bay)

a) Geography

Algoa Bay is found off the city of Port Elizabeth along the Eastern Cape coast of South Africa, facing the southwest Indian Ocean where it is influenced by the Agulhas current (Goschen & Schumann, 1995 & 2010). It is a 3100 km^2 bay with 135km of coastline, predominantly made up of sandy beaches and has three major rivers, namely the Sundays, Swartkops, and Coega rivers entering the bay between its headlands, Cape Recife to the West and Cape Padrone to the East (Goschen & Schumann, 2010; Fig. 3).

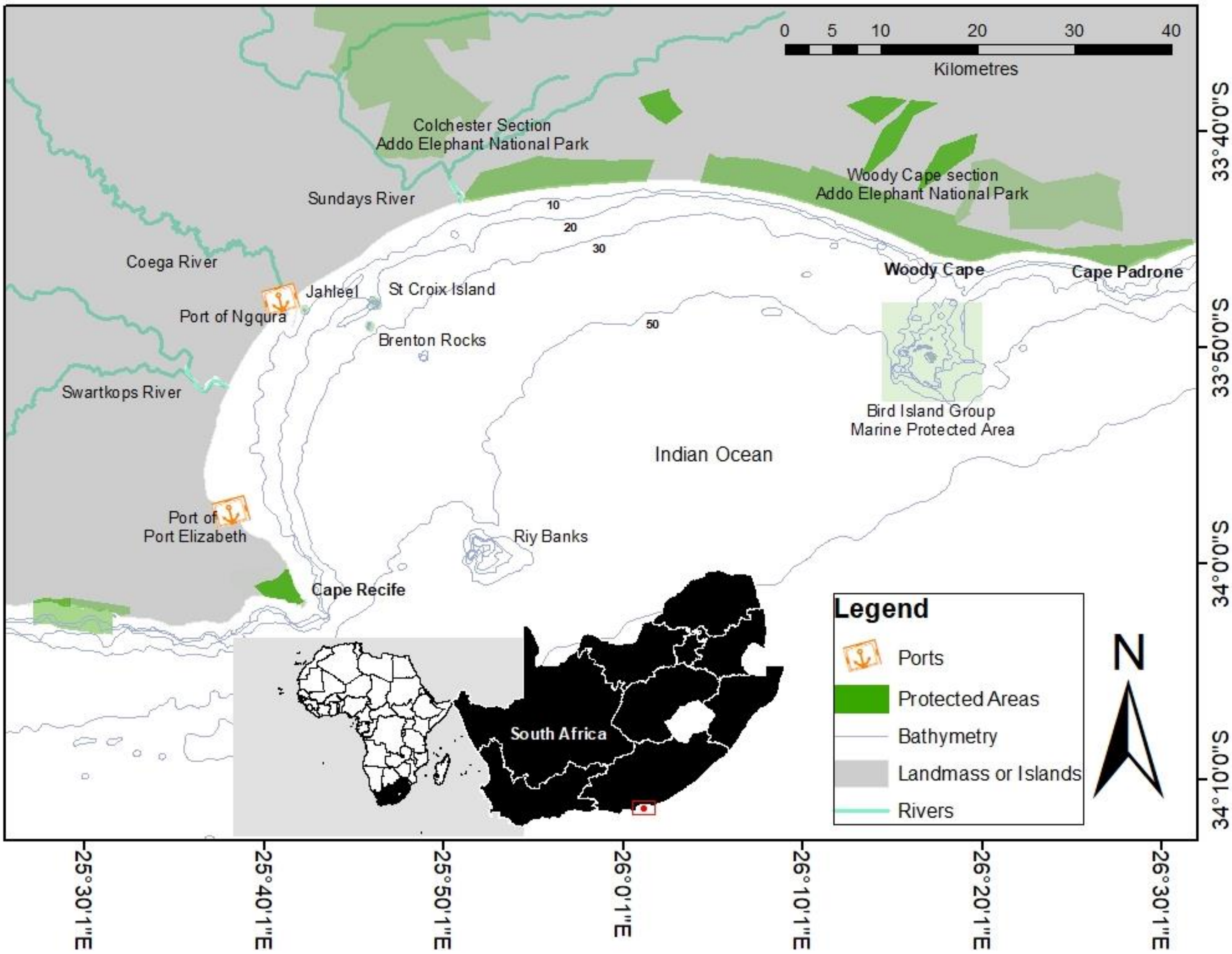


Figure 3. Map showing the location, physical features, protected areas, and ports of Algoa Bay.

The Bay has a gentle sea floor sloping towards Cape Padrone (Goschen & Schumann, 2010). Several depressions and islands disturb this gentle slope. Cape Recife is the roughest coastal area. The rocky islands, such as St Croix, Brenton Rocks, Jahleel and many reefs are isolated and mostly surrounded by smooth seabed (Goschen & Schumann, 2010). Research surveys were mostly carried out inshore where the sea floor is mostly fine sand (Goschen & Schumann, 2010).

b) Climate

Coastal lows, cold fronts, and high-pressure systems control the weather in Algoa Bay (Goschen & Schumann, 1988). Algoa Bay has two distinct seasons, winter and summer. Corresponding to the climatic pattern of the region (Heerden & Hurry, 1992), winter (May-October) and summer (November- April) are characterised by average temperatures of either lower or higher than 18 °C (Karczmarski *et al.*, 1999). Due to the fronts and coastal lows, Algoa Bay experiences cloud cover, rainfall, and high winds all year round (Goschen & Schumann, 1988; Schumann *et al*., 1991). Atmospheric temperatures provided by the South African weather services and the sea surface temperatures recorded during the project duration were plotted against season to determine if they conform with results by Karczmarski *et al*. (1999).

c) Natural resource economy

Algoa Bay experiences vessel traffic as it houses two ports: the Port of Coega (also known as Port Ngqura) and the Port of Port Elizabeth (Ports and Ships, 2015). There is also recreational activity, such as marine wildlife tourism (Raggy Charters, 2013). Marine aquaculture has been proposed within the bay (Department of Agriculture, Forestry, and Fisheries, 2016). The bay has three conservation zones: the proposed Greater Addo Elephant National Park marine protected area, and the marine protected areas around the Bird Island and St. Croix Island groups (WWF-SA, 2014). The bay is a vital habitat for birds (Batchelor & Ross, 1984), fish (Coetzee, 1989) and marine mammals (Melly *et al.*, 2017). The co-existence of industries and conservation area (Figure 3) indicate the need for appropriate management policies to ensure conservation friendly industrial growth (Culloch *et al.*, 2016).

d) Cetacean research in Algoa Bay

Several research projects have been carried out on several species, such as the southern right whale (*Eubalaena australis*), humpback whale (*Megaptera novaeangliae*), Bryde's whale (*Balaenoptera edeni*), long-beaked common dolphin (*Delphinus capensis*) (Melly *et al.*, 2017), Indo-Pacific bottlenose dolphin (*Tursiops aduncus)* (Ross, 1984; Reisinger & Karczmarski, 2010,) and Indian Ocean humpback dolphin (*Sousa plumbea*) (Karczmarski *et al*., 2000; Koper *et al*., 2016). Prior research in Algoa Bay on cetaceans has looked at population estimates (Karczmarski *et al.*, 1999; Reisinger & Karczmarski, 2010), distribution (Ross *et al.*, 1987; Melly *et al.*, 2017), habitat use and preference (Karczmarski *et al.*, 2000), and group dynamics (Karczmarski, 1999). However, there is still a need for continued long-term cetacean monitoring in Algoa Bay.

2.2 DATA COLLECTION

The project used opportunistic data (photographs) collected during dedicated boat-based surveys over a period of three years between June 2008 and May 2011. The data are referred to as opportunistic because they were collected during a multi-cetacean distribution study and due to this, photographs could only be taken 20 minutes per encounter for each species, including *T. aduncus*, to ensure sufficient coverage of the survey legs (Melly, 2011). The data collectors/recorders were all trained in cetacean ecology data collection. The research survey followed three predetermined survey routes in Algoa Bay. The first track started from the Port of Port Elizabeth (Port of P.E) to St Croix Island, around the island, to the Sundays River mouth, and along the coast back to the Port of P.E (going past the Port of Ngqura) (Figure 4). The second track went coastwise from the Port of P.E to Cape Recife. Upon completing this track, the boat continued along a different bearing towards Riy Banks (a shallow reef on the outskirts of the bay) if the weather was good, otherwise, the boat returned to the Port of P.E (Figure 4). The third track started at Black Rocks, going through the Bird Islands, towards the headland of Woody Cape and then coastwise along the Alexandria Dune field to Sundays River Mouth (Figure 4). These tracks ensured the entire coastline was surveyed once a month (Melly, 2011).

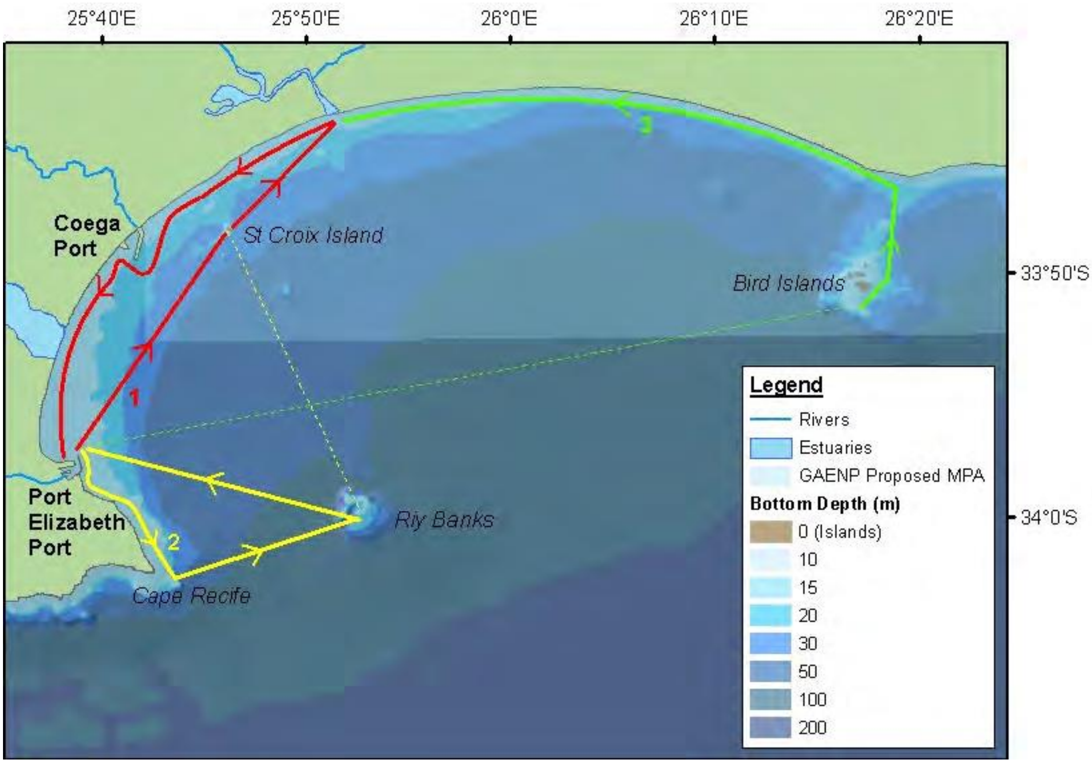


Figure 4. Outline of survey tracks performed in Algoa Bay. Dashed lines show the opportunistic tracks covered during surveys (Melly, 2011)

A semi-rigid boat was used to conduct the survey at the speed of about 9 knots, surveys were only conducted when the Beaufort Sea state was 4 or less. To increase sighting chances, dolphins were searched for by four observers on board, scanning the area 360 degrees around the research vessel. Upon encountering a dolphin group, the time and location of the sighting were recorded using a hand-held GPS device, the group size and composition were then recorded after several counts (Appendix A). Dolphins that were seen together in a radius of about 100m and exhibited the same behaviour were regarded as a group (Irvine *et al*., 1981; Wells *et al*., 1987). The predominant behaviour observed was recorded and defined (following Shane, 1990) into seven categories: travelling, slow travel, and fast travel, feeding, socialising, milling and resting (Table 1).

Table 1. Description of dolphin behaviour (Melly, 2011).

Behaviour	***Description***
Travelling	Persistent one-directional movement of the whole group at speeds of at least three knots.
Slow travel	Persistent one-directional movement of the whole group at speeds of less than three knots.
Fast Travel	Fast travelling involves porpoising, where the dolphins leap clear of the water while moving in a particular direction.
Feeding	Any effort to capture and consume prey which can be seen through direct evidence (prey in the mouth), or indirect observations, such as dolphins chasing prey at the surface of the water, frequent and asynchronous dives in one location with loud exhalations, or rapid sharp turning/ circular swimming on the surface, are indicative signs of foraging. There is usually no contact between individuals, although they are known to feed cooperatively.
Socialising	High levels of 'playful' activity, including surfing waves, breaching, jumping, chasing and tail slapping.
Mating	Belly-to-belly contact between two individuals of the same species. *
Resting	This was identified by dolphins engaging in extremely slow movements (and almost no forward movement) while surfacing very close together). Dolphins will surface together then sink slowly as a group, and at times the group appears to be stationary (floating on the surface).
Milling	Non-directional, relaxed movements in a confined area. This behaviour is frequently seen in conjunction with other behavioural states, such as foraging and socialising.
	**** for this project socialising includes mating as these behaviours were closely related in the field.***

Lastly, environmental data, such as sea surface temperature (SST) and depth (using a depth sounder), wind direction, force, and Beaufort Sea State were recorded for each sighting. The photographer attempted to photograph the dorsal fins of as many animals in the group, irrespective of the level of scarring or ability to identify them. Photographs were taken using a Canon EOS 40D camera fitted with a Canon EF 100-400 mm f/4.5-5.6L IS USM zoom lens.

2.3 GRADING OF PHOTOGRAPHS

To improve the recognition of detail in the pictures, photographs were cropped and adjusted using the default Windows 10 Photos application. The photograph rating system followed in this project was adopted from Urian *et al*. (1999) and Friday *et al*. (2000). The overall photographic quality was based on the quality of the photograph independent of the distinctiveness of the fin. Individual animals were identified from three quality ratings (Q1, Q2 and Q3) and only excellent to average quality (Q1 and Q2) images of all distinctiveness categories (D1, D2 and D3) were included in the statistical analyses. The quality rating and identifying were done by two independent observers to minimize errors and ensure consistency.

2.4 PHOTOGRAPHIC QUALITY

The overall photographic quality score was based on an evaluation and the sum of the following characteristics (these scores are absolute values, not a sliding scale):

Focus/Clarity - Crispness or sharpness of the image. Lack of clarity may be caused by poor focus, excessive enlargement, poor developing or motion blur; poor resolution resulting in large pixels.

Evaluation was based on the following scale: 2 = excellent focus; 4 = moderate focus; 9 = poor focus, very blurry.

Contrast - Range of tones in the image. Images may display too much contrast or too little. Photographs with too much contrast lose detail as small features wash out to white. Images with too little contrast lose the fin into the background and features lack definition.

Evaluation was based on the following scale: 1 = ideal contrast; 3= either excessive contrast or minimal contrast.

Angle - Angle of the fin to the camera.

Evaluation was based on the following scale: 1 = perpendicular to camera; 2 = slight angle; 8 = oblique angle.

Partial - A partial rating was given if so little of the fin is visible that the likelihood of re-identifying the dolphin was compromised on that basis alone. Fins obscured by waves, *X. globicipitus*, or other dolphins, were evaluated using this rating.

Evaluation was based on the following scale: 1 = the fin is fully visible, leading & trailing edge 8= the fin is partially obscured.

The proportion of the frame filled by the fin - An estimate of the percentage area the fin occupies relative to the total area of the frame.

Evaluation was based on the following scale: 1 = greater than 5%; subtle features are visible 5 = less than 1%; fin is very distant (see Appendix B).

To score overall photographic quality, the scores for each characteristic are added up:

6 - 9: Excellent quality ⟶ Quality 1

10–12: Average quality ⟶ Quality 2

>12: Poor quality ⟶ Quality 3

Distinctiveness

Overall distinctiveness was based on the amount of detail present on the fin; information content was obtained from leading and trailing edge features, and patterns, marks, and scars. Distinctiveness 1 - Very distinctive; features evident even in distant or poor-quality photographs (see Appendix B).

Distinctiveness 2 - Average amount of information content: two features or one major feature visible on the fin.

Distinctiveness 3 - Not distinctive; very little detail content in the pattern, markings or leading and trailing edge features.

2.5 IDENTIFYING INDIVIDUALS AND CREATING THE PHOTO-ID CATALOGUE

2.5.1 Types of markings

Different distinctive natural markings were used to identify individual dolphins: nicks on the trailing edge and leading edge of the dorsal fin, the shape of the dorsal fin, and wounds and lesions. Identifying dolphins within and across sightings is possible by using the combination of these unique natural markings (Würsig & Jefferson, 1990).

