

**ECOLOGY AND CONSERVATION OF THE BOTTLENOSE DOLPHIN**  
***TURSIOPS TRUNCATUS* IN JERVIS BAY, NSW**

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The work contained in this thesis has not been submitted for examination at any other institution and, except where acknowledged, is the result of my own investigations.

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To my mother Daphne, without whose encouragement and friendship this dream  
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To my son Isaac, who ventured to sea with me to find dolphins before he was born.

I hope the diversity of the natural world will be allowed to remain, so that its  
offerings of inspiration and comfort will be accessible to you also.

## ABSTRACT

*Tursiops truncatus* were observed from a small boat throughout Jervis Bay (120 sq. km) on the south coast of New South Wales (NSW). This main study within the Bay involved 98 survey days between January 1990 and June 1993. In addition, three Regional Surveys were conducted for three consecutive days each, simultaneously in the Bay and along the coast immediately north and south of the Bay.

In total 151 sighting events were recorded in Jervis Bay, on 107 days involving approximately 709 hours and travelling 6,626 km searching for dolphins. *Tursiops* were sighted on 71% of all survey days in the Bay. These included: 49 on the Search and Encounter Survey; 26 from the transect line on the Transect Survey; 54 in transit between sampled transects on the Transect Survey; and 22 on the Regional Survey.

In the Bay two survey methods were used. The first method involved recording opportunistic sightings around the periphery of the Bay, referred to as the Search and Encounter Survey. The second was a line-transect survey designed to quantitatively investigate if dolphins were distributed equally across the major habitats of the Bay. Sightings from the latter survey were divided into three subsets for the purpose of analyses. These were: sightings made from the transect line; initial sightings made at transect sites when these were not being sampled; and all sightings made in transit between sampled transect sites. Habitat was defined for the purpose of this study by depth and substratum, i.e. over seagrass, sand or rocky complex areas.

Based on these two different types of surveys the estimated dolphin density in the Bay was 0.12 and 0.13 per sq. km with no clear seasonal peak in density. Both surveys indicated a significant difference in the number of sightings across different habitats when the area of each was considered. Dolphins were sighted more frequently in shallow waters ( $\leq 10$  m) and over the rarer substrata of seagrass

and rocky complex areas. In waters < 10 m in depth animals were more abundant over seagrass than sand but the density of *Tursiops* was greatest in rocky areas.

Four ancillary sources recording over 700 sightings of bottlenose dolphins in Jervis Bay were also investigated; and four major faunal studies within the Bay were reviewed in terms of the distribution and abundance of potential prey items of this species. Across my Surveys and all ancillary data sets, where information was available, a number of general trends in the distribution of dolphin sightings were apparent, such as dolphins being present in the Bay throughout the year and their distribution varying significantly and consistently across different areas of the Bay.

Seventy-six individual dolphins were identified by photographs of their dorsal fins, 69 from inside the Bay. Because of the opportunistic nature of photographic sampling effort, this is seen as a bare minimum estimate of the number of animals that utilised the Bay during the study period. Of these 69 individuals, 19 (27%) were sighted only once, while 50 (73%) were resighted two or more times. The number of days on which an individual dolphin was sighted varied from 1-15. The possible residency status of individuals was investigated in terms of : the number of days an individual was sighted; the resighting opportunity ratio; the interval between first and last sighting; the average number of days between sightings; the number of years sighted; sightings on consecutive photographic surveys and the average number of days between consecutive survey sightings. These data suggest that the duration of time spent in and out of the Bay is highly variable between identified individuals.

In the concluding chapter, the results of this study are considered in terms of two proposed management strategies for the study area. My recommendations relate to increased protection and representation of habitats where high numbers of *Tursiops* sightings occur. The value of local area population studies and local habitat conservation measures are discussed as a general conservation strategy for coastal bottlenose dolphins, particularly in NSW.



## CHAPTER 1: INTRODUCTION

### 1.1 Rationale

Bottlenose dolphins are possibly the most abundant cetacean in Australian coastal waters yet their population abundances, distribution and stock discreteness are unknown. Although the taxonomic status of the genus *Tursiops* remains unresolved, it is generally considered there is one species worldwide (Hersh & Duffield, 1990; Ross & Cockcroft, 1990). Ross & Cockcroft (1990) examined specimens of *Tursiops* from eleven institutions around Australia which suggested the genus is distributed continuously around the continent and represents a single species, *Tursiops truncatus*. Although, Hale (1996 pers. comm., 18 January) has informed me that recent genetic studies on the genus from the Indian and Western Pacific Oceans suggest the possibility that *truncatus* and *aduncus* forms of *Tursiops* are in fact distinct species and that my studies may relate to *Tursiops aduncus*. However, at this point in time, this study and its conclusions on habitat use by bottlenose dolphins in Jervis Bay, NSW are assumed to relate to the “inshore”, coastal ecotype of *Tursiops truncatus*.

Prior to this study only two populations had been studied in detail in Australia. These are located at Shark Bay in Western Australia (Connor & Smolker, 1985; Smolker *et al.*, 1992) and Moreton Bay in Queensland (Lear & Bryden, 1980; Corkeron, 1989 & 1990). Other than opportunistic data collection on stranded *Tursiops truncatus* (Llewellyn *et al.*, 1994), no research had been conducted on this species along the southeastern coast of Australia, until recently when, in 1994, investigations into genetic variation along the east coast of the continent were initiated (Hale, 1996 pers. comm.).

This study attempts to quantitatively assess the distribution of sightings of a “population” of bottlenose dolphins, on a relatively small geographical scale, in terms of a range of group composition, habitat, environmental and behavioural variables. Population for the purpose of this research refers to those dolphins that

inhabited the study area at any time during this study (Shane, 1987). Like Shane (1987), I presumed that dolphins sighted in the study area were members of a single breeding unit, but I do not suggest I sampled the entire breeding stock.

Local area studies such as this offer invaluable opportunities for gaining much needed data on this species' use of specific coastal habitats and hence possible habitat requirements. Also, the application of these data by management agencies responsible for these habitats and their associated resources may assist in the conservation of inshore *Tursiops* populations. Habitat studies focused on local areas are important for five primary reasons:

- 1) the modest time and resources needed to obtain relevant overall population assessment data relative to larger geographic scales;
- 2) the ongoing alteration and/or degradation of the coastal environment, particularly in the nearshore habitats which inshore ecotypes of this species appear to utilise;
- 3) gaining an understanding of this species' "habitat requirements" is probably most realistic and functional at the local scale given that ecological processes which operate in any particular habitat and impact upon their associated resources may vary greatly, both temporally and spatially at a range of scales;
- 4) as inshore waters and resources are in most, if not all, countries of the world, likely to be within the jurisdiction of national and/or regional government agencies; and
- 5) it is at the local level where practical habitat protection strategies can be implemented.

If the protection of marine habitats and resources is to be an effective conservation tool for bottlenose dolphin populations, there are for example, two important aspects to consider. Firstly, the biophysical processes supporting these habitats and resources. Secondly, the ecological requirements of the bottlenose dolphin population as a component of the ecosystem, need to be understood. The best documented resource requirement of this species to date is its prey items. Much of this information is based on indirect behavioural observations, opportunistic data

from strandings and/or incidental kills (see Section 1.2.3). Consequently these data were not always readily available for, nor applicable to, populations outside a specific study area, especially for a species utilising a range of habitats worldwide. Hence one approach, presented in this study, may be to ascertain if preferential use of habitats occurs in local areas and if so, to investigate the importance of and possible explanations for, such patterns. Some insights into habitat requirements for this species, at least the coastal ecotype, may thus be highlighted. Also, if necessary, consideration may be given to the need for particular habitat and resource conservation in the study area.

## **1.2 Literature Review**

### **1.2.1 Overview of Research**

Bottlenose dolphins have been held and studied in captivity since at least 1914 (Townsend, 1914), consequently the volume of literature on them is large. Much of the early work was concerned primarily with reproduction and behaviour of captives (McBride & Hebb, 1948; McBride & Kritzler, 1951; Tavalga & Essapian, 1957; Essapian, 1963). Parallel with advances in scientific technology, the depth and extent of captive research has also developed. Some of these research directions have included brain morphology and physiology, psychophysics and other sensory mechanisms, and cognitive studies which are represented in volumes edited by Herman (1980), Schusterman *et al.* (1986), and Pryor and Norris (1991).

While observations of free-ranging dolphins have probably been made since people first watched and went to sea, early scientific reports were essentially opportunistic (Gunter, 1942; Caldwell, 1955; Brown & Norris, 1956; Caldwell & Fields, 1959). The literature largely remained that way from 1940 for the next three decades. In the early 1970s a number of studies were commenced on the east coast of the United States, South America and South Africa, to specifically investigate wild dolphins. For example, Irvine & Wells (1972) reported on the movements of tagged animals; Saayman *et al.* (1973) on diurnal activity cycles;

Odell (1975) conducted aerial censuses in Florida waters; and Würsig & Würsig (1977) wrote on the use of photographic techniques for determining social composition. It was from some of these early initiatives that long-term studies of animals in specific local areas began.

Würsig & Würsig (1979) reported a 21 month study focused on aspects of the ecology and behaviour of dolphins, observed and photographed from a cliff in an Argentine bay. Wells (1978) reported on association patterns of known individuals from Sarasota Bay, Florida with this community remaining a focus of research to date (e.g. Irvine *et al.*, 1981; Wells, 1986; Wells *et al.*, 1987; Scott *et al.*, 1990a). Other studies based on local area populations, on the east and west coasts of North America, with field observations ranging from 11-17 months include Shane (1977, 1987), Gruber (1981) and Hansen (1983). A review paper by Shane *et al.* (1986) summarised much of the findings from these and other studies. Examples of more recent projects conducted include Ballance (1987) and Bräger *et al.* (1994) in the USA and Williams *et al.* (1993) in New Zealand.

Concurrent with advancements in our understanding of the social organisation and behaviour of *Tursiops* was the development of boat and aerial survey design and procedures, focussing on estimating the abundance and densities of this and other cetaceans (Eberhardt, 1978; Leatherwood & Show, 1980; Smith, 1981; Burnham & Anderson, 1984; Hammond, 1986; Holt & Cologne, 1987). Another interesting area of research in recent years has been the potential for the study of hematological parameters and molecular genetic material (Duffield *et al.*, 1983; Duffield & Chamberlin-Lea, 1990; Duffield & Wells, 1991; Hoezel, 1992) to assist in the differentiation of populations and establishing paternity in known social groups. In the volume edited by Leatherwood & Reeves (1990) the variety of questions and approaches being pursued in current research initiatives on this species was well represented.

The following sections are reviews of topics particularly relevant to my research and focus on field work conducted in the southern hemisphere, where data are available.

## **1.2.2 Environmental influences on:**

### **1.2.2.1 Distribution**

A number of studies on different cetaceans have noted and attempted to quantitatively assess relationships between abundance and distribution, and factors such as topography (Evans, 1975; Hui, 1979, 1985), surface temperature (Gaskin, 1968; Selzer & Payne, 1988), other oceanographic features (Au & Perryman, 1985; Reilly, 1990) and physical features which concentrate prey (Watts & Gaskin, 1985). However, only a few studies on *Tursiops* have attempted to quantitatively analyse the environmental character of their distribution pattern at a local or larger scale.

Kenney & Winn (1986) investigated the distributional biology of the cetacean fauna of the northeast United States continental shelf. Kenney (1990) reported on geographically separate inshore (<20 fathoms) and offshore (>20 fathoms) stocks of *Tursiops* and provided evidence for seasonal migration parallel to isobaths, not inshore/offshore, with no significant seasonal variation in depth distribution. Kenney (1990) also found temperature-limited distributions, with inshore stocks found in relatively warmer waters than offshore stocks, with a distinct northern boundary; and depth-related habitat partitioning, with inshore stocks exploiting the extreme near-shore habitat. Kenney (1990) noted the data set was extensive in temporal and spatial coverage and as such represents long-term average patterns of distribution. Kenney (1990) speculated that "...the density of animals within any specific zone would be a reflection of overall habitat suitability, primarily prey availability but also including temperature regime, presence of intra- and interspecific competitors, etc....".

Scott & Chivers (1990) also looked at the larger scale and found bottlenose dolphins to be distributed widely in the eastern tropical Pacific Ocean. They were not confined to the oceanographic features which appear to define the ranges for four other dolphin species described by Au & Perryman (1985) and Reilly (1990) (e.g. water mass characteristics and thermocline depths) but rather included the collective ranges of two of the other species.

Wells *et al.* (1990) reported a 670 km migration of 5-12% of a population, previously only recorded from southern California, north beyond the previous extreme of the species' range. The initial northward movement coincided with an El Niño warm-water incursion. The authors suggested that dolphins may take advantage of such warm-water events to explore new regions and this could explain the occurrence of specimens well north of the animals' present range.

At a smaller scale along inshore waters only, Lear & Bryden (1980) investigated the possibility of preferred areas of use by bottlenose dolphins off eastern Australia. This aerial survey, of some 218 km, divided Moreton Bay and adjacent coastal waters into three general habitat classes. The greatest number of animals sighted were in ocean beach areas, less in rocky shore areas and least in bay shore areas. However when densities were calculated for the different habitat classes within one kilometre of the shore, the mean values showed that the density of dolphins was greatest in rocky shore areas, less in ocean beach areas and least in bay shore areas.

An example of a local area study concerned with environmental influences was Ballance's (1992) work on animals in the Gulf of California and her comparison of their habitat usage patterns with animals studied on the west coast of Florida. Specifically she assessed the distribution and behaviour patterns of *Tursiops* for two habitat types, estuarine and non-estuarine. Waters within three nautical miles (5.5 km) of an estuary were considered estuarine and waters farther away than this non-estuarine. The results indicated more sightings in waters close to estuaries with the majority of sightings involved in feeding activities. Ballance referred to a

number of studies which indicated estuaries were sites of high occurrence of bottlenose dolphins (e.g. Gunter, 1942; Gruber, 1981; Mead & Potter, 1990).