2.5.2 Identifying individuals and creating a photo-ID catalogue

The project used ID coding adopted by Urian *et al.* (1999) whereby photographs were placed into categories based on the location of their most distinctive/prominent feature on the dorsal fin, namely leading edge, trailing edge (lower third, middle third, or upper third), trailing edge (entire), scars, peduncle, mutilation and fin shape. Individual dolphins were identified using these distinctive features and assigned ID names developed in a sequential manner as new animal were identified. For example, 20080729_AB0001_R_S4_23, where 20080729 represented the survey date, AB0001 the ID name, with the letters AB representing Algoa Bay, R indicating the fin side (left or right), S4 showing the sighting number and 23 being the picture frame number. The left and right side of photographs were combined when identifying individuals. The categorising and naming of individual animals was done simultaneously using an image organizer application *(ACDSee Version 10*), which enables the creation of categories and allocation of photographs to these categories. Subsequently, a photo-ID catalogue was developed, which was hosted in *Finbase*, a Microsoft Access database program used to run digital dolphin image analysis functionality (Adams *et al*., 2006). In *Finbase*, images of individual dolphins were linked to the specific information of their sighting, e.g. date, GPS coordinates, associates, and behaviour.

2.6 DATA ANALYSES

2.6.2 Statistical analyses

All statistical significance tests were carried out in *Statistica* (Version 13.2) analytics software package at a 95% confidence level and probability level (p)= 0.05, take into account the error associated with the dataset (Norman & Streiner, 2008; Logan, 2010).

a) Database and photographic-identification catalogue

The group size estimates from the field were compared to the number of individuals identified from the photographs, this was done to determine the level of underestimation or overestimation within the database and catalogue.

b) Site fidelity and residency

Site fidelity was measured by how often the identified individuals were re-sighted over the study period. To overcome the bias of a small number of individuals to cross-match with on the first day, the re-sighting rate was only measured from the 2nd day of photo-identification, i.e. 23 October 2008 to 12 May 2011. To relate the total number of sightings for an individual and the number of months in which this specific individual was seen, a residence index (RI) was calculated (Karczmarski, 1996) using the following formula:

$$\boldsymbol{RI = S \times M/100}$$

Where: **S -** total number of sightings of an individual and **M –** total number of months in which this specific individual was seen.

The statistical significance of variations in identifications of new individuals, re-sighting and Identifications per unit effort (IDsPUE), was tested across years and season. The identifications were measured as the ability to identify new individuals over the years and seasons. The re-sighting is how often already identified individuals are seen again. IDsPUE i.e. identification per hour, was used since the sampling effort was not evenly distributed across the study period, the relative discovery of new individuals was calculated as identifications per hour of effort; this is an adaptation and modification of the sightings per unit effort (SPUE). IDsPUE was calculated as follows:

$$\boldsymbol{IDsPUE = n \;/\; e}$$

Where: n = number of individuals identified and e = time spent observing *T. aduncus* dolphins in hours

IDsPUE effort was calculated for each of the 60-survey days, the significant difference was calculated between these values, taking years and seasons into account.

c) Association Analysis

To quantify the associations between the 32 dolphins sighted three or more times, the Half-Weight-Index (HWI) (Quintana-Rizzo & Wells, 2001; Wiszniewski *et al.,* 2009; Louis *et al*., 2015) was manually calculated and for comparison and accuracy purposes also extracted from *Finbase*. HWI corrects for missed identifications of a member of a pair, a common feature in photo-identification studies (Smolker *et al*., 1992). The HWI values range from 0-1, with zero indicating no association and one indicating individuals always sighted together. HWI is computed as:

$$HWI = \frac{x}{x + 0.5(y1 + y2)}$$

where X, is the number of times both individual 1 and 2 were seen together in the same group; Y1, is the number of times individual 1 was seen, but not individual 2 and Y2, is the number of times individual 2 was seen, but not individual 1 (Ginsberg & Young, 1992). Using the above equation, an association matrix was developed in *Microsoft Excel*. *SOCPROG* Version 2.8 (compiled), a set of programs that analyses animal associations developed by (Whitehead, 2009; Whitehead, 2017), was used to draw charts to provide further details about associations.

d) Analysis of *Xenobalanus* occurrence

The number of dorsal fins with *Xenobalanus* present was recorded for each survey day on which individual animals were identified. These records are a subset of the good and excellent quality images used for photo-identification purposes. The aim of this analysis is to monitor the presence of *Xenobalanus* on dolphins hence, *Xenobalanus* was simply marked 'absent' (no visible *Xenobalanus)* or 'present' (at least one visible *Xenobalanus)*. A dorsal fin with multiple parasites had an equal value as a dorsal fin with one parasite. Statistical significance of the presence of parasites was measured across years and seasons. The proportion of dolphins with *Xenobalanus* was also compared with the group size estimates for each survey day and the statistical significance in these proportions also measured across seasons.

e) Spatial distribution

Habitat use was inferred from the spatial distribution of identified individuals across Algoa Bay, and how the different observed behaviours were distributed in relation to the sighting location of the identified dolphins. Habitat preference analyses by Melly, 2011 on the same data set was taken into consideration to avoid repetitive work.

2.6.3 Spatial analyses

To present the distribution of dolphin sightings and habitat use and use in Algoa Bay, the specific sighting locations were analysed using the GIS program ArcGIS v10.5.

CHAPTER THREE

Results

3.1 Climate

The South African Weather Service (SAWS) provided raw weather data of Port Elizabeth for the period of 2008 to 2011, which corresponded to the seasonal trend described by Kaczmarski *et al.* (1999) (Figure 5). The mean sea surface temperature SST for the study period was 18.9 °C, while the maximum SST mean was 22.9°C (March 2009) and the minimum 16 °C (June 2010) the fluctuation in SST matched the changes in seasons (Figure 6).

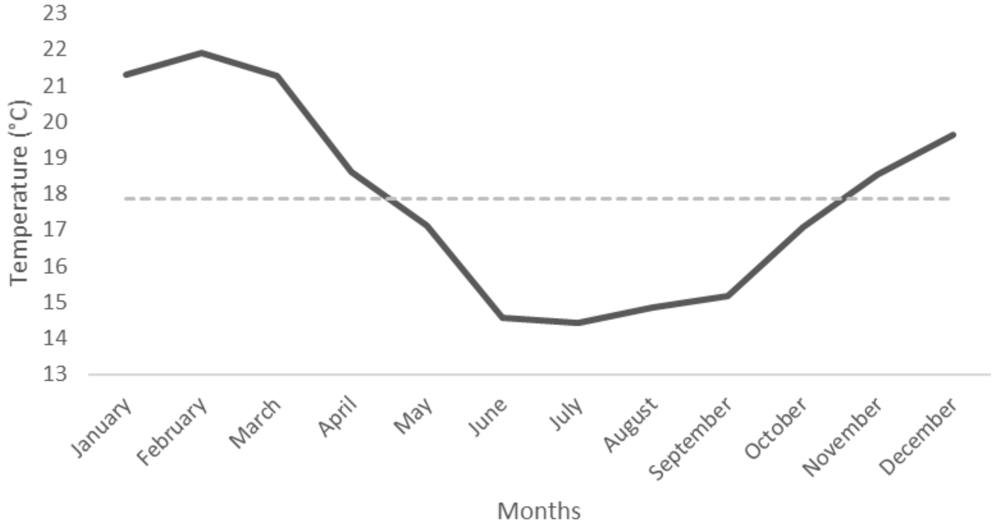


Figure 5: Mean monthly air temperatures in Port Elizabeth between 2008-2011, average 17.9 °C (SAWS).

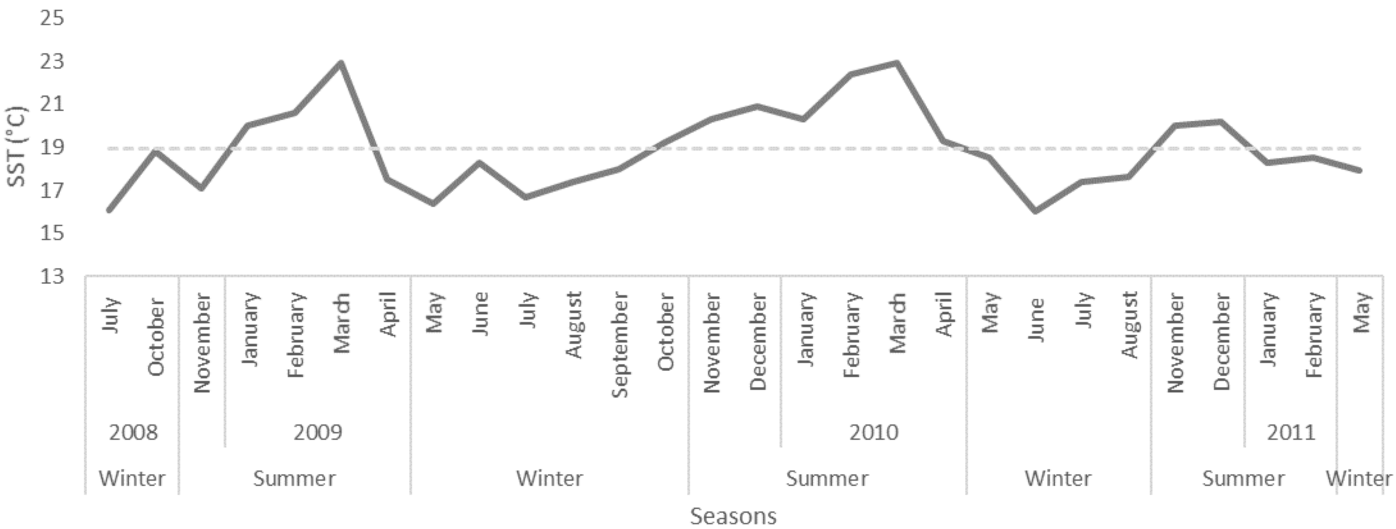


Figure 6: The seasonal fluctuation in sea surface temperatures, as collected from the field.

3.2 Database and photographic-identification catalogue

Between 13 June 2008 and 12 May 2011 over 10 000 opportunistic photographs of *T. aduncus* were taken during 60 boat surveys, resulting in 340.3 hours of effort. Of these, 11% (35.9 hours) were spent observing bottlenose dolphins during 88 sightings. 13% (8) of the surveys were carried out in 2008, 41% (25) in 2009, 36% (22) in 2010, and 8% (5) in 2011. During 28% (17) of the surveys, either no photographs were taken, or the photographs were of poor quality (Quality 3). 53% (9) of these surveys with no images were undertaken in 2010. The most number of surveys per month was six (April 2009) and the most number of identified individuals per survey was 364 encountered during six sightings 3 October 2009 (Figure 7).

2472 photographs met the criteria for cataloguing and analysis. 84.4 % (2087) of these images were of average quality (Quality 2) and 15.6% (385) of the images were of excellent quality (Quality 1). In total 2002 dolphins were identified and catalogued. 132, 1455, 313 and 102 dolphins were identified in 2008, 2009, 2010 and 2011, respectively. 985 of the catalogued individual were left-sided, 732 were right-sided and 285 individuals were catalogued on both left and right side. The identification and accumulation of individual dolphins were plotted to create a discovery curve (Figure 7). The discovery curve rises gently during the initial phase of the survey in 2008, gets steep during 2009, and beyond that continues to gently, but steadily rise (Figure 7).

The group size estimate obtained from observers on the boat versus the one determined by the analysis of photographs was the same during six sightings (Figure 8), but was underestimated during 25 sightings (Figure 8) i.e. observers determined a lower group size than was determined from the analysis of photographs) and indicated a higher group size than was obtained from the analysis of photographs during 57 sightings (Figure 8). The table in Appendix D shows the raw data of field group size estimates, total identifications, and total new identifications.

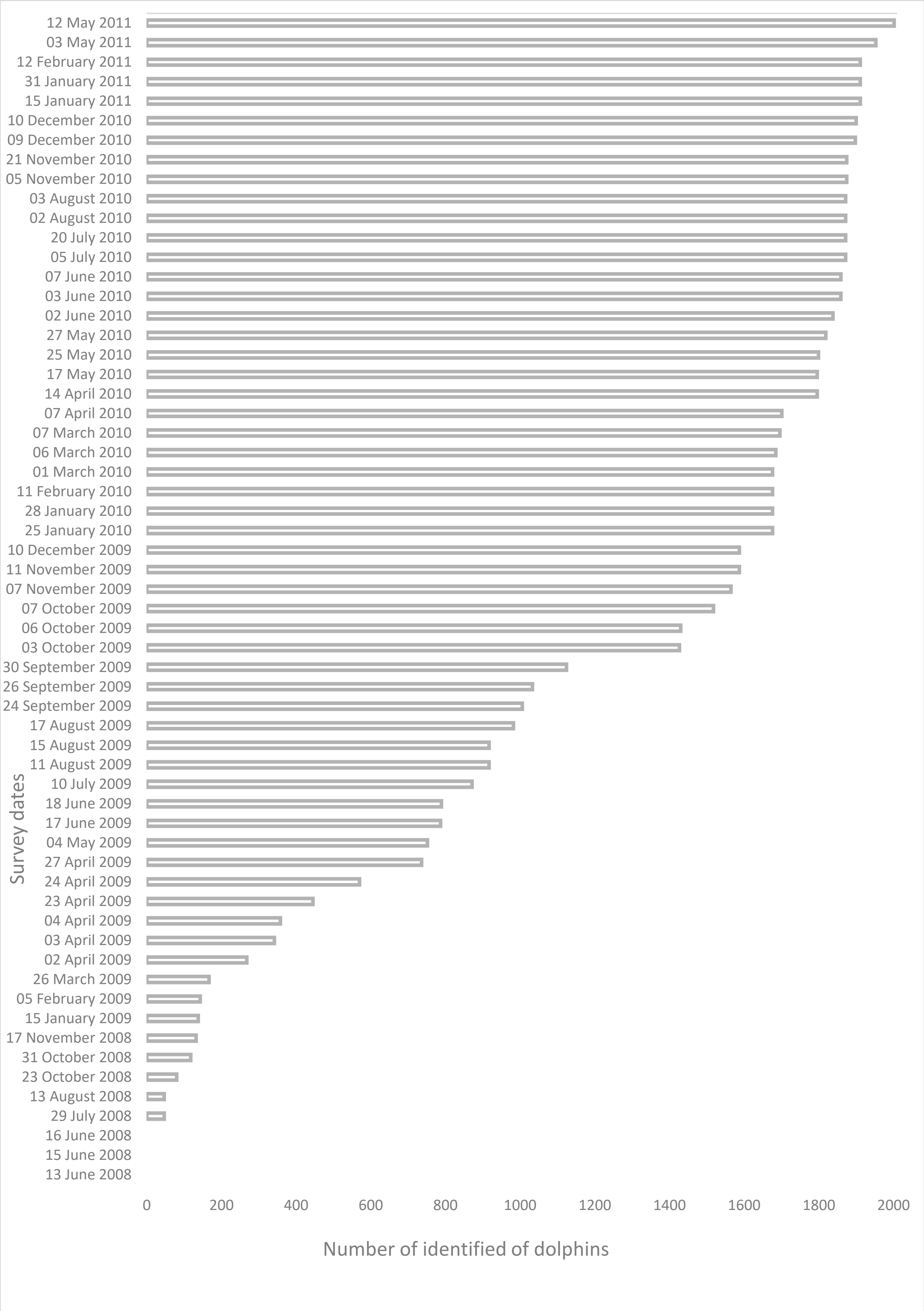


Figure 7: Accumulation curve and number of identified individuals per survey day for the duration of the study.

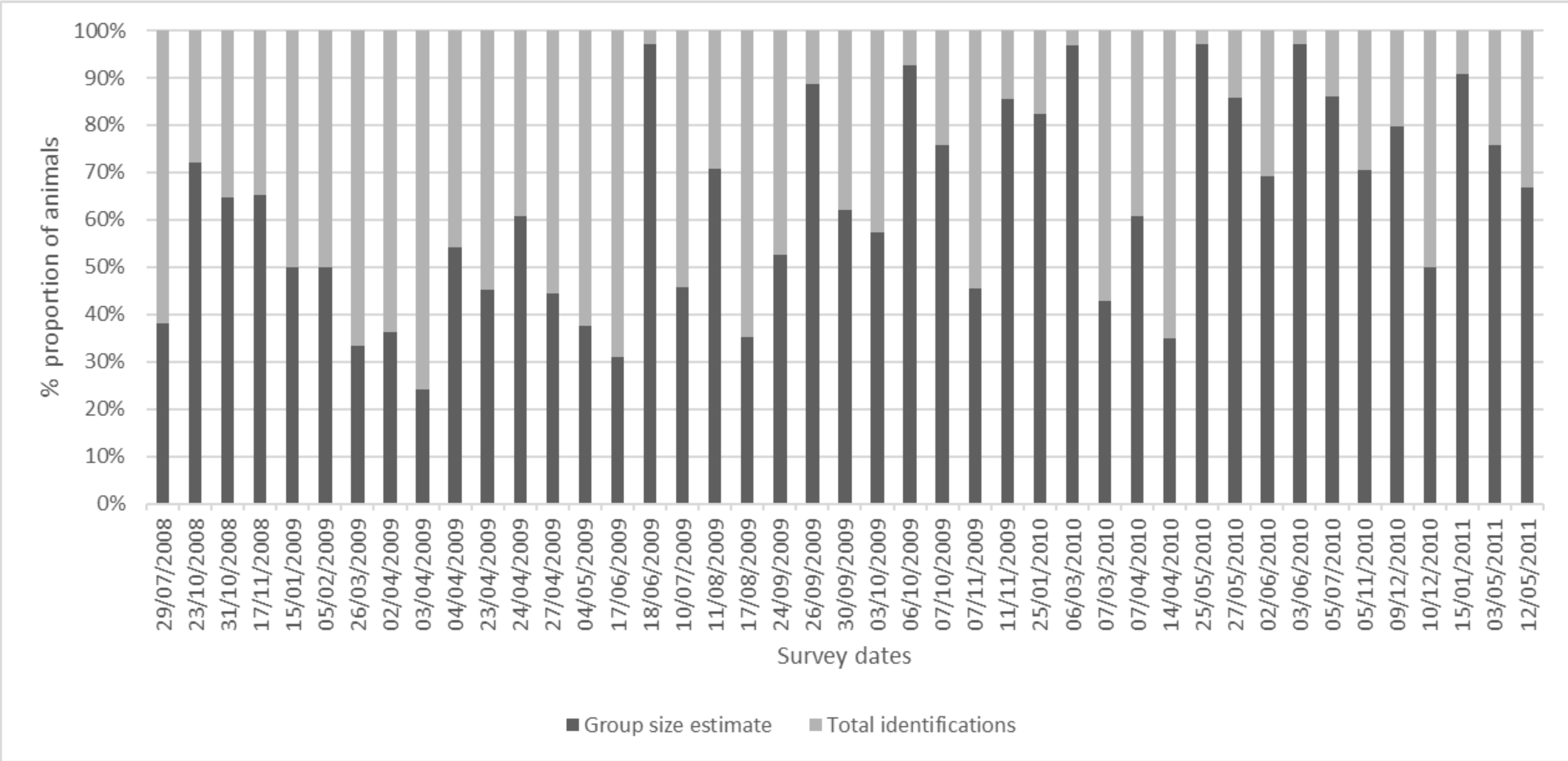


Figure 8: Proportion of field group size estimates vs photographic identified individuals.