#### **1.2.2.2 Movement and Home Range**

Mead (1975) described seasonal changes in these animals' range and Norris & Dohl (1980) suggested that seasonal movements are related to prey movements. Leatherwood & Reeves (1982) suggested long-distance seasonal migration is primarily undertaken by offshore bottlenose dolphins but long-distance movements have been reported for inshore forms as well (Würsig & Würsig, 1979; Hansen, 1990; Wells *et al.*, 1990). Hansen (1990) noted that the northern and southern boundaries of the normal range of a coastal population off southern California were marked by distinct topographical features, the use of which as navigation and boundary markers, has also been suggested by Würsig & Würsig (1979) and Shane *et al.* (1986). However, Hansen (1990) considered water temperature to be probably more influential than topography in determining the home range of this population, with the areas at each end tending to be cooler. Shane *et al.* (1986) noted that *Tursiops* movement patterns vary from year-round residency in a well defined area to seasonal migrations. Wells *et al.* (1990) suggested that these different patterns may be related to water temperature, with populations living in warmer waters tending toward residency and those inhabiting colder waters exhibiting migratory movements. Wells *et al.* (1990) also reported the northward movement of dolphins from southern to central California which coincided with an El Niño warm-water incursion, but noted that these animals may have been responding more to secondary effects of this event, such as changes in the distribution of prey.

Saayman *et al.* (1973) reported movement into Plettenburg Bay, South Africa of "large schools" frequently numbering 100-500 individuals, in the early morning and late afternoon which was associated with peaks in feeding activity. These authors also suggested that use of at least a semi-permanent home range was a feature of the social organisation of the dolphins studied.

Lear & Bryden (1980) suggested dolphins sought shelter near shore to avoid rough water offshore during storms and that some movement was probably related to the influence of tidal state on their prey.

Numerous studies have applied the definition of home range that is the area over which an animal normally travels during its routine activities (Burt, 1943), to *Tursiops* movement and activity patterns (Caldwell, 1955; Shane & Schmidly, 1978; Wells *et al.*, 1980; Gruber, 1981; Weigle, 1990). Wells *et al.* (1980) found the use of particular regions within the home range of the “herd” (the largest population unit within their study area) varied seasonally.

Shane *et al.* (1986) suggested home range size may be a function of dolphin density which may indicate variable habitat quality. This review noted that the influences of food resources, habitat and environmental variables on the seasonal and daily movements of *Tursiops*, were characterised by variability between localities.

Ballance (1992) concluded that the degree of site fidelity may be related to habitat differences. She suggested that the large estuarine systems of the west coast of Florida, for example, may support permanent prey resources which allow for “resident” populations of dolphins, while the smaller estuaries of the Gulf of California provide only temporary, more ephemeral prey resources, prompting dolphins to range between these areas in search of food.

#### **1.2.2.3 Social Structure**

Aspects of social structure which have been described for *Tursiops* include group size and composition, spatial patterns of groups and individual patterns of association. The former is probably the best documented, being the most readily observable. Some early studies (e.g. Shane, 1977 and Odell, 1976 cited in Wells *et al.*, 1980) found that groups were generally larger in open waters than in constrained, complex areas such as channels and passes or shallow, coastal

marshlands. Sub-group size and the stability of group composition was suggested by Würsig (1978) to be primarily determined by food availability.

Wells *et al.* (1980) found in the Sarasota area, off Florida, that mean group size consisted of four to five animals, but occasionally groups of approximately 40 were sighted. Group size was significantly affected by time of day but not tidal state. Group size varied across the six physiographic regions described in their study area with significantly larger groups found in the passes (in contrast to earlier studies) and offshore Gulf waters. The authors summarised information on group size and concluded that group size is related to such factors as season and physical characteristics of the habitat. Norris & Dohl (1980) suggested that group size may be related to predation pressure such that in riverine habitats, where few predators are found, groups are smaller but in coastal and pelagic environments, where more predation pressure might be expected, groups need to be larger. Shane *et al.* (1986) concluded group size depends on both habitat and activity.

In the pelagic waters of the eastern tropical Pacific, Scott & Chivers (1990) found, in contrast to the hypothesis that group size increases from inshore to offshore habitats, that the median herd size (10) is within the range typical of coastal populations, although the mean herd size (57) is considerably larger. They concluded that, in these pelagic waters, small herds are still the norm but it is the occasional occurrence of very large herds that distinguishes the pelagic form from the coastal populations, i.e. herd size is more variable in the pelagic environment. When considering the previously identified influences of predation pressure and the rich but patchy nature of prey resources, these authors suggested that: (a) pelagic populations face no greater, or perhaps less, predation pressure than do coastal populations; and (b) data for some known prey items suggest that these do not always school but instead display wide variation in their schooling behaviour, similar to variations in herd size of bottlenose dolphins.

A number of studies have recorded group composition, in terms of the presence or absence of known individuals and discussed individual patterns of association (e.g.

Würsig & Würsig, 1977; Shane, 1977; Gruber, 1981; Hansen, 1983; Ballance, 1990; Bräger *et al.*, 1994). Some studies have identified age and sex classes (e.g. Corkeron, 1989; Wells *et al.*, 1980; Smolker *et al.*, 1992).

Ballance (1990) in comparing studies from Sarasota, Florida (Wells *et al.*, 1980; Wells, 1986), Golfo San José, Argentina (Würsig, 1978; Würsig & Würsig, 1979) and her own work in Kino Bay, Gulf of California, noted that group composition across all three systems "... can be described as dynamic, with individuals changing groups and sizes varying daily..." but that there were also stable "subgroups" at each location "...who remain together over long periods...[and] resident individuals who are not members of such stable subgroups but who associated with many different subgroups over time in a fluid manner...". In summary Ballance (1990) suggested that "...the number of dolphins in a particular area, the average group size, and the residence patterns ...with respect to a particular site appear to be flexible parameters that vary across several geographic locations...[but] group membership and stability appear to be somewhat less flexible...".

It may be that this generalised pattern noted by Ballance reflects the hypothesis relating to mating systems of bottlenose dolphins proposed in Wells *et al.* (1980) and Wells (1986) and supported by genetic analyses (Duffield & Wells, 1991). That is, in three areas including Sarasota, "...there is local 'population', 'sub-population' or 'group' differentiation in terms of genotype frequencies, as well as evidence that these groups are not reproductively isolated from each other. To explain the apparent contradiction...the hypothesis is that the genetic distinction of a community is due to a social system built around related female kinship groups which are maintained over several generations, while genetic exchange is accomplished by the movements of males, and occasionally females, into and out of the female band core areas..." (Duffield & Wells, 1991). Dowling & Brown (1993) found from investigations of mitochondrial DNA that considerable genetic isolation exists between Gulf of Mexico and Atlantic Coast bottlenose dolphins and regional differentiation was apparent along the Atlantic Coast. However, in

contrast to the above study considerable gene exchange was indicated among Gulf of Mexico populations.