3.2 Site fidelity and residency

From the 2002 identified individual dolphins, only 8.9% (n= 178) were re-sighted. 18.5% (n=32) of the re-sighted dolphins were seen more than twice (Figure 9). Some animals were re-sighted over a brief period. The residence index (RI) was calculated for all re-sighted animals to overcome the bias of animals being sighted over a brief period, i.e. an animal seen on three consecutive days and never again, might be a visitor for those 3 days, while an animal seen frequently on over a longer period might be resident. The RI averaged 0.05, the RI minimum was 0.02 (for animals seen twice in one month) and reached its maximum at 0.25 (for animals seen five times in five months). The intervals between the first sighting and the last sighting ranged from less than seven days to more than 24 months. Most of the animals

42.13%) were re-sighted between four weeks and six months from the first sighting and only 2.81% of the animals were re-sighted after 24 months (Figure 10).

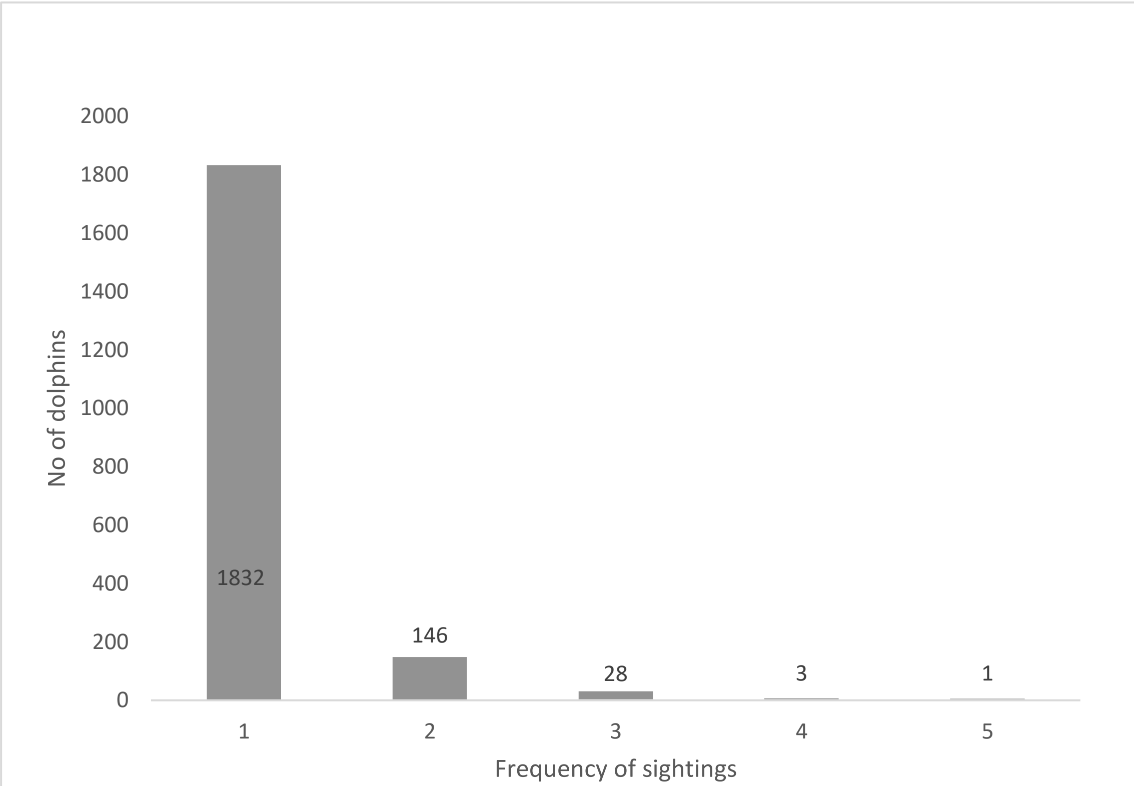


Figure 9: Re - sighting frequency of dolphins

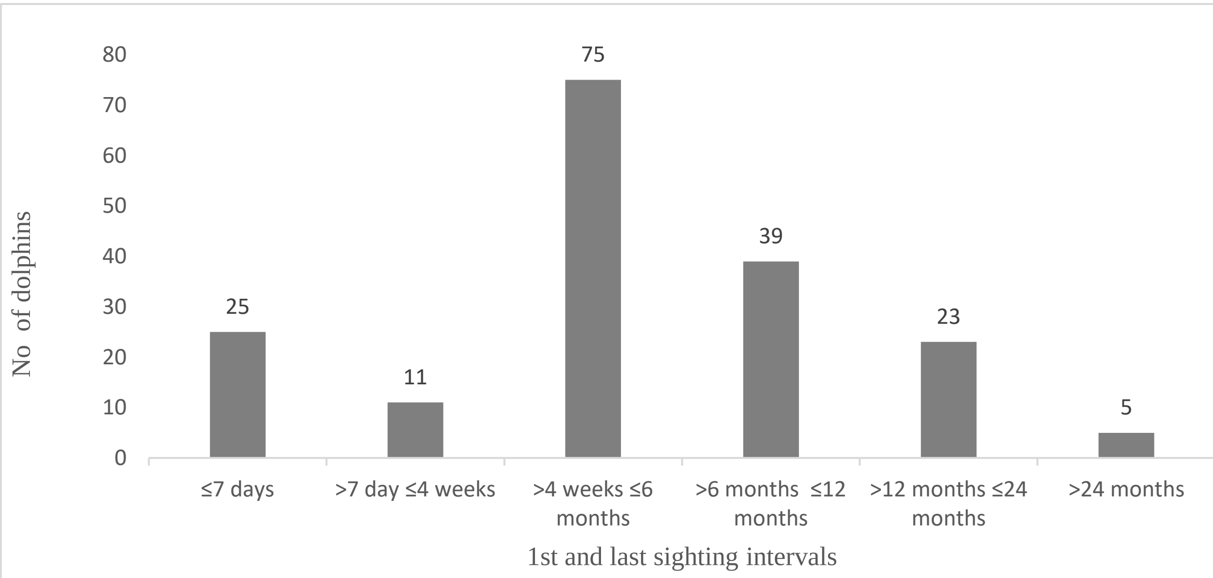


Figure 10 : Intervals between the 1st and last sighting for all re-sighted dolphins**.**

T. aduncus were seen and identified throughout the year during the entire study period (60 surveys) in Algoa Bay. There was a significant difference between IDsPUE across years (Kruskal-Wallis Anova, KW= 11.59 n=60, p= 0.009) due to the difference between 2009 and 2010 (p =0.008) (Figure 11a). In addition, IDsPUE was statistically different between the 2008/2009 and 2009 and 2010 winters (p=0.011) 2010/2011 summers (p=0.006), 2010 summer and winter 2008/2009 (p=0.003), 2008/2009 summer and 2008 winter (p=0.017), and 2008/2009 and 2009/2010 summers (p=0.34), hence IDsPUE significantly differed across seasons (KW= 17.47, n= 60, p=0.007) (Figure 11b). Melly, 2011 computed sightings per unit effort using field estimates from the same data set.

There was a significant difference in the distribution of identifications across years (KW=13.29, n=60, P= 0.004), the significant difference was due to the significant difference between 2009 and 2010 winter (p=0.004) (Figure 12a). Across seasons there was also a significant difference in the distribution of identifications (KW=17.81 n=60, P=0.007) due to significant difference between 2008 winter and 2008/2009 summer (0.030), 2008 and 2009 winter (0.037), 2009 and 2010 winter (0.006), 2008/2009 summer and 2010 winter (0.005), 2008/2009 and 2010/2011 summer (p=0.008) and 2009 winter and 2010/2011 summer (p=0.009), (Figure 12b).The there was no significant difference in the spread of re-sightings between years (KW = 6.9, n=56, p= 0.8) as well as between seasons (KW=12.26, n=56, p=0.6) (Figure 13).

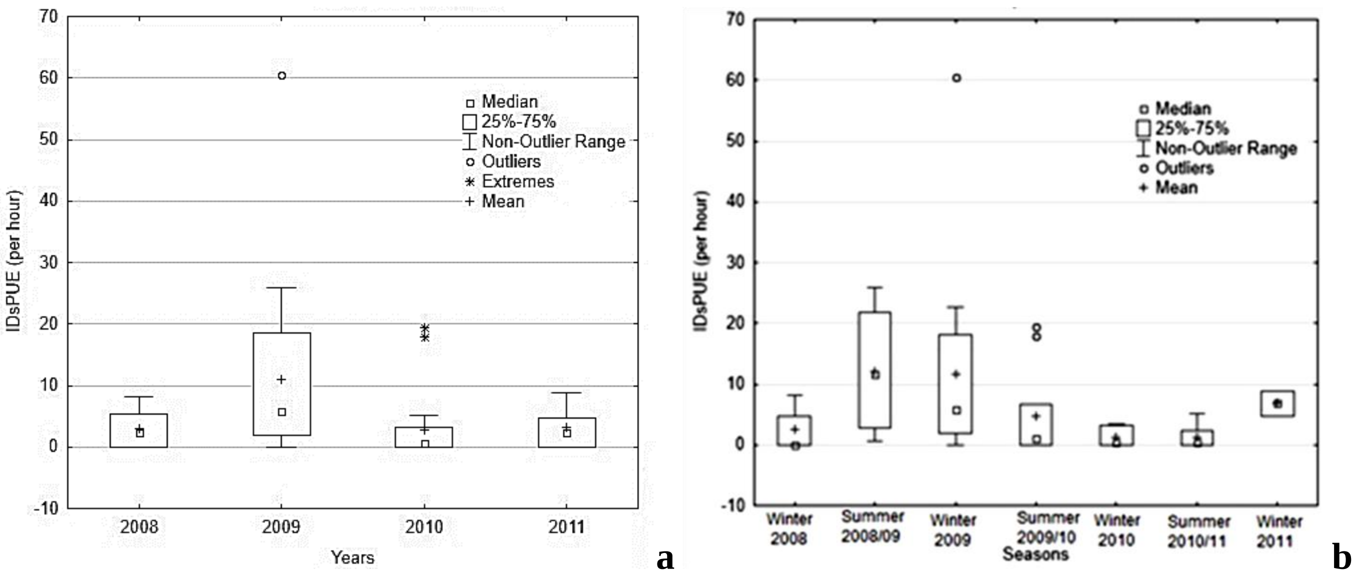


Figure 11: Boxplots showing statistical differences and distribution of IDsPUE across years (a) and across seasons (b).

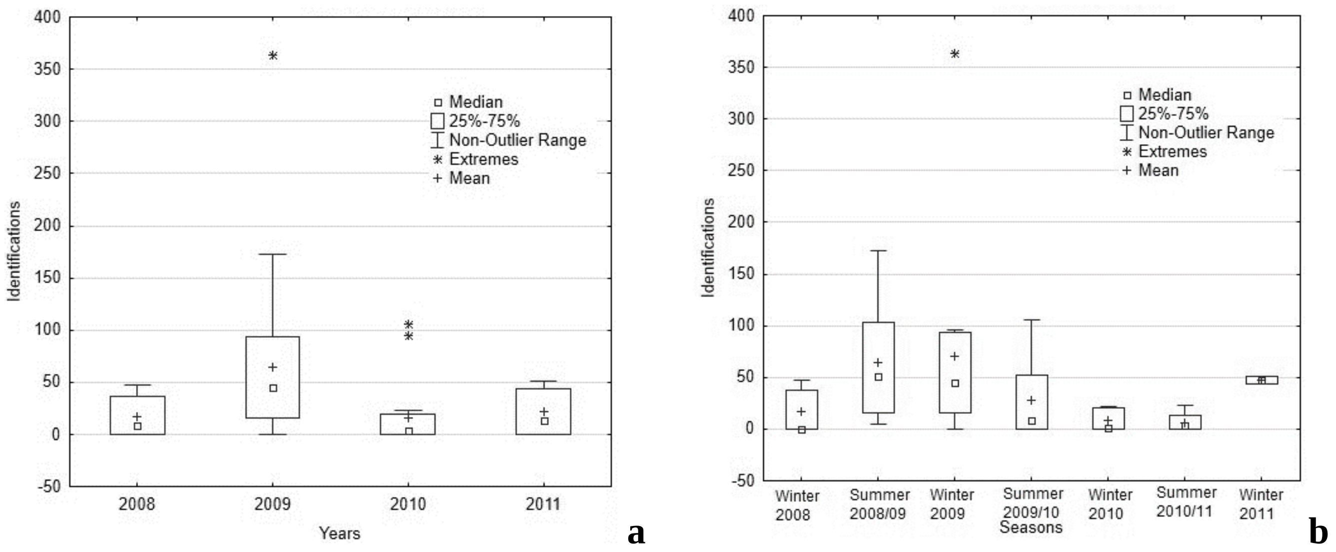


Figure 12: Boxplots showing statistical differences and distribution of identifications across years (a) and seasons (b).

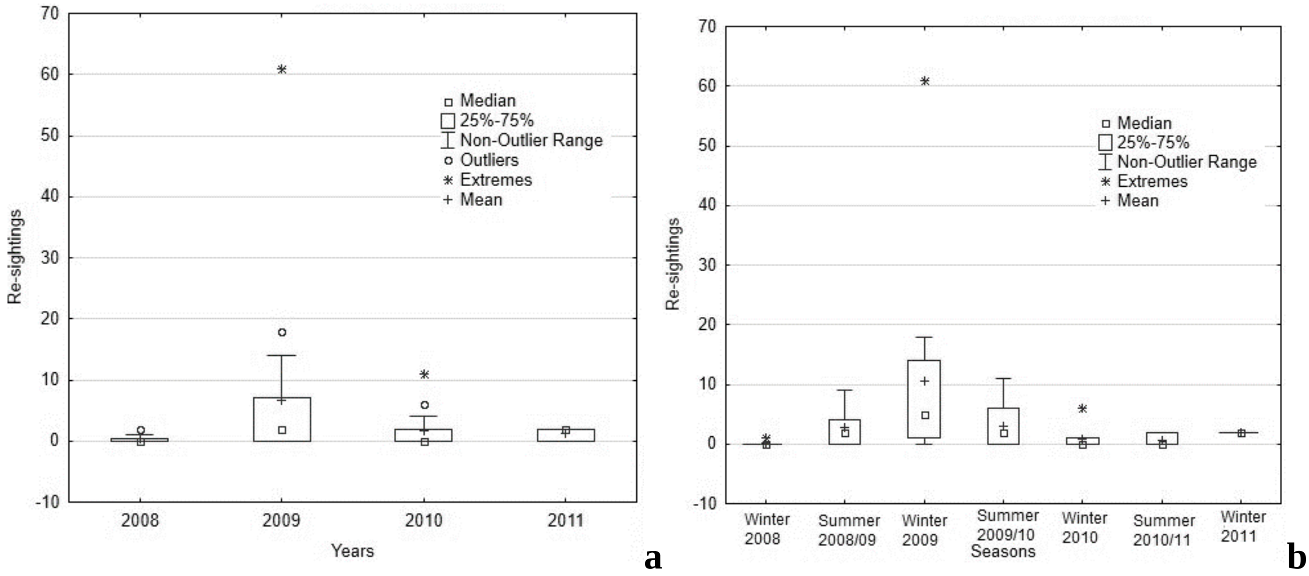


Figure 13: Boxplots showing statistical differences and distribution of re-sightings across years (a) and seasons (b).

3.3 Association analysis

An association matrix showing the association among all 32 individuals re-sighted more than three times was used to create a hierarchical cluster (dendrogram) using *SOCPROG* (Table 2). The dendrogram showed two major clusters consisting of smaller clusters as well as individual AB0526 with no associations. **Cluster 1** consists of 23 dolphins and **Cluster 2** consists of eight dolphins (Figure 14). The HWI average for individuals in **Cluster 1** was 0.15, while **Cluster 2** individuals averaged 0.04 (Table 2).

The HWI ranged from 0 to 1, with indices of 0.57 and 0.67 being the most common, recorded seven and 14 times, respectively. Individuals AB0826 and AB0827, as well as AB0870 and AB912, were always sighted together, resulting in an HWI of one (Figure 15).

A sociogram also generated with *SOCPROG* shows the distinctive social networks between these two clusters (Figure 16).

Table 2: Association matrix showing association of all individuals sighted ≥3 times. The grey area shows individuals with an HWI average of 0.04. Dark grey shows individual AB0526, with no associations. The top triangle shows the number of times animals were seen together and the bottom triangle shows the HWI coefficient among individuals

	AB0003	AB0007	AB0030	AB0034	AB0035	AB0050	AB0052	AB0076	AB0078	AB0079	AB0104	AB0116	AB0131	AB0141	AB0163	AB0166	AB0172	AB0175	AB0265	AB0289	AB0395	AB0422	AB0526	AB0826	AB0827	AB0831	AB0865	AB0870	AB0884	AB0912	AB0958	AB0981
Sighted	5	3	3	4	3	3	3	3	3	3	3	4	3	3	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
AB0003		1	2	3	2	1	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	1	1	1	0	1	2	1	0	0
AB0007	0.25		1	1	1	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
AB0030	0.05	0.33		2	2	1	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	1	2	0	1	1	1	0	1
AB0034	67	0.29	0.57		2	1	0	0	1	1	1	1	0	2	0	0	0	0	0	0	0	0	0	2	2	2	1	1	2	1	0	0
AB0035	0.5	0.33	0.67	0.57		2	0	0	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1
AB0050	0.25	0	0.33	0.29	0.33		1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	2	0	0	0	0	0	1
AB0052	0.25	0	0	0.29	0	0.33		2	0	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	2	0
AB0076	0.25	0.33	0	0	0	0.33	0.67		0	1	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0
AB0078	0.25	0	0.33	0.29	0.67	0.33	0	0		2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1
AB0079	0.25	0	0	0.29	0.67	0	0.67	0.33	0.67		1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0
AB0104	0.25	0	0	0.29	0.33	0	0	0	0.33	0.33		1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0
AB0116	0.22	0	0.29	0.25	0	0	0	0	0	0	0.29		0	1	0	0	0	0	0	0	0	0	0	2	2	1	2	1	1	1	0	0
AB0131	0	0.33	0	0.57	0	0	0.67	0.67	0	0.33	0	0		1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	2	0
AB0141	0.25	0.33	0.33	0.57	0	0.33	0	0.33	0	0	0	0.29	1		0	0	0	0	0	0	0	0	0	2	2	2	1	1	1	1	0	0
AB0163	0	0	0	0	0	0	0	0	0	0	0	0	0	0		1	1	1	0	1	2	0	0	0	0	0	0	0	0	0	0	0
AB0166	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.25		1	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0
AB0172	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.29	0.29		1	0	0	0	1	0	0	0	0	0	0	0	0	0	1
AB0175	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.29	0.29	0.29		0	0	0	0	0	0	0	0	0	0	0	0	0	0
AB0265	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.57	0	0		1	0	0	0	0	0	0	0	0	0	0	0	0
AB0289	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.29	0	0	0.33		0	0	0	0	0	0	0	0	0	0	0	0
AB0395	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.57	0	0	0	0	0		1	0	0	0	0	0	0	0	0	0	0
AB0422	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.33	0	0	0	0.57		0	0	0	0	0	0	0	0	0	1
AB0526	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0
AB0826	0.25	0	0.33	0.57	0	0.33	0	0	0	0	0	0.57	0	0.67	0	0	0	0	0	0	0	0	0		3	2	2	1	1	1	0	0
AB0827	0.25	0	0.33	0.57	0	0.33	0	0	0	0	0	0.57	0	0.67	0	0	0	0	0	0	0	0	0	1		2	2	1	1	1	0	0
AB0831	0.25	0	0.67	0.57	0.33	0.67	0	0	0.33	0	0	0.29	0	0.67	0	0	0	0	0	0	0	0	0	0.67	0.67		1	1	1	1	0	0
AB0865	0.25	0	0.33	0.29	0	0	0	0	0	0	0.33	0.57	0	0.33	0	0	0	0	0	0	0	0	0	0.67	0.67	0.33		2	1	2	0	0
AB0870	0.25	0	0.33	0.29	0	0	0.33	0.33	0	0.33	0.33	0.29	0.33	0.33	0	0	0	0	0	0	0	0	0	0.33	0.33	0.33	0.67		1	3	1	0
AB0884	0.5	0	0.33	0.57	0	0	0	0	0	0.33	0.33	0.29	0	0.33	0	0	0	0	0	0	0	0	0	0.33	0.33	0.33	0.33	0.33		1	0	0
AB0912	0.25	0	0.33	0.57	0	0	0.33	0.33	0	0.33	0.33	0.29	0.33	0.33	0	0	0	0	0	0	0	0	0	0.33	0.33	0.33	0.67	1	0.33		1	0
AB0958	0	0	0	0	0	0	0.67	0.33	0	0.33	0	0	0.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.33	0	0.33		0
AB0981	0	0.33	0.33	0	0.33	0.33	0	0	0.33	0	0	0	0	0	0	0	0.33	0	0	0	0	0.33	0	0	0	0	0	0	0	0	0	
Ave. HWI	0.18	0.08	0.19	0.26	0.14	0.13	0.13	0.12	0.12	0.14	0.1	0.16	0.13	0.18	0.05	0.06	0.05	0.03	0.03	0.02	0.04	0.04	0	0.19	0.19	0.21	0.18	0.2	0.15	0.22	0.08	0.08

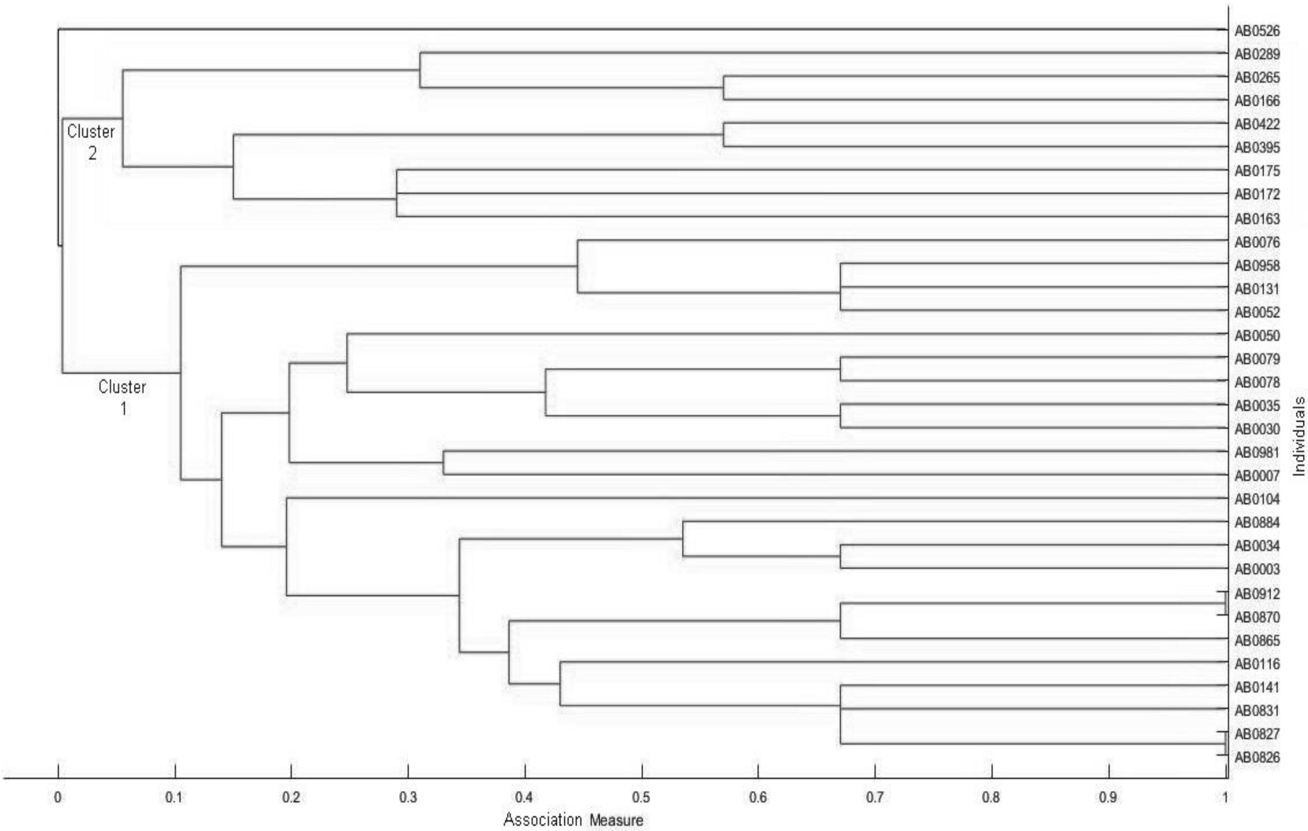


Figure 14: A dendrogram showing the hierarchical cluster of the animals re-sighted ≥ 3 times.

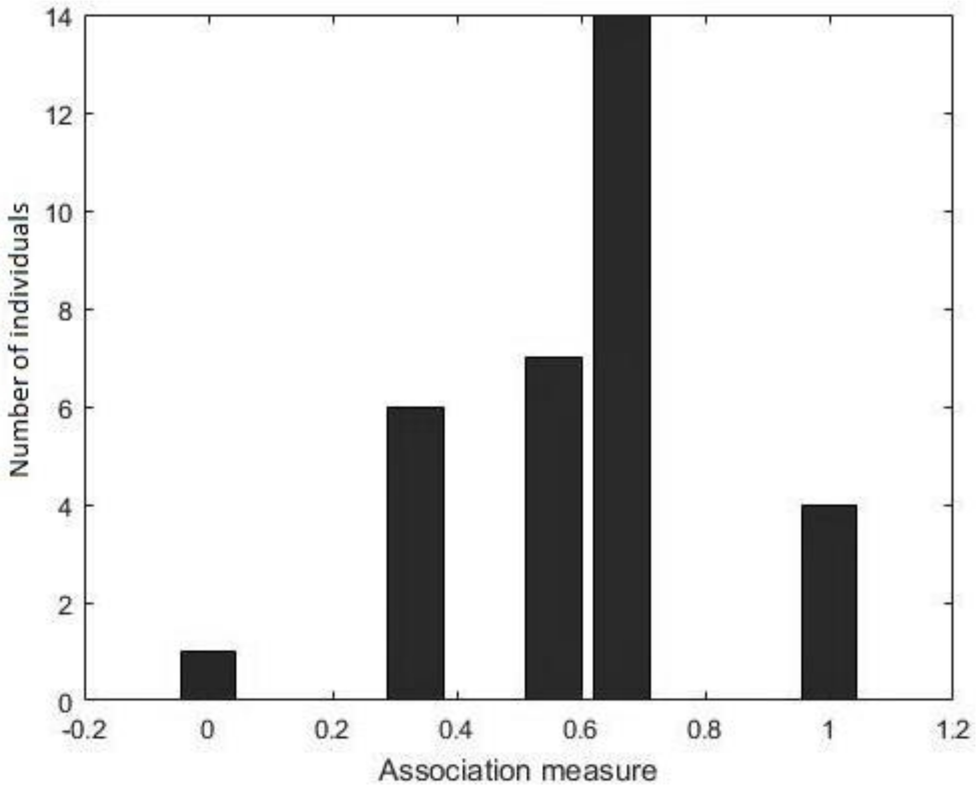


Figure 15: Distribution of the maximum association index for individuals seen three or more times.

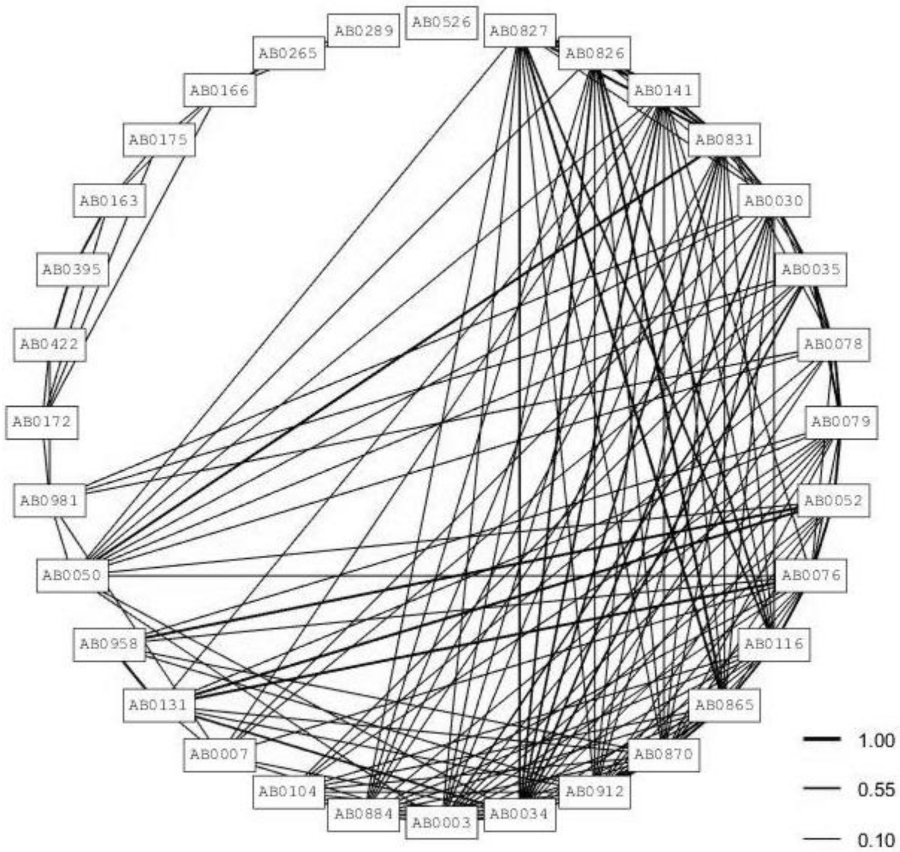


Figure 16: Social network diagram indicating the strength (shown by the thickness of the line) of association between individuals sighted three or more times.

3.4 *Xenobalanus*

Xenobalanus were recorded during the entire duration of the study. Out of 43 days during which dolphins were identified, five days (4 April 2009, 18 June 2009, 24 September 2009, 25 May 2010 and 10 December 2010) had no records of *X. globicipitus*. 24 and 27 April 2009 presented the most dolphins with parasites: 22 and 25 unique fins with *X. globicipitus*, respectively were recorded on these days (Figure 17). The average number of dolphins with *Xenobalanus* per day was 6.5. Figure 18 shows the proportion of dolphins with Xenobalanus from the group size estimates, there was no significant difference in the proportion of dolphin with Xenobalanus across seasons (KW =11.81, n=43, p=0.66). *Xenobalanus* sightings per unit effort were the same across years (KW=1.05, n=43, p=0.79) and seasons (KW=5.21, n=43, p=0.39) (Figure 19). There was also no statistical significance for the number of fins with *X. globicipitus* among years (KW=1.49, n=42, p=0.68) and seasons (KW= 6.59, n=43, p=0.36) (Figure 20). The number (and spue) of dolphins with Xenobalanus is a function of the number of dolphins seen.