Smolker *et al.* (1992) suggested that habitat differences (e.g. open versus topographically complex) may exert different pressures on social relationships and result in widely different social organisations.

#### 1.2.2.4 Behaviour

Shane (1987) proposed that “...the key characteristic permitting *Tursiops* to thrive in...diverse habitats is the animal’s[sic] behavioral flexibility...”. Shane (1987) cited Roughgarden (1972) and Partridge (1978) stating that behavioral flexibility is selected for in animals inhabiting unpredictable and variable environments; and that they should occupy a broad ecological niche. Shane (1987) noted the variability of the coastal areas inhabited by *Tursiops* and used the variety of reported prey items of this species (Leatherwood & Reeves, 1982) as another indicator of its wide niche. Shane *et al.* (1986) noted *Tursiops* as being a large-brained social mammal which, as recorded by other authors, exhibits an extended period of parental care (e.g. McBride & Kritzler, 1951; Essapian, 1963; Wells, 1986; Cockcroft & Ross, 1990c). Shane (1987) suggested such factors were prerequisites for an “open genetic program” (citing Mayer, 1974) which allows an animal to learn about the variable environment it inhabits and, in turn, leads to a wide niche.

Shane (1990a) indicated that “...the behavior of bottlenose dolphins...is closely tied to local ecology, and behavior patterns change according to ecological factors such as prey distribution and tidal regime...”. Shane (1990a) reported on the association between a range of environmental variables on five different dolphin activities and found that dolphins discriminated between ecologically different patches in their habitat and used these patches in various ways. For example, dolphins spent far more time travelling and less time feeding in the Gulf of Mexico than in “bay” waters, i.e. waters between Sanibel Island and the Florida coast. Shane (1990a) suggested that the diversity of habitats in the bay resulted in higher

fish densities than in the ecologically less diverse Gulf which was mostly used as a transit area. On the basis of her study Shane (1990a) concluded that "...a complex array of temporal, environmental and social factors is associated with the activity patterns of dolphins... and no single factor is very useful in explaining it...".

### 1.2.3 Food Resources

Several authors have described the diet of *Tursiops*; one of the earliest was Gunter (1942) who reported on 28 specimens taken from the Gulf of Mexico off the Texas coast. He listed 12 species of fish and one shrimp, 83% of fish were identified as *Mugil cephalus* (striped mullet), one of the four most abundant species on the Gulf coast. Even though just two species represented almost 91% of the fish present (the second most abundant being gizzard shad, *Dorosoma cepedianum*), it was concluded that the "...taste of the bottlenose dolphin is catholic so far as fishes are concerned...". Tomilin (1957, cited in Cockcroft & Ross, 1990b) "...described bottlenose dolphins from the Black Sea as benthic feeders, only feeding on schooling fish when they formed dense aggregations...". These two general perspectives of this species as "opportunistic" and "benthic" feeders dominated the literature until recently (Mitchell, 1975; Evans, 1980). More recent studies suggest that preferences are exhibited by this species in local areas, involving various combinations of benthic, demersal and pelagic fish, cephalopods and, in some areas, crustaceans.

Cockcroft and Ross (1990b) examined 165 *Tursiops* stomachs, from animals caught in shark nets between 1975 and 1986, along the Natal coast of South Africa. More than 72 species of prey were found, supporting the usual interpretation that these dolphins are opportunistic feeders. However these authors concluded that, as only six species contributed approximately 60% by mass of all prey taken, it seems inappropriate to consider this species an opportunistic predator. Four of these six species were fish and the other two cephalopods. Two fish species were described as benthic, inhabiting inshore reef and sandy-bottom areas (*Pomadasys olivaceum* and *Pagellus belloti*, respectively) and the other two were pelagic shoaling fish,

occurring in inshore waters in this area, particularly as juveniles (*Trachurus delagooae* and *Scomber japonicus*). The two cephalopods *Loligo* sp. and *Sepia officinalis* were described as common in the Natal inshore environment. Cockcroft and Ross (1990b) noted that "...though there is some indication of annual, seasonal and geographical variation in the proportions of the six major prey species, their continued importance throughout this study, for all age and sex classes, is particularly significant...". Furthermore, Cockcroft and Ross (1990b) found that "...the mean prey length for each of five length, sex and maturity classes showed a significant increase with predator size...". The mean lengths of prey found in calves was significantly less and they contained significantly fewer species than in all other groups. These authors suggested that subgroups within schools, having different prey preferences, are likely to employ different feeding strategies.

Another quantitative study of the diet of this species was conducted by Barros and Odell (1990), who analysed the stomach contents from 76 individuals stranded between 1973 and 1987 from the southeastern United States. They found that most of the fish species were bottom dwellers but surface dwellers and pelagic fish were also represented. It was noted that many fish species were estuarine-dependent, including most sciaenids (found in 60.5% of stomachs and representing 78.4% of all identified fish), and that the primary squid species, *Lolliguncula brevis*, is associated with estuaries throughout its distribution. A geographical variation in dominant prey species was found and this reflected latitudinal changes in fish fauna, which suggested to the authors that diet changes according to local food availability. Unlike Cockcroft and Ross (1990b), no clear differences in prey species were detected between males and females but similar to their study no clear seasonal preferences could be seen.

From the stomach contents of four animals stranded or accidentally drowned, Lear & Bryden (1980) reported that Queensland dolphins feed on benthic and pelagic fishes and also cephalopods. After observing *Tursiops* feed behind trawlers in Moreton Bay, Queensland, Corkeron (1990) concluded that, although opportunistic, they display distinct food preferences. Corkeron (1990) concluded

that social factors associated with the interaction of different sex and age classes may affect access to food and consequently the composition of diet.

Shapunov (1971) determined captive Black Sea dolphins consume on average 5.6 kg of fish per 100 kg when the energy value of the food, assimilation and energy expenditure were considered. Mitchell (1974) stated daily food consumption of captive bottlenose dolphins is 6-7 kg. However, based on Sergeant's (1969, cited in Leatherwood & Reeves, 1982) estimated daily requirement of 4-6% of body mass, a large adult in the wild may eat up to 16.5 kg daily. Cockcroft & Ross (1990c) in their study of the early development of a captive calf reported the requirements of a lactating female was "...8.3% of her body mass daily compared to 5.2% subsequent to birth and lactation. The additional energy required for lactation was contained in 5 kg of fish per day...". These authors (1990b) considered that "...the daily requirement of mature males is probably similar to that of nonlactating females and comparable to the 4.2% given for captives by Sergeant (1969)...". Cheal & Gales (1992) in a study of captive Indian Ocean animals found food intake ranged between approximately 5.2-6.3% of body mass and increased significantly with decreasing water temperature. These authors noted that "...water temperature is not the only influence on an animal's food intake. During periods of peak sexual activity dolphins may become inappetent....sexual activity was often noted at the beginning of spring and mid-summer, coincident with times of low food intake...". Calorific content may also vary seasonally influencing the mass of food consumed (Cheal & Gales, 1992).