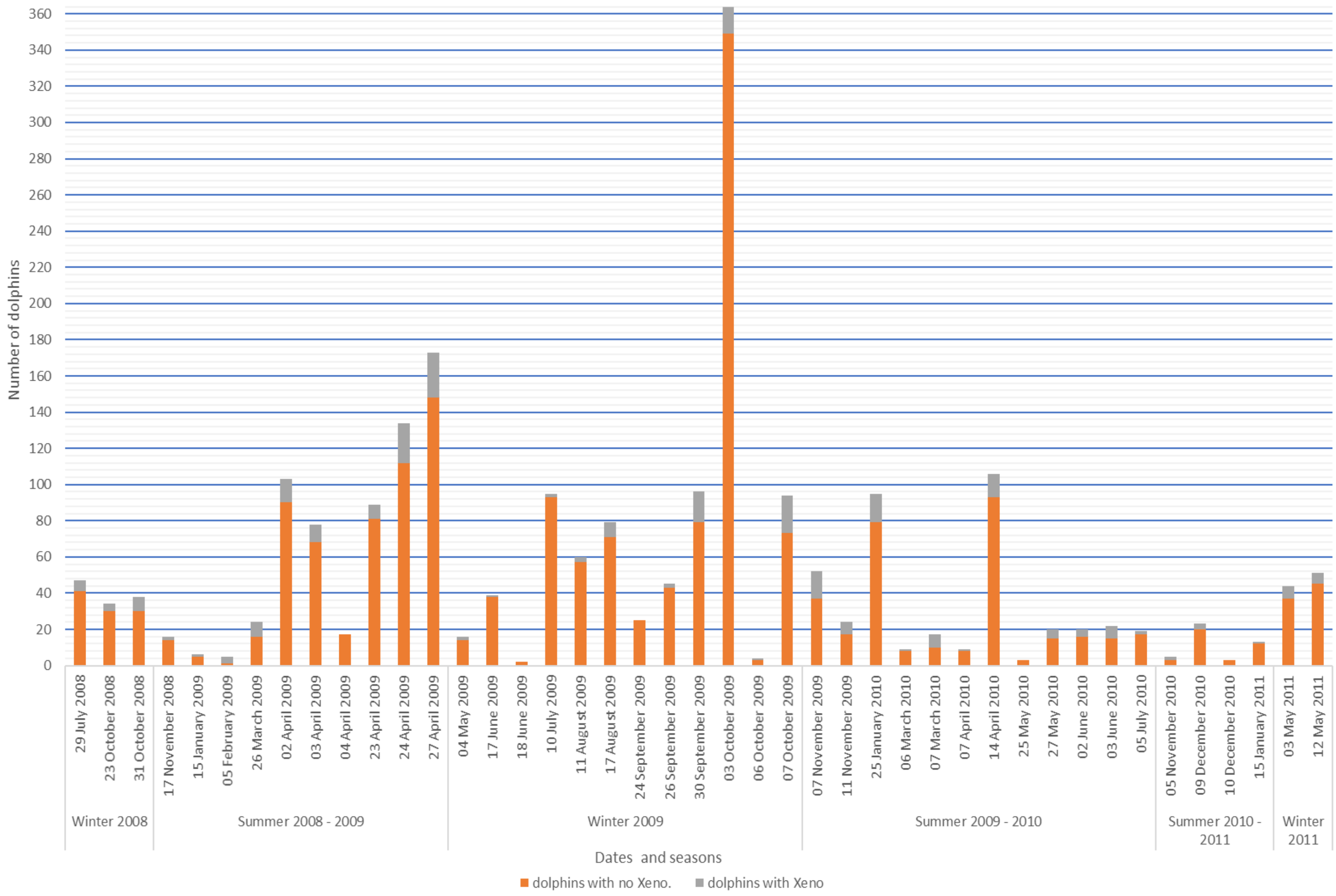


Figure 17: The number of identified dolphins with and without Xenobalanus per survey day.

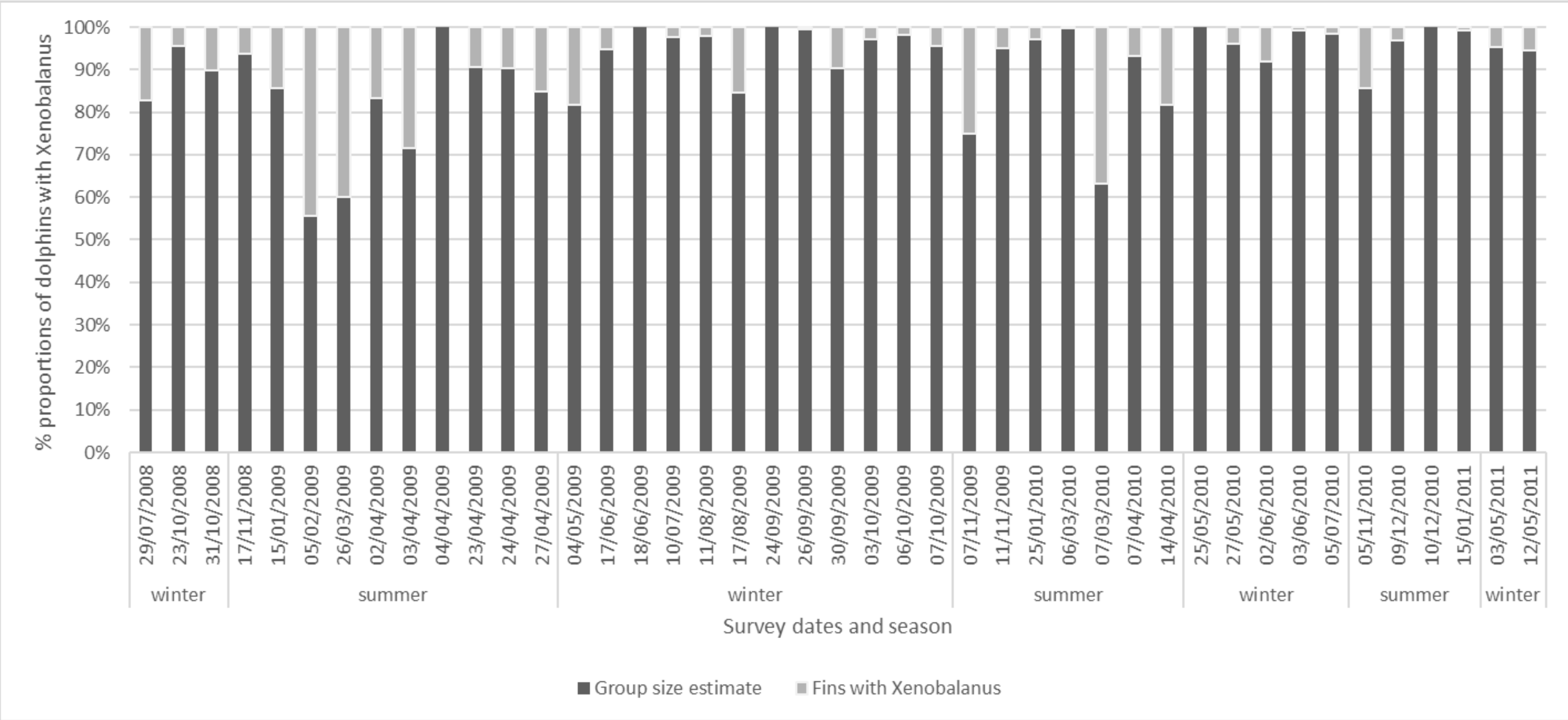


Figure 18: The proportion of dolphins with Xenobalanus

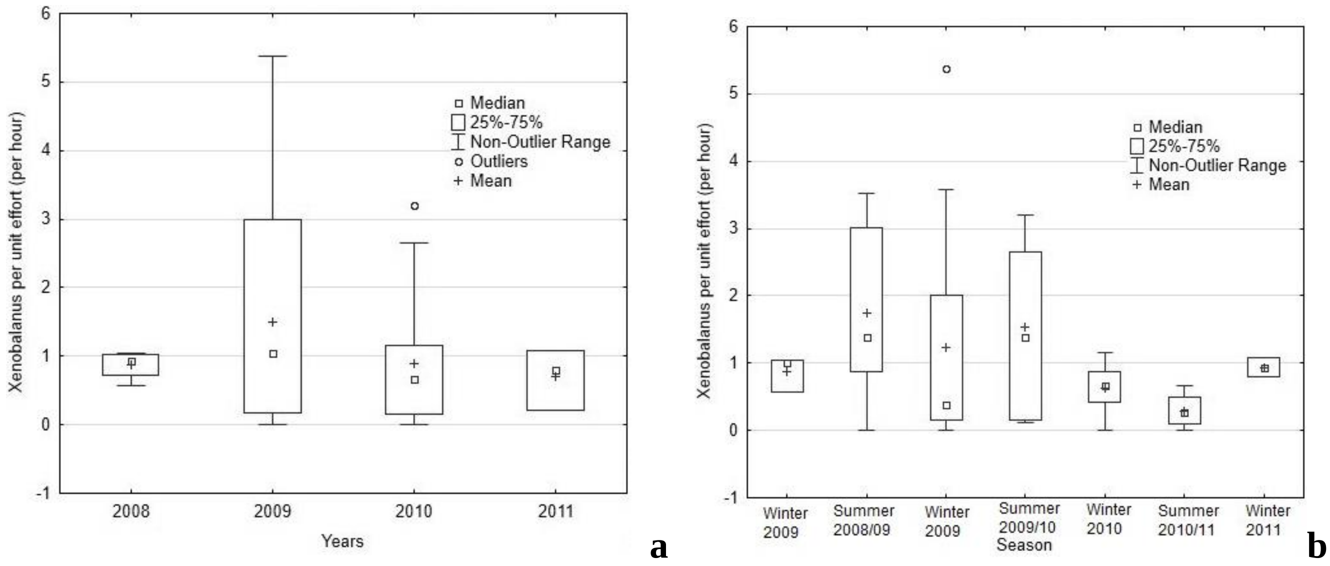


Figure 19: Boxplots showing the statistical differences of *Xenobalanus* sighting per unit effort across years (a) and seasons (b)

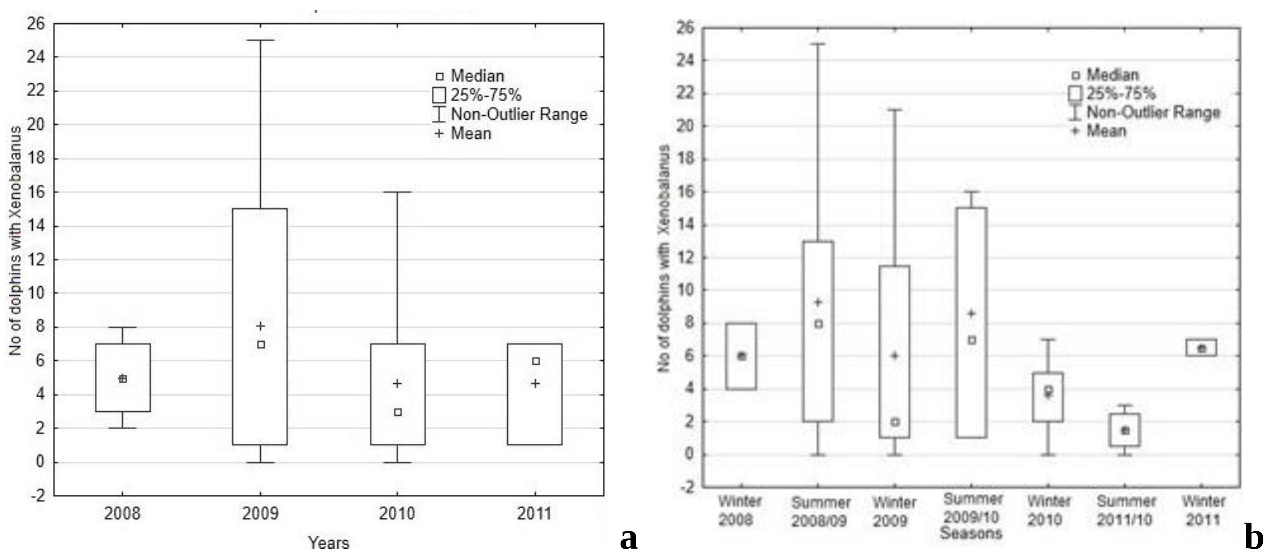


Figure 20: Boxplots showing statistical differences and distribution of dolphins with *Xenobalanus* across years (a) and season (b).

3.5 Spatial distribution

3.5.1 Spatial distribution of sightings

Identified dolphins where dominantly sighted within the 15-metre depth coastal zone around the entire bay, which is predominantly sandy seafloor. Sightings are clustered in three areas: 1. Cape Recife to the Port of Port Elizabeth (Port of P.E.), 2. Swartkops River Mouth, Port of Ngqura and around St. Croix Island, and 3. Sundays River Mouth to Woody Cape, with outliers at Riy Banks and Bird Island (Figure 21). The area 1 cluster is the most concentrated. The sightings along the North and East coast of Algoa Bay (between Swartkops River Mouth and Woody Cape) are closer to shore, within the surf zone, while sightings on the West and South coast (between the Port of P.E to Cape Recife) are relatively offshore, although still within the 15-metre depth contour (Figure 21). Two areas within the 15-metre depth contour had no sightings: the area between the Port of P.E. and the area from the Port of Ngqura Eastwards to the East of Sundays River mouth (Figure 21).

When analysed individually, the sighting distribution of individuals seen on three or more occasions followed a similar distribution pattern as above, but with a higher concentration of sightings in areas 1 and 2. The ten sightings in zone 3 were made up of six individuals: four of the sightings were of individual AB0508, two were of AB0175, and AB0289 was, while individuals AB0166 and AB0265 were each sighted once (Figure 22). A detailed analysis of spatio- temporal patterns and habitat preference of bottlenose dolphins in Algoa Bay was carried out by Melly, 2011 and Melly et al., 2017.

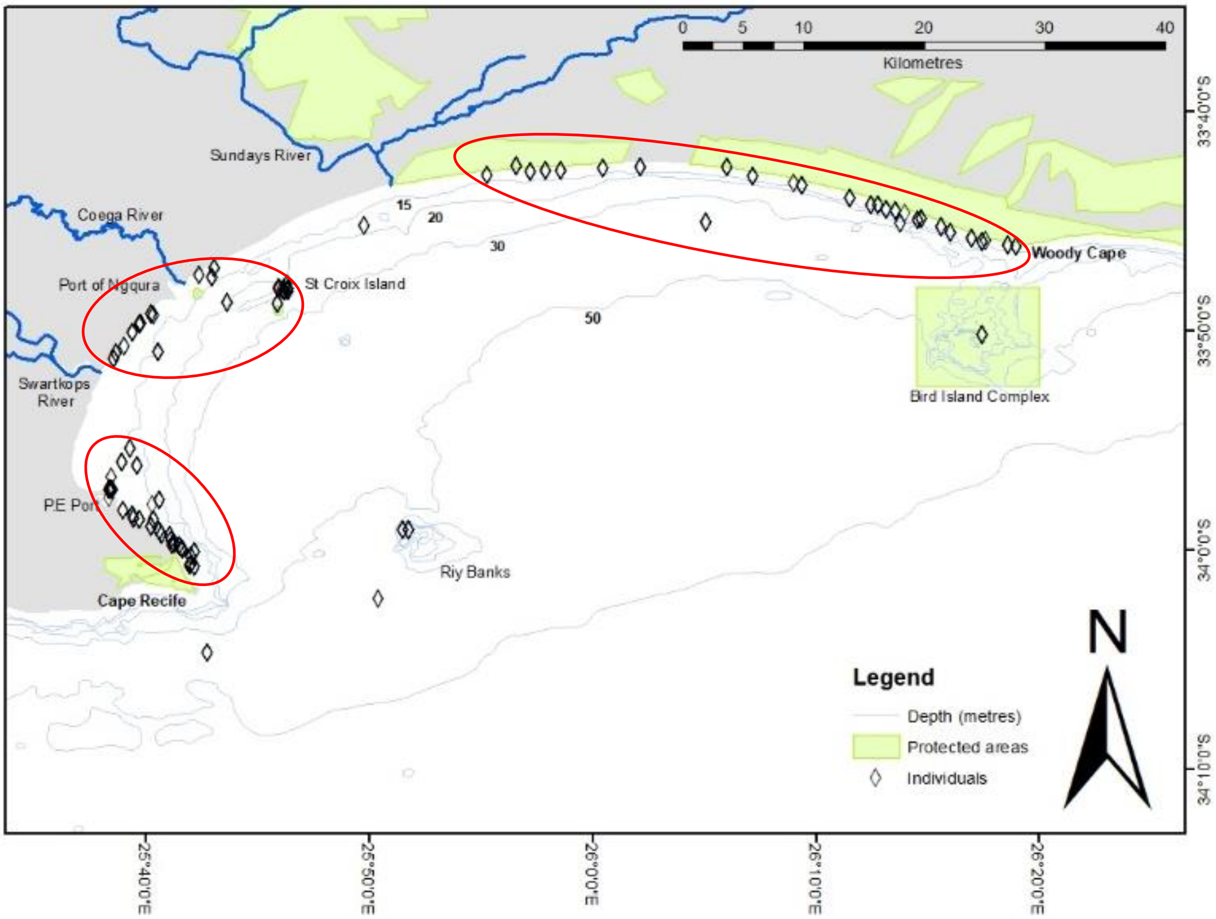


Figure 21: Distribution of all photo - identified bottlenose dolphin sightings, with the 3 clusters circled in red.

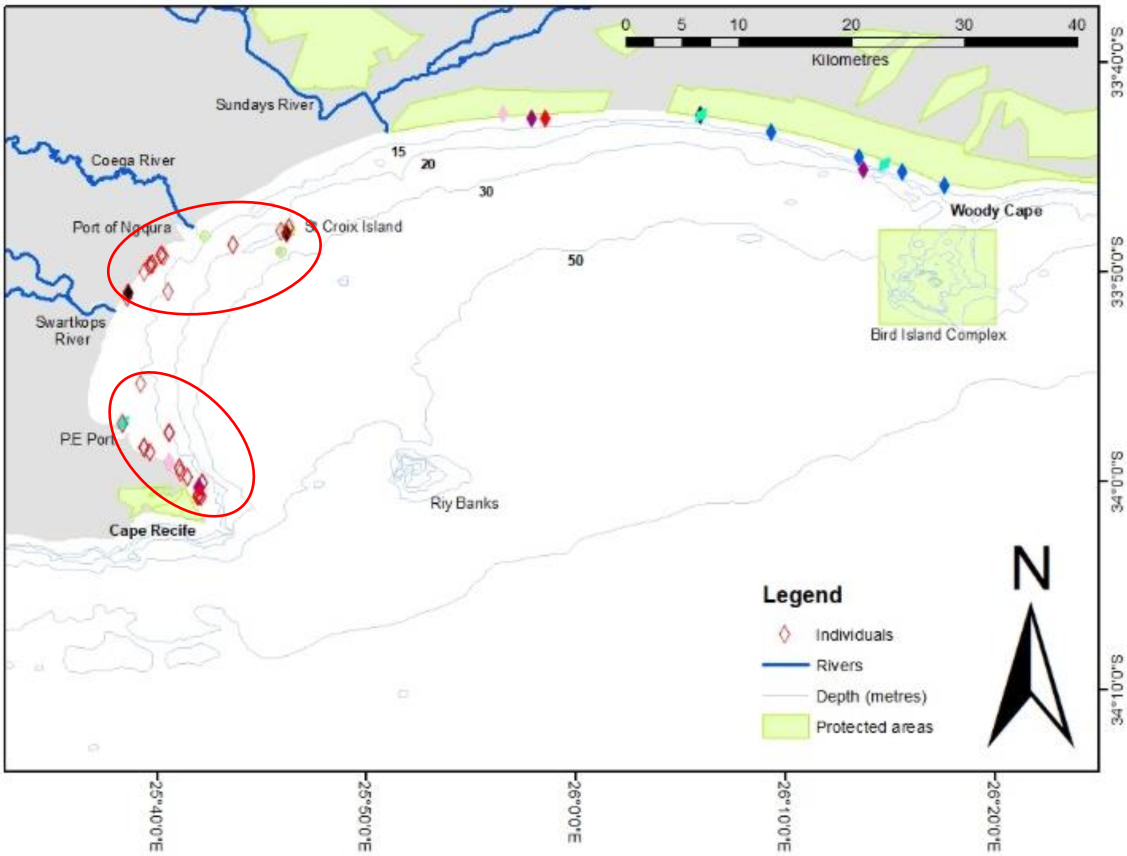


Figure 22: Distribution of identified individuals seen three times or more. The coloured diamonds show individuals AB0508 (blue), AB0175 (purple), AB0163 (black), AB0289 (green), AB0166 (red), and AB0265 (pink), which were sighted along the Eastern coast of the bay.