#### **1.2.4 Seasonality of calving and estimated proportion of calves in the "population"**

Seasonality of mating and calving is evident in most captive colonies and all wild populations studied (Perrin & Reilly, 1984). However, the degree of seasonality (intensity of breeding/calving peaks) appears to vary greatly. Numerous methods for estimating reproductive rates are available but are not intended for review here;

rather, recent examples of the range of estimates for the percentages of calves of the year in populations are presented (see also Leatherwood & Reeves, 1982).

Tavolga & Essapian's (1957) observations of a captive colony in the northern hemisphere suggested a peak in mating activity from February-May and established the gestation period to be about 12 months. Essapian (1963) provided some evidence for a second calving and mating period from September to November in southern Florida waters. In recent studies Scott *et al.* (1990a) also refer to a calving peak in spring through to early summer for the Sarasota community off Florida, and a secondary peak from late summer to early autumn. Further north along the Atlantic coast Mead & Potter (1990) found evidence for a prolonged calving season with a peak in spring, as above, but not the secondary peak in autumn. Along the Californian coast, Hansen (1983) suggested bottlenose dolphins calve year round with a peak in autumn. While Schroeder & Keller (1989) found seasonal variation in sperm density and serum testosterone levels in a mature male caught from southeastern Florida and housed in Hawaii, with the former peaking in September and October.

Leatherwood & Reeves (1982) considered "...seasonal differences in the number of calves observed in free-ranging populations support the hypothesis of year-round breeding and calving with peaks in spring and fall [in the northern hemisphere]...". These authors reported estimated percentages of calves of the year in U.S. coastal populations which varied from 2.7% to 15.6%, with a mean of approximately 9%. Gruber (1981) estimated calves constituted 7.2% of all sightings over one year in a 75 sq. km study area off Texas where population estimates ranged from a high of approximately 98 dolphins in February (i.e. winter) to approximately 30 animals in April (i.e. spring). Hansen (1983) estimated the size of the population he studied to be 173-240 animals with an estimated "reproductive rate" (percent of calves in the population) of 7.2%, based on historical sighting records covering a 13 year period. Weigle (1990) conducted boat surveys in Tampa Bay, Florida between April and October (i.e. spring-autumn) in two consecutive years and found for the

apparently open population using the 230 sq. km study area, calves constituted 9.7% of all dolphins observed, with a peak in August.

In the southern hemisphere, although Williamson *et al.* (1990) stated "...wild bottlenose dolphins breed predominantly in spring and autumn...", the three reported live births in their captive study in Western Australia occurred in January, March and April (i.e. summer to autumn). Connor *et al.* (1992) reported that calving at Monkey Mia, Western Australia occurred from spring through summer (i.e. September-February). Data summarising 32 months in the field at Monkey Mia, used by Smolker *et al.* (1992) in their analysis of association patterns, indicated calves constituted a peak of approximately 18% of the total number of animals observed (in March-November, 1987 i.e. autumn to spring) and a low of approximately 10% in May-August, 1986 (i.e. late autumn-winter).

Data from dolphins captured in shark nets off Natal, South Africa indicated births occurred throughout the year with a peak in summer (i.e. November-February), when over 60% of calves were born (Cockcroft & Ross, 1990a). Cockcroft & Ross (1990a), using the theoretical natural rate of increase (Reilly & Barlow, 1986), calculated that the Natal bottlenose dolphin population, estimated at 900 animals, would increase annually by 4-6%.

The pattern off Argentina, reported by Würsig (1978), was a calving peak in summer with births occurring from late spring through to autumn (i.e. November-April). A maximum of two births per year were reported from a minimum population estimate of 53 (i.e. approximately 3.8%).

Lear & Bryden (1980) noted that only 1.2% of all animals sighted were calves, on 15 aerial surveys conducted approximately monthly, along embayment and open coastal waters off southern Queensland. These authors noted that "...no calves were recorded...in January to March, but were observed in all other months of the year...".

### 1.2.5 Habitat Requirements

Gaskin (1982) stated that “...the distributional ecology of these animals becomes largely a study of the distributional ecology of their prey species, and an analysis of the factors which may limit the ability of cetaceans to reproduce or rear calves to maturity...”. While Gaskin (1982) was referring to factors operating at the population level, these concepts appear reiterated in different ways in much of the literature associated with local-area population studies. It seems that four main habitat requirements of inshore *Tursiops* emerge, specifically in the context of local areas with high occurrence patterns and in some instances high degrees of residency by bottlenose dolphins. These are:

1. **Prey Abundance:** Habitats that support a high abundance of potential prey are suggested to be a requirement for high usage and residency by dolphins (see Shane, 1990; Kenney, 1990; Ballance, 1992);
2. **Diversity of prey species and size classes:** The geographical variation in dominant prey species of bottlenose dolphins reported by Barros and Odell (1990), reflected latitudinal changes in fish fauna. That is, while preferences in food items may be exhibited locally (Gunter, 1942; Cockcroft and Ross, 1990b), across their world-wide range an equally wide range of prey species is taken. Mead & Potter (1990) summarised the reported diets of bottlenose dolphins from the Atlantic, off the U.S. and African coasts, and from the Black Sea, and concluded “...they show a consistent preference for sciaenids, scombrids and mugilids....[but] seem to be rather catholic in their taste for occasional items...”. It is the variety of these occasional items in the diet of bottlenose dolphins from local areas that may suggest, prey diversity is an important habitat requirement in high use areas.

Cockcroft and Ross’s (1990b) study indicated differences in prey species and sizes taken by different age and sex classes of bottlenose dolphins. Corkeron (1990) concluded that social factors influence the accessibility of different sex and age classes to different prey items, “...and consequently the composition of their diet...”. Cockcroft and Ross (1990b) noted that “...dolphins reside in preferred

areas for relatively long periods...[and] probably exert continuous pressure on available food resources in these areas. Under such circumstances inshore dolphins may have adapted socially and behaviorally to alleviate intraspecific competition for food. These behavioral adaptations may include partitioning of the school into subgroups and the use of different foraging ranges or different prey sizes and species...". The implication of these latter adaptations may possibly be reflected in different patterns of habitat usage.

**3. Protection from Predation:** A variety of shark species are suggested as predators of *Tursiops* in Australian waters (Corkeron *et al.*, 1987). Both shallow waters and topographically complex habitats are suggested to reduce or limit predation pressure on *Tursiops* and other species (Wells *et al.*, 1980; Corkeron, 1990). Wells *et al.* (1980) and Shane *et al.* (1986) hypothesised that the nature of this protection was related to the reduction in the volume of water that must be monitored or the provision of physical barriers or paths for predators; and

**4. Nursery Areas:** As a result of sightings of females with calves of a resident population off Sarasota, Florida Wells *et al.* (1980) suggested that certain areas were used seasonally as nurseries, especially shallow flats, sheltered bays and river mouths. Subsequently, for the same community, Scott *et al.* (1990a) speculated that one such area may provide sufficient food in its extensive seagrass meadows for mothers to meet the energetic costs of lactation. Also, its shallowness and distance from deeper and more exposed waters would afford calves protection from shark predation. This concept has also been considered important for other delphinids (Neave & Wright, 1968).