3.5.2 Spatial distribution of behaviours

Seven behaviours where reported among the 2002 identified individuals, namely *feeding, travelling, slow travelling, fast travelling, socialising (including mating), resting,* and *milling*. The 122 entries of dominant behaviour consisted of 36% travelling, 29% feeding, 15% socialising, 11% milling, 6% slow travel, 2% resting and 1% fast travel records. Behaviours are made up of dominant behaviour (initially observed) and secondary behaviour (observed behaviour) (Figure 23). Notes on secondary behaviours were recorded in the general comments section of the data collection sheet and were logged 27 times, making up 22% of the total behaviour records. Feeding and socialising were the most common secondary behaviours (Figure 23). Analyses of the relationship between dominant behaviour and secondary behaviour (which secondary behaviour tends to be associated with which dominant behaviour), showed that socialising (50%) and feeding (88%) occurred with dominant travelling behaviour, and secondary travelling (80%) was mostly associated with primary feeding. The relationships between dominant behaviours and secondary behaviours are detailed in Figure 24.

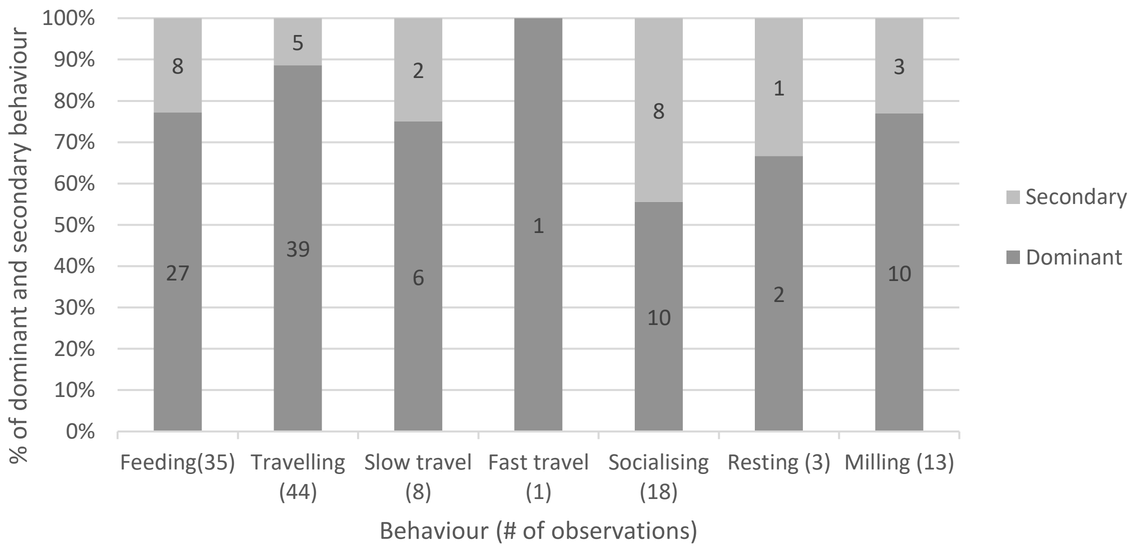


Figure 23: The stacked column showing how much dominant and secondary behaviour contributes to the sum of behaviour observations.

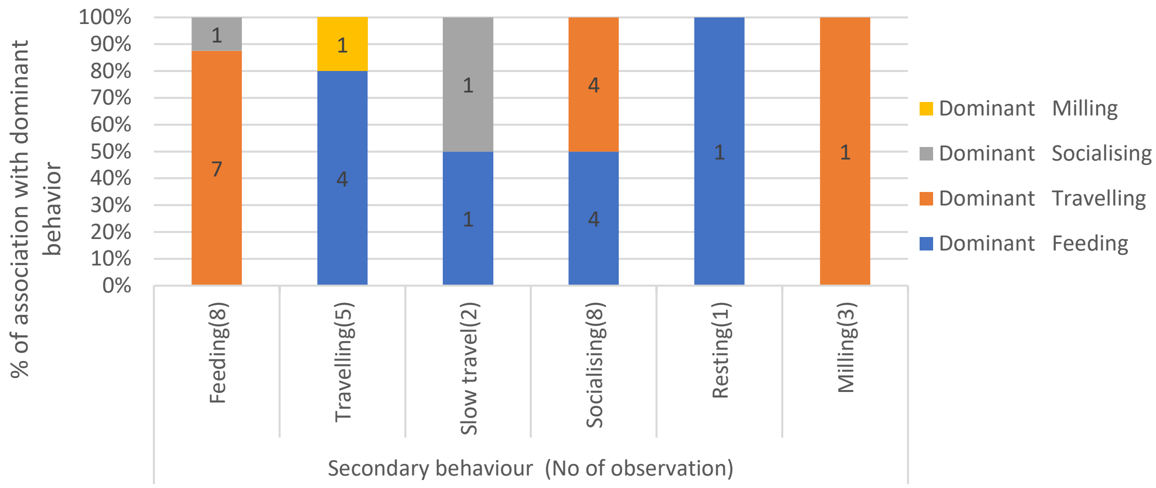


Figure 24: Stacked column showing the association between primary and secondary behaviour.

a) All identified individuals

Feeding:

Feeding was recorded throughout the bay but mostly seen in the Western part of the bay. Secondary feeding behaviour distributions mostly follow the pattern of dominant feeding behaviour (Figure 25).

Travelling:

Dolphins exhibit travelling throughout Algoa Bay and this was the most common behaviour (36%) noted (Figure 26).

Slow travel:

Slow travel was mostly seen in the Northern part of the bay, with secondary slow travel being seen in the Western part as well as around St. Croix and at Woody Cape (Figure 26).

Fast travel:

Fast travel was recorded only once near the Port of P.E. (Figure 26).

Socialising:

Socialising behaviours were often logged in the Eastern and Western part of the bay, secondary socialising followed a similar trend. However, additional locations of observations of socialising behaviour were at St. Croix Island and North of the Swartkops River Mouth (Figure 27).

Resting:

Resting was noted south of the Port of P.E on two occasions and was recorded as a secondary behaviour at St. Croix Island (Figure 28).

Milling:

Milling was seen in two clusters in the Western part of the bay and at Woody Cape. Isolated milling cases were recorded offshore from Cape Recife and near Riy Banks, and along the Northern part of the bay. Secondary milling behaviours were seen around the Port of P.E and off Sundays River Mouth (Figure 28).

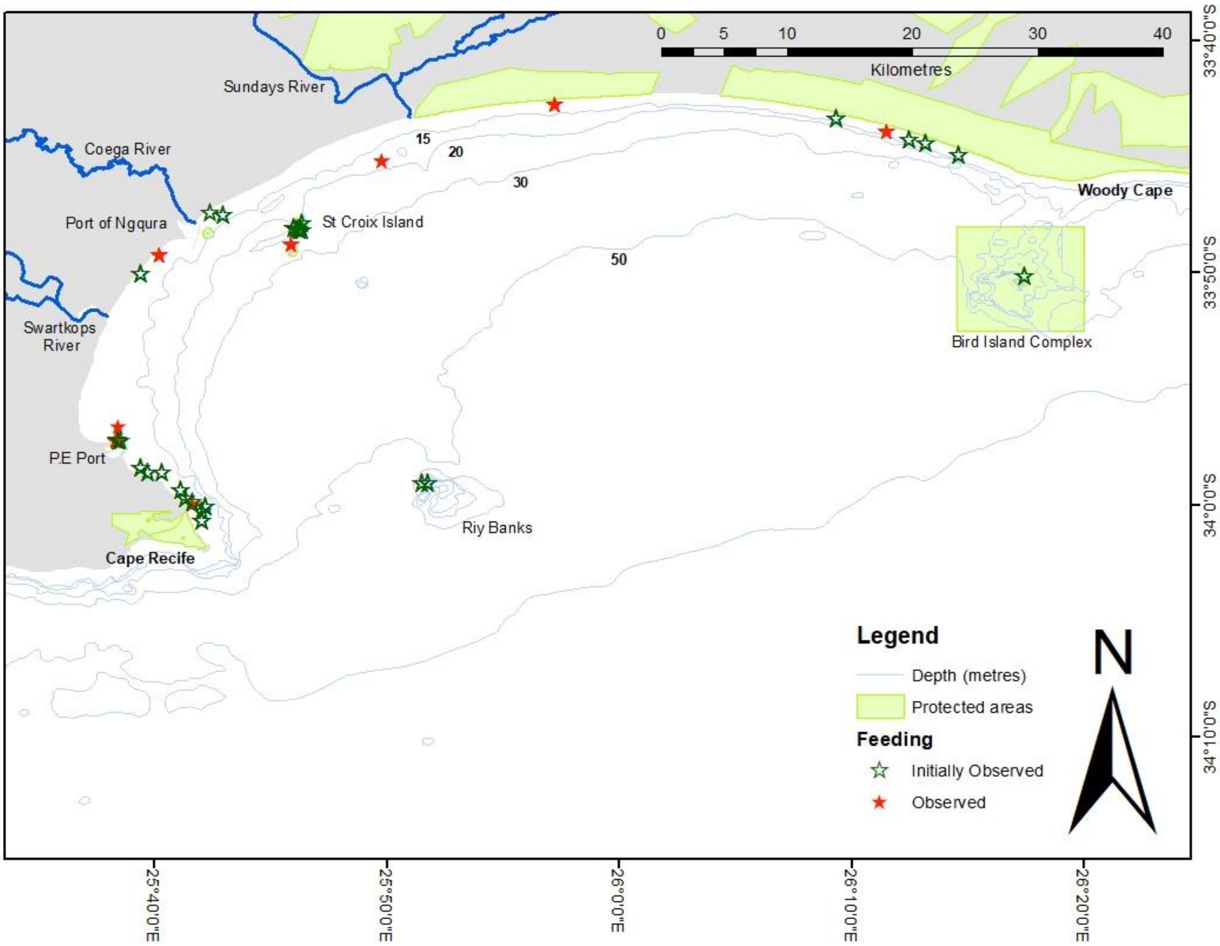


Figure 25. Map showing the feeding distributions.

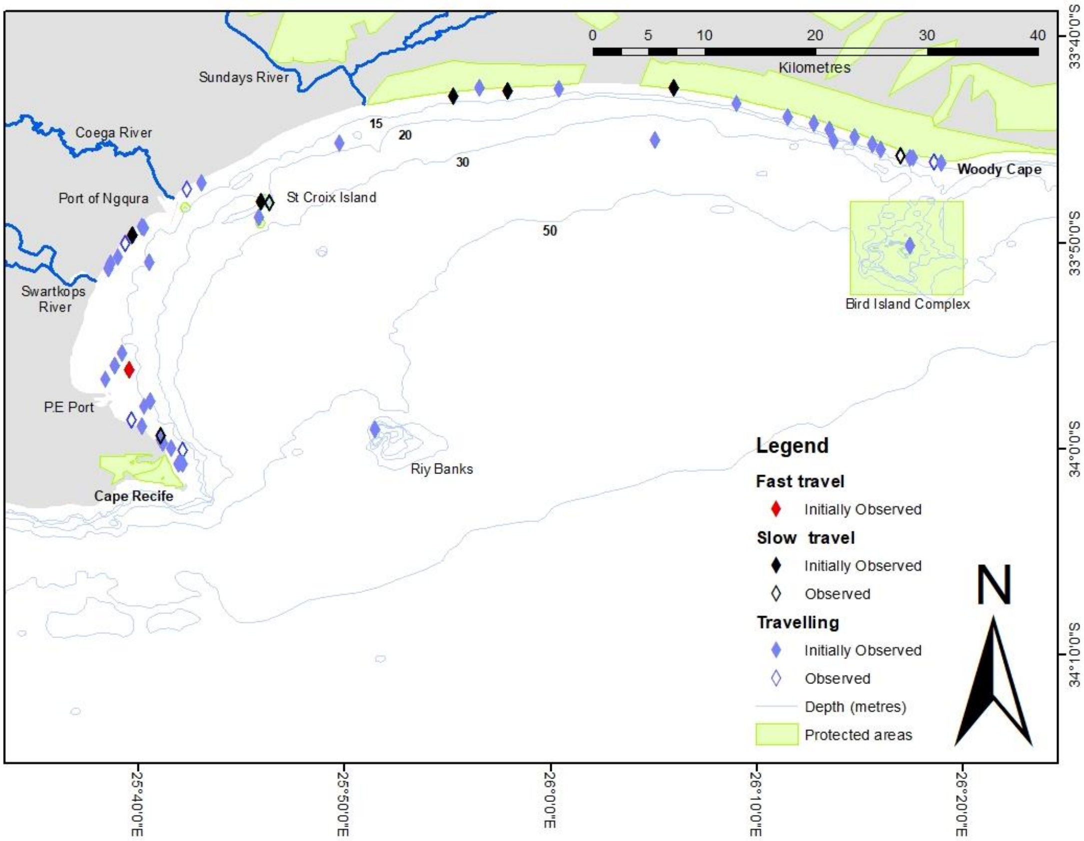


Figure 26. Map showing the fast travel, slow travel and travelling distributions.

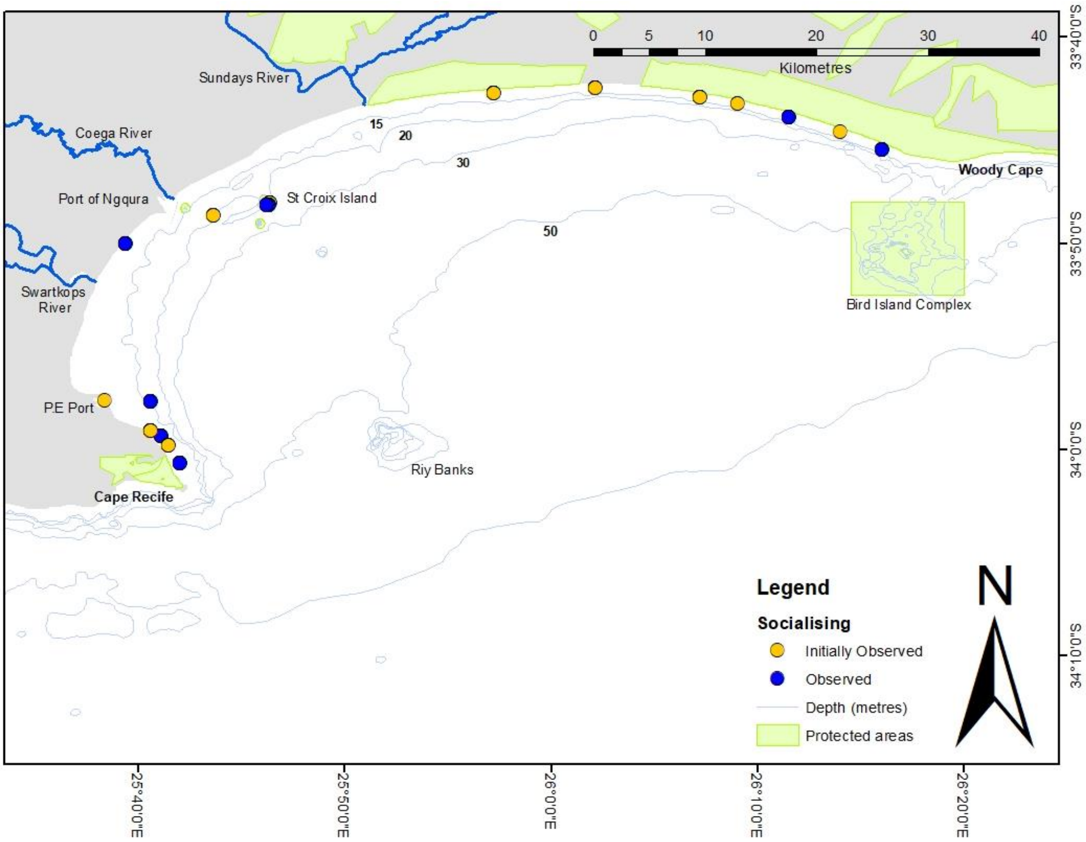


Figure 27. Map showing socialising distributions.