### **1.3 Objectives of this Study**

The main aim of my research was to gain detailed baseline information on aspects of *Tursiops truncatus* ecology in Jervis Bay, NSW, which would be useful to authorities responsible for their conservation. Jervis Bay remains a relatively undisturbed environment along the NSW coast, however, historically it has been the subject of numerous and varied large scale development proposals (Adam *et al.*, 1987). In more recent years several major reports relating to its conservation

and management have been produced (Cho *et al.*, 1995). Hence, I considered Jervis Bay represented an invaluable opportunity to incorporate, for the first time in NSW, possible patterns of habitat usage of a local bottlenose dolphin population in future management plans for the region (Mandelc & Fairweather, 1995).

Three types of surveys were used for comparative purposes. Two surveys searched primarily shallow waters and recorded opportunistic sightings, one within Jervis Bay and the other north and south of the Bay (see Chapters 3 and 5). The third was a systematic survey throughout the main study area (i.e. within Jervis Bay) recording sightings using line transect methodology (see Chapter 4). All surveys, where appropriate, included:

- a) a quantitative assessment of sightings in terms of their general group characteristics and their relation to environmental variables and the major “habitats” in the study area. The latter being defined by depth and the three main substratum types; and
- b) investigation of the “residency status” of individual dolphins using the study area, based on individual photographic identification (see Chapter 6).

As in Kenney & Winn (1986), it is an assumption of this study that the habitats where dolphins were sighted were being utilised by them, for feeding, socialising, travel or some other activity. Hence, based on the results of the above surveys, a quantitative assessment of ancillary sightings and a review of the distribution and peak abundances of potentially important prey items (Chapter 7) I consider it may be possible to:

- a) identify important habitats for bottlenose dolphins within the study area, based on sighting frequency and character of sighting groups;
- b) suggest reasons for any patterns of preferred use; and
- c) if necessary, identify potential management issues concerning the conservation of bottlenose dolphin high use habitats and their associated prey resources.

## **CHAPTER 2: STUDY AREA AND GENERAL METHODS**

### **2.1 Study Area**

During this study most field work was done within Jervis Bay, referred to as the main study area, which is described below. Three “regional” surveys which extended north and south of Jervis Bay along the open coastline were also conducted and this survey area is described in Section 2.1.2.

#### **2.1.1 Jervis Bay Survey Area**

Jervis Bay (35° 06'S., 150° 46'E.) is located approximately 200 km south of Sydney and is a large, deep, temperate marine embayment (Cho, 1995). It has a north/south orientation with a maximum length and width of approximately 16 and 9 km, respectively (R.A.N., 1986) and a total area of approximately 120 sq. km. The entrance to the Bay is approximately 3.5 km wide with a maximum depth around 35 m (R.A.N., 1986).

Jervis Bay appears to be in the transition zone between the warm temperate (or Peronian) and the cold temperate (or Maugean) biogeographic zones (West, 1987). Mills (1993) reported “...There are five major geological units in the region surrounding the Bay. All but one of these belongs to the Permian Shoalhaven Group - a group of sedimentary rocks on the southern edge of the Sydney Basin system. The sandstone of the Snapper Point Formation, mainly on the Beecroft and Bherwerre Peninsulas has been covered by broad areas of sand dunes...” (see Fig. 2.1). Most of the region is low lying and below 100 m in elevation, with the highest points along the eastern coastal cliffs (Mills, 1993).

The streams entering the Bay are generally short and their catchments small, the total catchment is 400 sq. km which is small compared with the total area of the

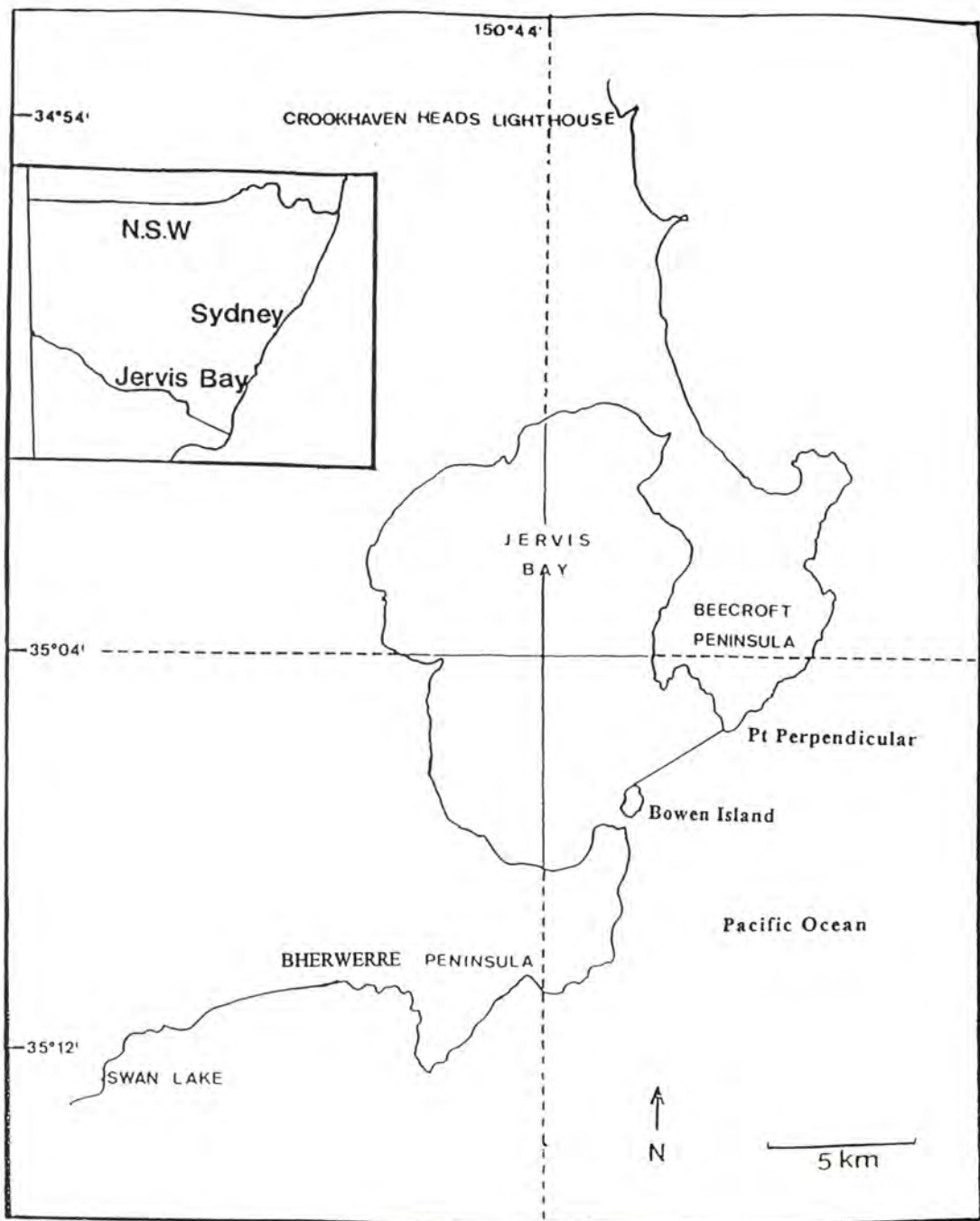


Figure 2.1: Location of Jervis Bay and the northern and southern boundaries of the Regional Survey (i.e. Crookhaven Heads and Swan Lake) along the NSW coast. The straight lines indicate the boundary of the main study area at the entrance to Jervis Bay and the arbitrarily chosen boundaries of the quadrants of the Bay.