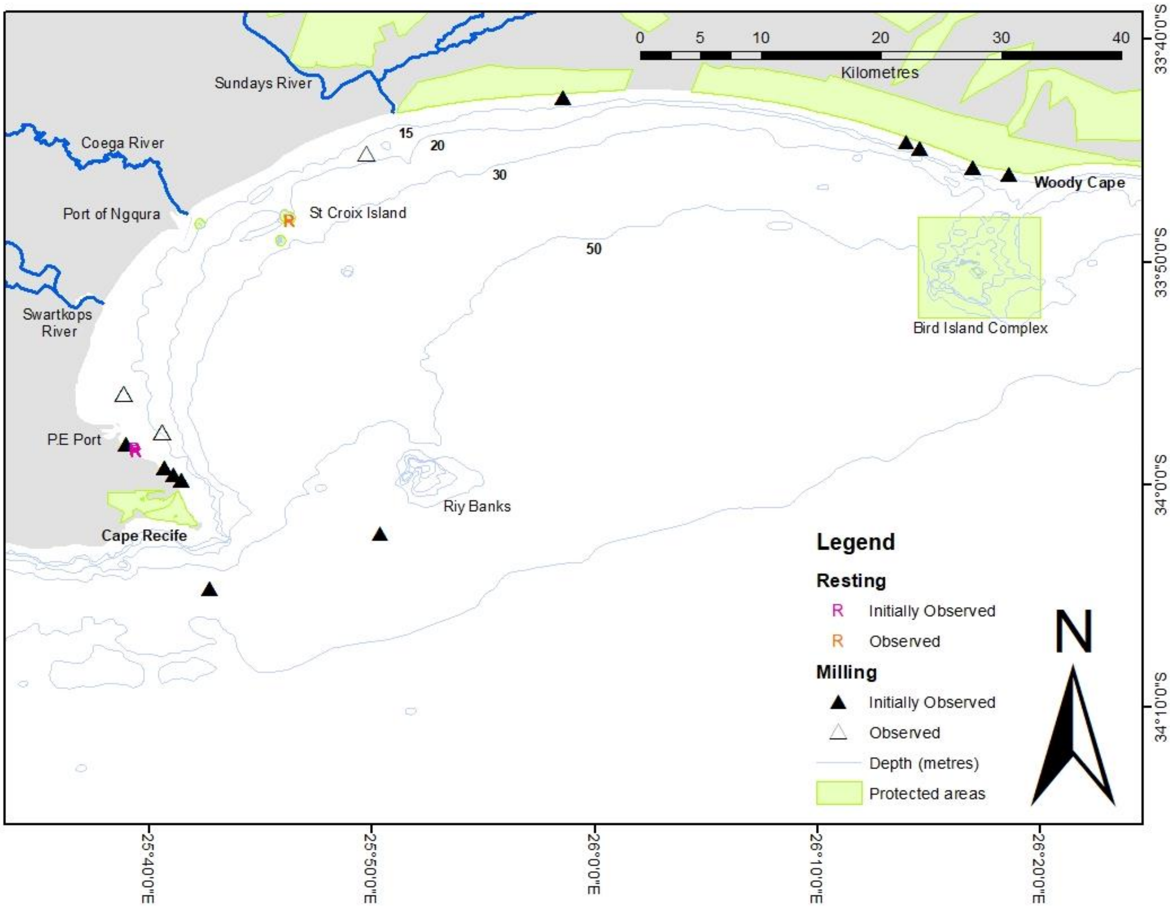


Figure 28. Map showing resting and milling distributions.

b) Individuals sighted three or more times

Spatial distribution of key behaviours (feeding and socialising) for the individuals seen three or more times were analysed separately.

Feeding and socialising

Feeding and socialising had similar distribution patterns; these behaviours were often seen along the Western part of the bay and at St. Croix Island, with some isolated cases around the Port of Ngqura and along the Eastern part of the bay (Figure 29).

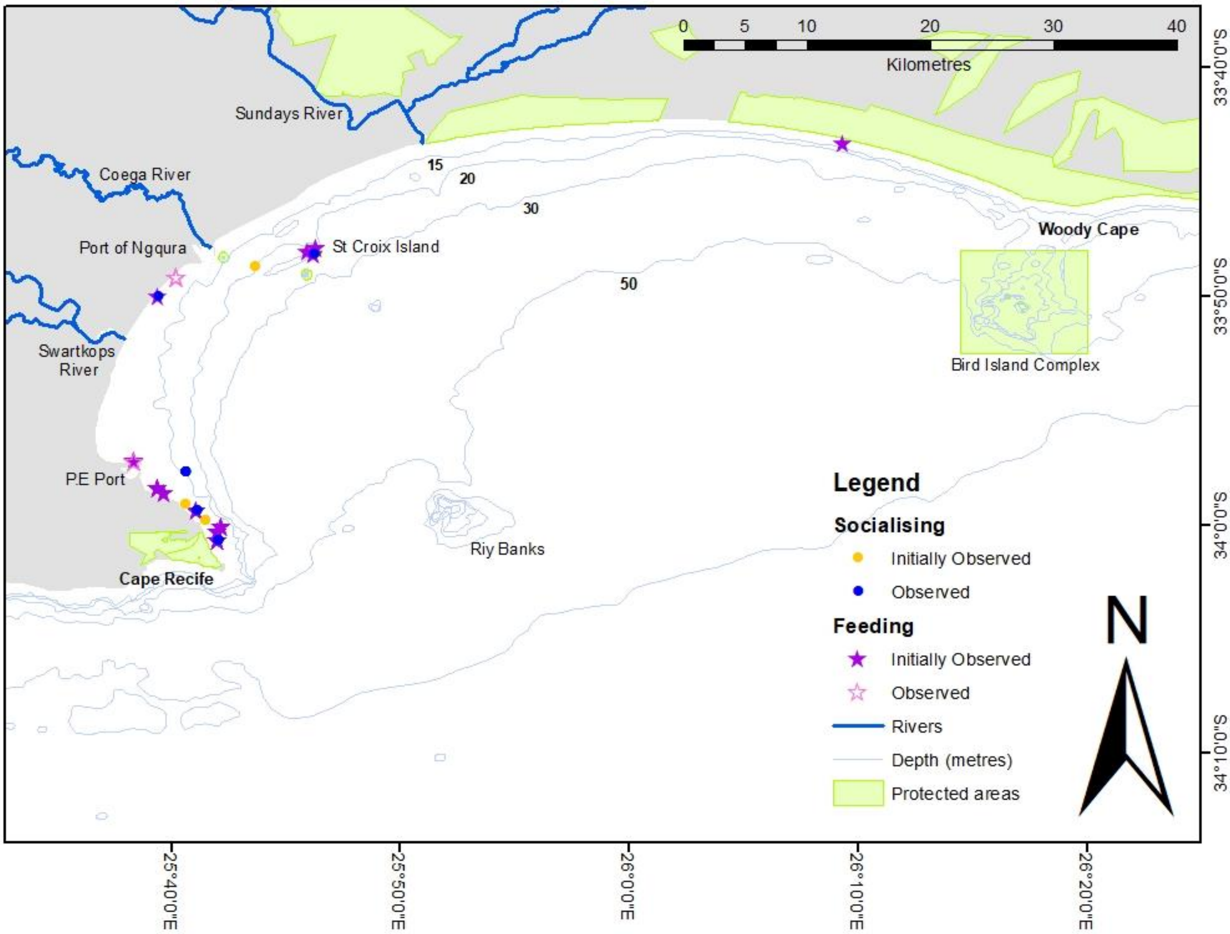


Figure 29. Map showing socialising and feeding distributions of dolphins seen ≥ 3 times.

CHAPTER FOUR

General Discussions

4.1 DATABASE AND PHOTOGRAPHIC-IDENTIFICATION CATALOGUE

Data collection for this study was carried out over the period of three years between June 2008 and May 2011. The photographic data collection during this study was not the primary purpose of the surveys, hence data are referred to as opportunistic. The photo ID catalogue, held in both *ACDSee* and *Finbase* provides a reference point for ecological studies of *T. aduncus* not only for Algoa Bay but for cetacean research in South Africa as a whole. The use of computer programs to manage photo-ID catalogues is convenient for record keeping and for getting specific details and statistics from the catalogue (Markowitz *et al.*, 2003), but developing the catalogue requires patience and carefulness. Developing the catalogue and entering data as soon as data are collected, could improve the efficiency and detail of publishing photo-ID studies.

The discovery curve shows that the 2002 individually identified dolphins are a sub-sample of a larger population in Algoa Bay as it is continuing to slowly rise. The gentle slope seen during 2010 was due to the diminished amount of photo-ID data collection during that period and there are more new animals seen during 2010 than were re-sighted. Photo-ID studies of populations of *Tursiops truncatus* form the Eastern Ionian sea; Greece, Marlborough sound; New Zealand, and Camp Legeune, Northern South Carolina and Southern New Jersey; USA (Bearzi *et al.*, 2005; Merriman *et al.*, 2009; Silva *et al.*, 2011; Toth *et al.*, 2011; Read *et al*., 2012), *Grampus griseus* off Wales (de Boer *et al*., 2013), *Lagenorhynchus albirostris* in Icelandic waters (Bertulli *et al*., 2015), and *Cephalorhynchus heavisidii* of the West coast of South Africa (Elwen *et al.*, 2008) all had discovery curves that did not reach an asymptote, indicating that this is because not all individuals in the population were identified due to continuous immigration into the study area, recruitment of new individuals, and/or that the identified individuals were part of a larger, open population. The discovery curve of the current study is similar to the discovery curve for *T. aduncus,* from Algoa Bay collected between 1991-1994 (Reisinger & Karczmarski, 2010). Individuals in Algoa Bay are potentially part of a larger population, which ranges widely in South African waters (Reisinger & Karczmarski, 2010). The discovery curve is indicative of an area with a high influx of transient animals, which possibly use Algoa Bay as a stopover habitat.

The group size estimation recorded at sea versus the analysis of catalogued animals shows that 20 minutes data collection time was suitable for relatively small groups as exact estimates could be achieved from field estimates and photographs for small pods. However, this time span was not ideal to photograph large dolphin groups, like pods of over 50 individuals. This is evident in the 57 sightings in which the group estimates were larger than the catalogued animals. Despite this, photographs reveal information that could sometimes be misjudged with the naked eye as seen with the 25 cases of group size underestimation (Appendix D). Given that the dataset analysed in this study is opportunistic and the limitations of photo-ID studies (Hammond, 2008; Urian *et al*., 2014), the results herein are likely to be negatively biased.

4.2 SITE FIDELITY

Although dolphins are found and were identified in Algoa Bay all year round, the re-sighting of 8.9% (178) of 2002 identified dolphins further suggest the individuals in Algoa Bay are part of a larger population with a large home range. Previously reported evidence of movement between Algoa Bay and Plettenberg Bay suggests home ranges of over 200km (Ross, 1984). Reisinger & Karczmarski (2010) found similar results, re-sighting 8.3% (131) of 1569 *T. aduncus* in Algoa Bay. This comparison of these statistics gives an indication that the population size between 1991-1994 and 2008-2011 of Algoa bay's *T. aduncus* might not have changed much. Comparison studies are important for monitoring changes in population parameters over time (Koper *et al.,* 2016).

Baird *et al*. (2008) attributed the low site fidelity of *Steno bredanensis* in the Hawaiian Archipelago to their large population size and Bertulli *et al.* (2015) credited the low site fidelity of *L. albirostris* in Icelandic waters to a large home range.

In comparison to the current study, studies of *T. aduncus* in Australian waters mostly resulted in relatively high site fidelity indices as the populations had higher re-sighting rates (Möller *et al.,* 2002; Fury & Harrison, 2008; Brown, 2016). The high re-sighting rate in these studies was due to relatively small populations (Möller *et al.,* 2002) and small home ranges (Fury & Harrison, 2008; Brown *et al.,* 2016). Other factors suggested to influence site fidelity are prey availability (Reeves & Brownell, 2009) and anthropogenic disturbances (Fury & Harrison, 2008).

Although South Africa's *T. aduncus* population appears larger (Reisinger & Karczmarski, 2010; Cockcroft *et al*., 2016) and potentially has a larger home range compared to other populations, its site fidelity is subject to a difference in spatio-temporal prey distribution (Peddemors, 1999 as cited in Natoli *et al.*, 2008; O'Donoghue *et al.,* 2010) and anthropogenic disturbances, such as shark nets (Cockcroft, 1990; Dudley & Cliff, 1993), marine wildlife tourism (O'Connor *et al.*, 2009), and marine traffic (Ports and Ships, 2015). Marine tourism (Raggy Charters, 2013) and marine traffic (Ports and Ships, 2015) are present in Algoa Bay and their influence on site fidelity or other aspects of *T. aduncus* ecology in Algoa Bay have to date not been investigated. Marine traffic can affect cetacean communication and physically harm cetaceans by collision (Dolman *et al.*, 2006; Elwen & Leeney, 2010) and noise pollution (Tyack, 2008; McAdams, 2016).

The low re-sighting rate might present a challenge for researchers trying to examine the movement patterns of the species. However, it is indicative of Indo-Pacific bottlenose dolphins having adapted to living in diverse environments. This is key to their survival as they are versatile enough to colonise different sites to satisfy their biological needs. In contrast, *T. truncatus* in the Western Mediterranean showed strong site fidelity and were vulnerable to boat disturbance, tourism and overfishing as they are dependent on this degraded environment (Gonzalvo *et al*., 2014). Dedicated long-term individual dolphin photo-ID studies are required to improve our understanding of the residency (or lack thereof) of *T. aduncus* in Algoa Bay and the entire distribution range of the South African coast at large.

4.3 Associations

32 individuals out of 2002 animals is a relatively small number to draw strong conclusions from regarding the social and association patterns of dolphins in Algoa Bay, but could be used as a reference point for further research. Association index shows that there are some alliances between individuals in Algoa Bay, and particularly the strong association index' and social network between 23 of 32 individuals sighted three or more times suggests there could be a resident group within the bay. The opportunistic data, however, did not include sexes of individuals, as they could not be determined, and mostly underestimated group sizes because of the large group size. Hence the details of association between individuals could not be fully assessed and the overall association assessments are likely inaccurate (Brager *et al.,* 1994; Chilvers & Corkeron, 2002).

Associations between individuals can be influenced by, but are not limited to kinship, age, sex, prey availability, predation risk, and group size (Wells *et al*., 1980; Wells *et al*., 1987). Bearzi

(1997) found *T. truncatus* in the Northern Adriatic Sea to mostly associate in two social network modes: groups of only adults and groups of adults and calves. In Panama City, Florida (USA), *T. truncatus* have been found to have stronger male-male association compared to female-female, male-female, and all individuals associations (Bouveroux & Mallefet, 2010). Wells *et al*. (1980) stress that an increase in group size in cetaceans is vital for foraging and protection from predation, this was thought to potentially influence association in *T. truncatus* in Florida, USA, too. Kinship was found to foster association between females in *T. aduncus* in south-eastern Australian waters (Möller *et al.*, 2006). Association patterns in Algoa Bay could be influenced by these factors, too. However, more research is needed to get a deeper understanding of the association patterns of *T. aduncus* in Algoa Bay.

4.4 *Xenobalanus*

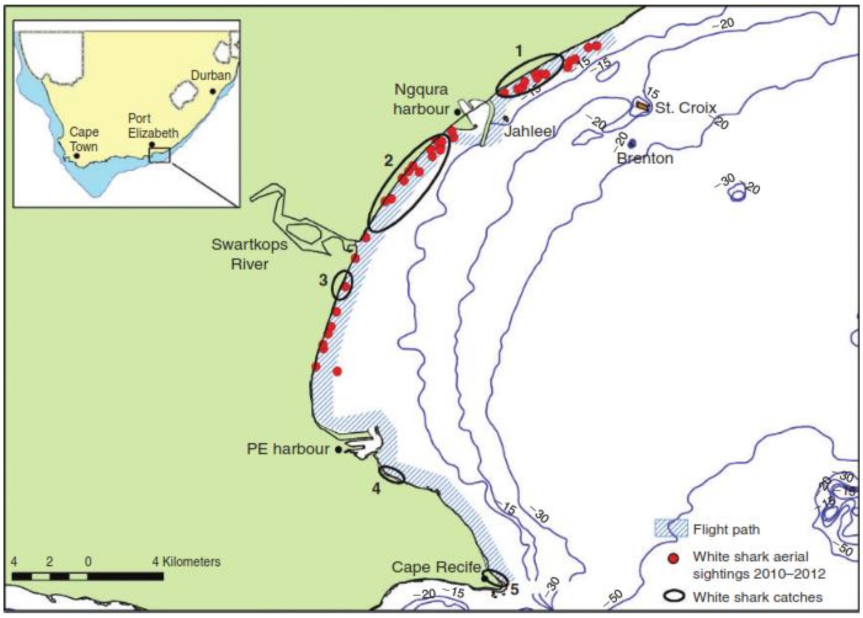
Xenobalanus analyses were carried out with the aim to possibly recommend them as geotags for future studies if there was any inter-annual or inter-seasonal variation in their prevalence in Algoa Bay. Seasonal variations in the presence of *Xenobalanus* could not statistically be detected. This does not, however, mean *Xenobalanus* cannot be used as geotags or do not have a preference for a specific season, as the analysis of *Xenobalanus* presence in this study was not detailed. This project simply looked at the presence of *Xenobalanus* on dorsal fins, and the proportion of dolphins with *Xenobalanus* in the overall group size estimate, but not at specific details, such as the age of the individual, size of *Xenobalanus*, the number of *Xenobalanus* on a specific fin or position of *Xenobalanus* on the fin (Orams & Schuetze, 1998; Bearzi & Patonai, 2012). Further research is needed to improve knowledge on *X. globicipitus,* not only in South African waters but globally as well (Kane *et al.,* 2008). This will improve our knowledge of this cirripeds species and could potentially give additional insight on movement patterns of cetaceans worldwide.