Bay (West, 1987). Only six creeks are of any significance and these are in order of decreasing size, Currumbene Creek (Ck), Carama Inlet, Moona Moona Ck, Callala Ck, Wowly Gully and Duck Ck (West, 1987) (Fig. 2.2). Currumbene Ck is navigable by small craft for approximately 17 km. Carama Inlet is only about 4 km in length (West, 1987). The four largest creeks have saltmarsh, mangrove and seagrass communities along most of their length. There are approximately 125 ha of mangrove forests and 233 ha of saltmarshes, both of which are generally restricted to the creeks (West, 1987). The main alluvial deposits are associated with the floodplains of these streams.

The shoreline of the Bay consists of sandy beaches and intervening rocky outcrops with a total length of approximately 47.5 km, from Dart Point around to the northern tip of Bowen Island, i.e. excluding the entrance to the Bay (R.A.N., 1986) (Fig. 2.2). The main substrata within the Bay are seagrass beds, subtidal rocky reefs and platforms, and unconsolidated sediments. For the purpose of this study these three substrata were defined as: seagrass, including meadows of *Posidonia australis* and *Zostera* spp. (which were not distinguished); rocky complex areas, which included rocky shorelines, intertidal platforms, reefs and kelp beds out to their maximum depth and margin with the rest of the seafloor, in this case unconsolidated sediments; and unconsolidated sediments, primarily consisting of, and hereafter referred to as “sand” (Fig. 2.3). Sandy substratum in over 10 m depth of water comprises more than 70% of the area of Jervis Bay (CSIRO, 1991). While there is some disparity between authors as to the actual area of the Bay and its different habitats, the estimated total areas for each substratum used in this study, unless otherwise stated, are listed in Table 2.1. The maximum depth recorded during the study was 38.4 m, in the middle of the entrance to the Bay; however, more than half of the Bay is 20 m deep or less (Fig. 2.3).

The water circulation in the Bay is a response to three major forcing effects: winds, horizontal density gradients, and large-scale water movement external to the Bay (CSIRO, 1989). The resulting current flow in Jervis Bay is complicated. The most significant component “...in terms of transporting material into and out