4.5 Spatial distribution

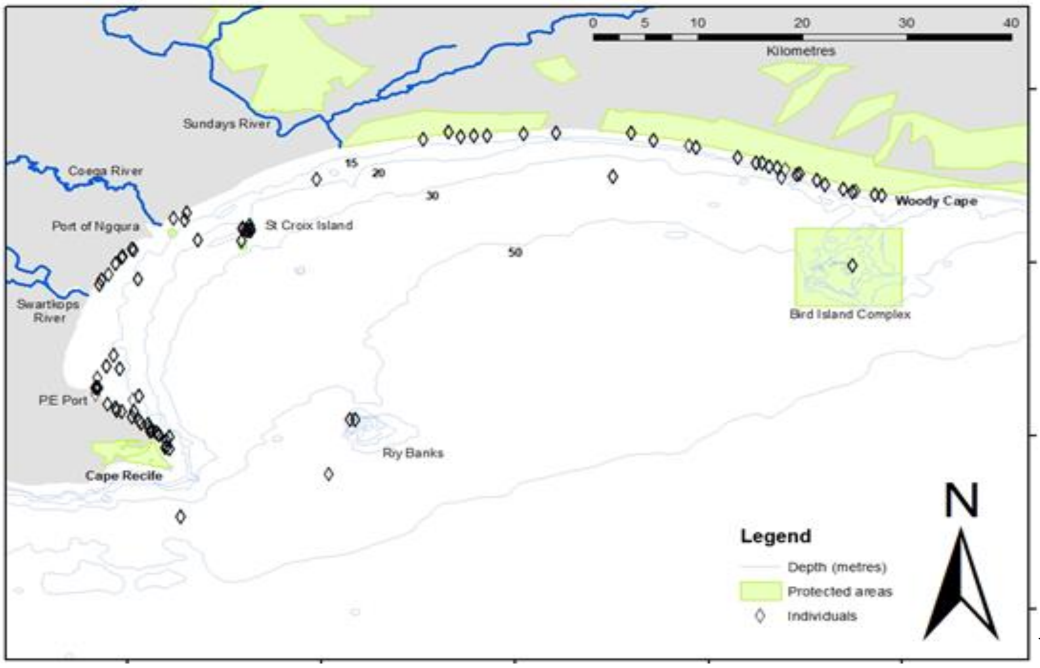
4.5.1 Spatial distribution of sightings

The spatial distribution of *Tursiops aduncus* sightings in Algoa Bay showed a preference for depths of less than 15 metres, which is similar to previous reports by Ross *et al*. (1987) for Algoa Bay. There were also isolated sightings of dolphins around the Bird Islands and Riy Banks. *T. aduncus* in Northern New South Wales, Australia, mostly occurred in depths of less than 12 metres (Fury, 2009), and in estuarine waters off Bunbury, Western Australia, *T. aduncus* typically occurred in depths of 1 to ~ 15m. This further highlight the preference of coastal habitats by Indo-Pacific Bottlenose dolphins.

The spatial distribution of sightings around the Islands and within the 15-metre bathymetry in Algoa Bay could be linked to prey availability and/or predation risk. *T. aduncus* off KwaZulu-Natal have been found to feed on several fish species such as *Etrumeus teres*, *Monodactilus falciformis*, *Pomatomus saltatrix, Trachurus trachurus, Liza dumerilii, and Pomadasys olivaceum* (Kaiser, 2012) These species have been found to inhibit the surf zone in Algoa Bay (Rishworth *et al.*, 2014). Algoa Bay is home to some shark species, such as hammerhead shark (*Sphyrna zygaema*), copper shark (*Carcharhinus brachyurus*), and great white shark (*Carcharodon carcharias*) (Smale, 1993; Dicken & Booth, 2010). Hammerhead and great white sharks potentially predate on dolphins as has been reported for the waters off Kwa-Zulu-Natal and Algoa Bay (Tayler and Saayman, 1972; Cockcroft, Cliff and Ross, 1989). An aerial survey for great white sharks carried out along the Algoa Bay coastline sighted sharks strictly between 4km north of the port of PE and 6km north of the Port of Ngqura (Dicken and Booth, 2010). Comparing the distribution of the shark sightings to those of *T. aduncus* sightings, the shark sightings appear to be in areas of the least dolphin sightings (Figure 32), suggesting dolphins could be avoiding this area due to shark predation risk. Great white sharks aggregate around the Bird Island groups, too (Dicken *et al.*, 2013), where they are known to prey on Jackass penguins (*Spheniscus demersus*) (Randall *et al.*, 1988*)* and Cape fur seals (Stewardson, 1999). *T. aduncus* have only been sighted once around the Bird Islands group during the study period, which also suggests dolphins are avoiding this area due to the high risk of shark predation. *T. aduncus* were mostly seen travelling around this area. Heithaus and Dill (2002) found that the distribution of *T. aduncus* in Shark Bay, Australia, matched the distribution of their prey when tiger sharks (*Galeocerdo cuvier*) were absent, but not so when sharks were present. How prey availability and predation risk influences bottlenose dolphins' distribution around Algoa Bay is not fully understood, and further research of the relationship between the dolphin's distribution and prey availability and predation risk could give more insight on the habitat use of *T. aduncus* in Algoa Bay.



a



b

Figure 30. Distribution of great white sharks *C. carcharias* (a) (Dicken & Booth, 2013) and bottlenose dolphins *T. aduncus* in Algoa Bay (b).

4.5.2 Spatial distribution of behaviours

The dominance of travelling behaviour in Algoa Bay could be due to their biological needs; thermoregulation, predator avoidance and searching for prey and conspecifics can cause dolphins to travel (Shane, 1990). However, dolphins in Algoa Bay likely spend more time travelling because of the unfamiliarity with the habitat. *T. aduncus* with high site fidelity have been found to exhibit feeding behaviour as the most common behaviour in their habitat (Harzen, 1998). The flexibility in feeding behaviour and social nature of free-ranging *T. aduncus* means they often associate travelling with feeding and socialising behaviour (Tayler & Saayman, 1972; Shane, 1990). This could explain why the dominant travelling behaviour is mostly associated with the secondary behaviours of feeding and socialising as well as why dominant feeding behaviour is associated with the secondary behaviours of travelling and socialising in the current study. Behaviours of *Tursiops spp*. have previously been reported to change throughout the diurnal cycle as the tide changes (Saayman *et al.*, 1972; Würsig & Würsig, 1979; Shane *et al.*, 1986). Saayman *et al.* (1972) studied the diurnal cycle of *T. aduncus* in South African waters and found that travelling, feeding and socialising occurred mostly during daylight hours and resting occurred at night. During the current study, resting behaviour was recorded only twice, which might be because *T. aduncus* in Algoa Bay mostly rest at night, and the data were collected only during daylight hours.

Dolphins co-operate and use different foraging strategies, dependent on the habitat type and prey availability (Würsig, 1986; Bel'kovich *et al.,* 1998). *T. truncatus* in the Black Sea were found to cooperatively hunt by often surrounding fish shoals in deep waters, while close to shore they herd their prey against the shore and catch the fish as these try to escape (Bel'kovich *et al.,* 1998). Feeding behaviour around St. Croix Island and off Riy Banks, suggests that dolphins might be using islands and rocks to herd and corner prey. Tayler & Saayman, (1972) reported *T. aduncus* herding fish against the shoreline in Plettenberg Bay. *T. aduncus* in Algoa Bay may potentially use the same feeding strategy, thus explaining the spatial distribution of feeding behaviour in the surf zone. Resting and fast travel behaviour were seldom seen in the bay. Milling behaviour had a clear spatial distribution pattern, being regularly reported along the West coast and off Woody Cape, which suggests a preference of these areas for milling. Further research is needed to fully understand how dolphin behaviours exhibited in Algoa Bay are related to the biotic and abiotic factors in Algoa Bay.

4.6 Conclusions

A photo-ID catalogue was created consisting of 2002 individuals, 985 entries were of the animals left side, 732 were on the right side, and 285 entries were of both left and right side. The catalogue is hosted in *Finbase* and *ACDSee v10.* Only 8.9 % (178) of the individuals were re-sighted, indicating low site fidelity in Algoa Bay. The discovery curve does not reach an asymptote, suggesting *T. aduncus* in Algoa Bay are part of a larger population. Indo-Pacific Bottlenose dolphins were mostly sighted at depths of <15 metres. They seem to avoid the area between North of the Port of PE and North of the Port of Ngqura, possibly to avoid predation by sharks. *T. aduncus* bottlenose dolphins appear to carry out most of their daily behaviours within the <15-metre coastal zone, but do not seem to have a specific area preference for specific behaviours within the 15-metre bathymetry. The project adds to the literature about Indo-Pacific bottlenose dolphins and provides information that can be used for further research and conservation management of the species. Photographs used in this project were opportunistically collected, which did not allow for an alternative sampling design which resulted in a smaller number of photo-identified individuals than would be the case if more time would have been dedicated. Subsequently, this had an effect on the site fidelity and association index figures within this project.

4.7 Recommendations and limitations

While photo-ID provides a relatively inexpensive method of investigating cetacean population parameters, it alone cannot fully address all research questions. Particularly when the population under investigation is large. Large dolphin populations, possibly like the ones along South Africa's coastline, requires long-term monitoring across different research methods and platforms, such stable isotope analysis to reveal information on the feeding habits and ecology, genetics to reveal information about the species and life history, and acoustics to expose the social and hierarchical structure. The result of this project and previous research have suggested that Indo-Pacific dolphins in Algoa Bay are part of a larger population or subpopulation of South Africa. This calls for collaborative research: collecting data, sharing and comparing datasets from different study sites (i.e. False Bay, Plettenberg Bay, Algoa Bay, The Wild Coast and KwaZulu-Natal) along the South African coastline. Collaborative research would go a long way towards exposing *T. aduncus* population parameters, such as the number of subpopulations, populations size, population structure and home ranges. A comparison of photo-ID catalogues between habitats off South Africa could potentially result in an asymptotic discovery curve. Simultaneous photo-ID surveys among *T. aduncus* hotspots in South Africa could result in more explicit information on home ranges and site fidelity of Indo- Pacific bottlenose dolphins.

This current project used opportunistic data from a multi-cetacean study, which is a cost-effective research method that produced some useful findings, but it also highlights some of the of the challenges of photo-ID research. Over 80% of the catalogued pictures were of good quality (Quality 2 rating), this shows the difficulty of trying to take pictures of individual moving dolphin that often occur in large groups from a floating 6-metre rubber duck, this requires good technical skills of the camera as well as an understanding and ability to anticipate the animals' movement. This coupled with the opportunistic nature of which these pictures where collected has limited the number of pictures taken, consequently this negatively affected the number of excellent quality images (Quality 1 rating) and thus the results are an underestimation of *T. aduncus* statistics in Algoa Bay. The long-term monitoring of *T. aduncus* in Algoa Bay or anywhere else should be ideally done with a dedicated study and a research design suitable to satisfactorily assess the population parameters over a given period.

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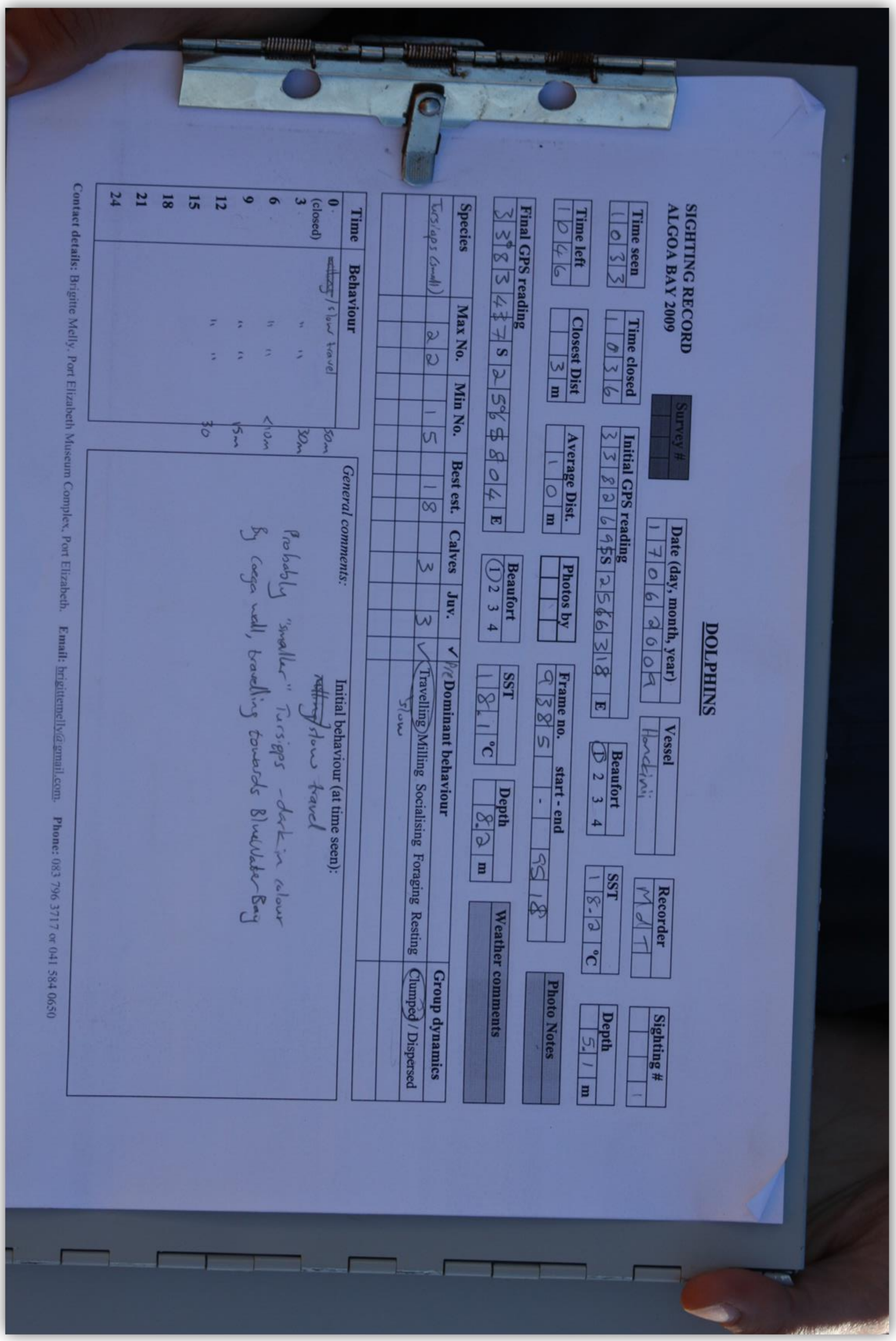
APPENDIX A: Data collection form



APPENDIX B: Distinctiveness categories - amount of detail on the fin

Distinctiveness 1

Distinctiveness 2

Distinctiveness 3

APPENDIX C: Photo quality categories

Excellent quality 1(Q1)

Average quality 2 (Q2)

Poor quality 2 (Q3)

APPENDIX D: Raw data of group size estimates, total identifications and total new identifications per survey day.

Survey date	Group estimate	Total identifications	Total new identifications
29/07/2008	29	47	47
23/10/2008	88	34	33
31/10/2008	70	38	38
17/11/2008	30	16	14
15/01/2009	6	6	6
05/02/2009	5	5	5
26/03/2009	12	24	24
02/04/2009	65	114	101
03/04/2009	25	79	74
04/04/2009	19	16	16
23/04/2009	76	92	87
24/04/2009	208	134	125
27/04/2009	140	175	166
04/05/2009	9	15	16
17/06/2009	18	40	35
18/06/2009	70	2	2
10/07/2009	80	95	82
11/08/2009	140	58	46
17/08/2009	44	81	65
24/09/2009	30	27	24
26/09/2009	360	46	27
30/09/2009	158	97	91
03/10/2009	520	387	303
06/10/2009	50	4	3
07/10/2009	463	149	88
07/11/2009	45	54	47
11/11/2009	135	23	22
25/01/2010	518	111	89
06/03/2010	275	9	9
07/03/2010	12	16	11
07/04/2010	14	9	5
14/04/2010	58	108	95
25/05/2010	100	3	3
27/05/2010	120	20	20
02/06/2010	45	20	19
03/06/2010	800	23	21
05/07/2010	118	19	13
05/11/2010	12	5	3
09/12/2010	90	23	23
10/12/2010	3	3	2
15/01/2011	130	13	11
03/05/2011	141	45	42
12/05/2011	105	52	49