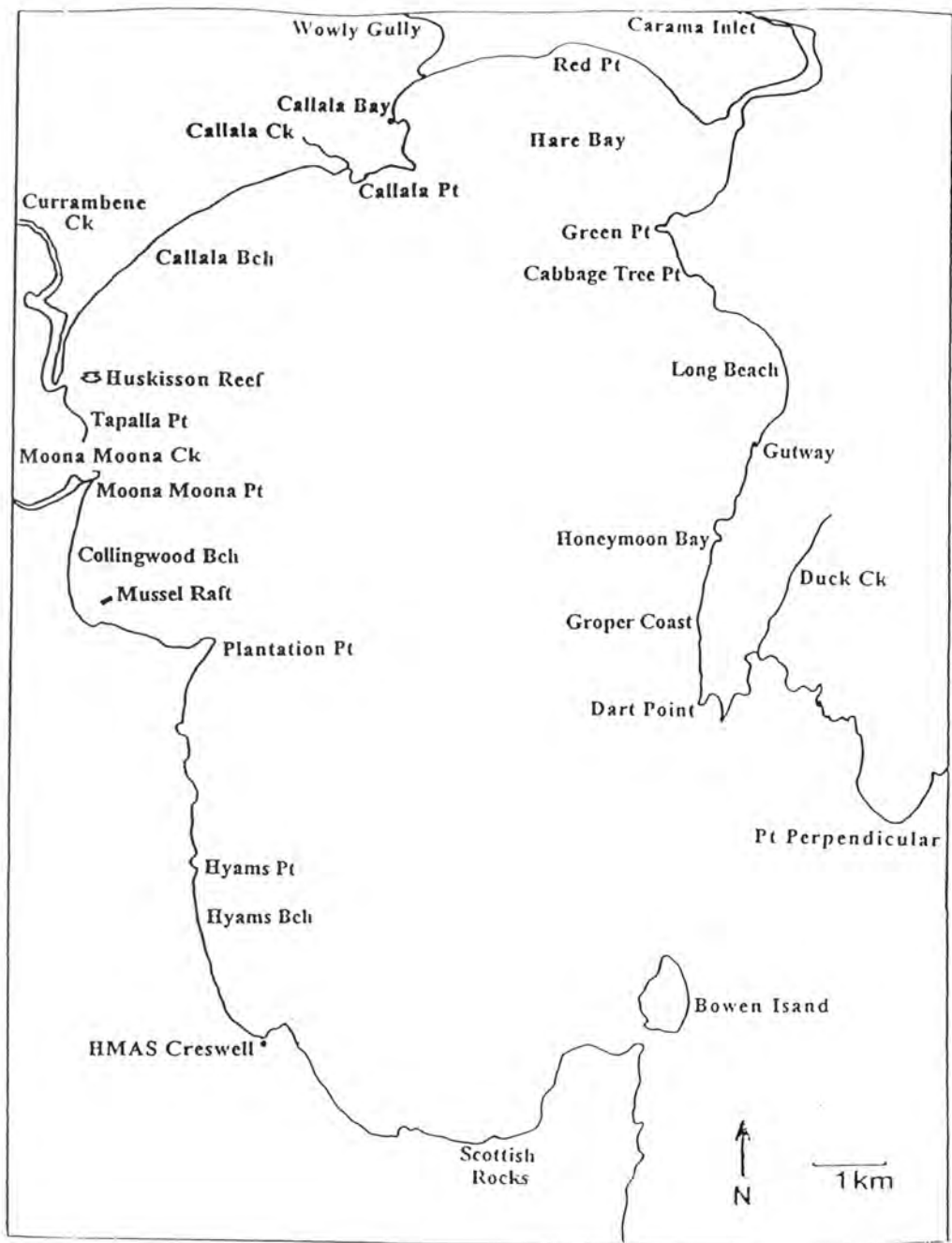


Figure 2.2: Jervis Bay Locality Map

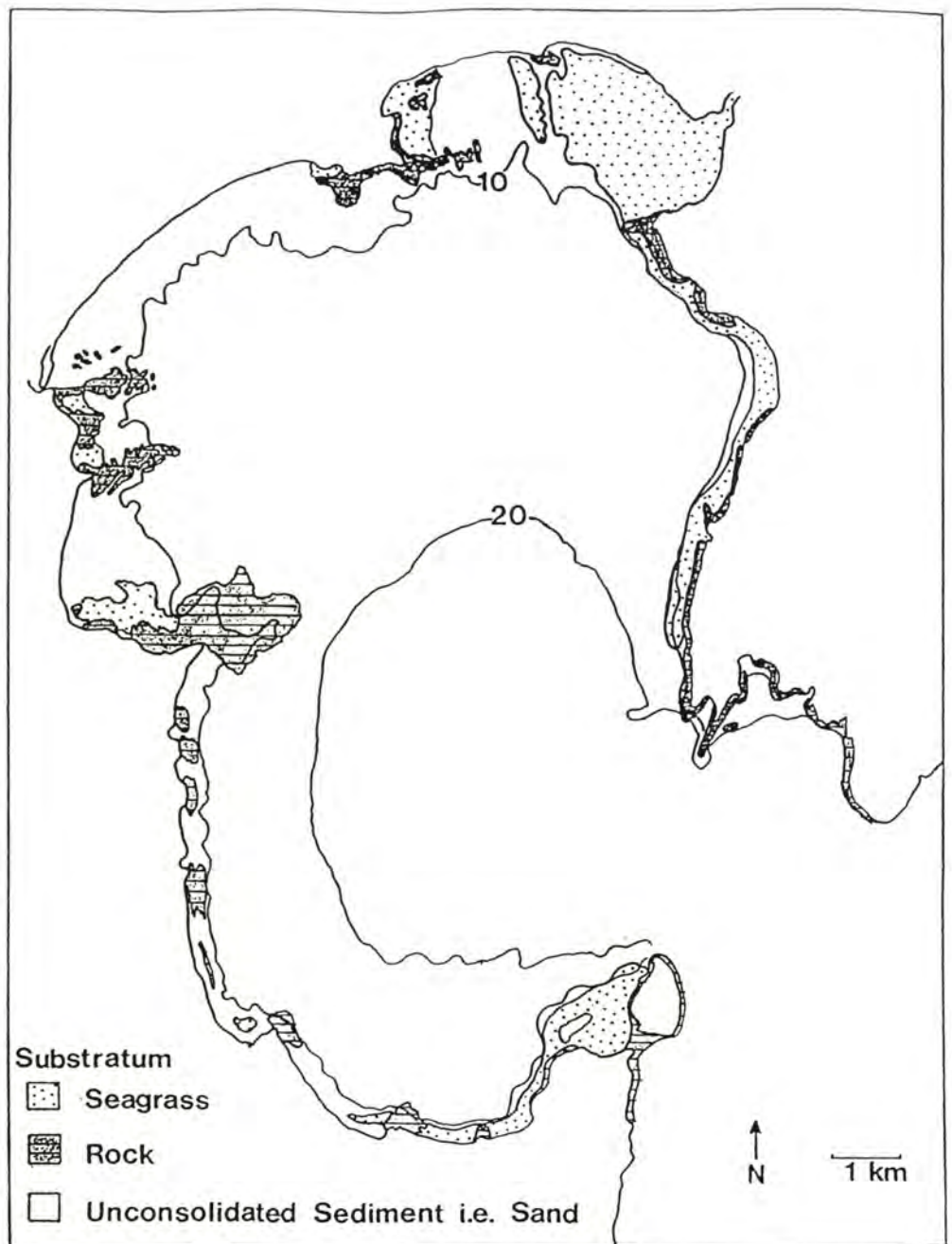


Figure 2.3: Map indicating three main substratum types and the 10 m and 20 m depth contours in Jervis Bay (modified from West, 1987 & CSIRO, 1994).

of the bay and within the bay itself, is a persistent mean flow that forms a circulation pattern of inflow to the bay concentrated near the surface on the southern side of the entrance with a compensating outflow concentrated near the sea bed on the northern side of the entrance...it seems that this clockwise circulation pattern is present for most of the time..." (CSIRO, 1994) (see Fig. 2.1).

"...Within the bay, currents generally show very little coherence with the wind... [also] the bay is vertically stratified for much of the year, mostly by temperature but occasionally by salinity when there is heavy rainfall..." (CSIRO, 1994).

Holloway *et al.* (1992) reported there were strong differences between summer and winter for currents in the Bay with strong thermal stratification in summer and weaker stratification in winter. Tidal currents are weak and make only a minor contribution to the dynamics of the Bay (CSIRO, 1994).

The CSIRO (1989) report indicated that two nautical miles offshore of the mouth of the Bay there are periods of strong persistent southward flow associated with the East Australian Current. Any reverse northward flow appears much weaker although it is persistent at the Bay entrance and may influence the bay circulation (CSIRO, 1994). Warm waters of the Coral Sea fed south by the East Australian Current are, for most of the year, warmer and less dense than the waters in the Bay. It is suggested that this horizontal density gradient between the Bay and shelf may drive the mean flow in the Bay (CSIRO, 1994).

The observed mean circulation through the bay entrance is shown to flush the Bay an average of each 24 days (CSIRO, 1994). This mechanism and a combination of the low suspended solid load entering the Bay and the predominantly oceanic origin of the waters, are considered to result in the characteristic clarity of the Bay's waters. The majority of the shoreline remains undeveloped, with only limited hinterland development, although the nature of existing activities (e.g. naval training college, deepwater mooring facilities and bombardment range, urban development and sewage outfalls) does impact on the Bay's marine environment.

### 2.1.2 Regional Survey Area

The regional survey area included waters within Jervis Bay and routes north and south of the Bay. The survey routes extending beyond the Bay commenced east of the line marked by Point Perpendicular and the northern tip of Bowen Island (see Fig. 2.1).

The northern route began at Point Perpendicular and extended to Crookhaven Heads Lighthouse ( $34^{\circ}54'$  S.,  $150^{\circ}46'$  E.). The southern route commenced at Bowen Island and extended to the mouth of Swan Lake ( $35^{\circ}12'$  S.,  $150^{\circ}30'08''$  E.), (see Figs. 2.1 & 2.4).

The northern leg is approximately 37 km long, passing vertical cliffs for over one third of the distance, with a maximum recorded height of 85 m (CMA, 1985). After rounding Beecroft Head, which provides protection from prevailing south-easterly winds, the remainder is a sandy beach coastline interrupted by only a small rocky headland, Penguin Head, and smaller rock outcrops (Fig. 2.4).

The southern leg, although shorter (approximately 33.5 km), is almost a mirror image of the northern leg, except that the cliffs are a little lower along the Bherwerre Peninsula, with a maximum height of 71m (CMA, 1986). This southern headland cuts away west of St. Georges Head to form Wreck Bay, which is protected from north easterly winds prevailing in summer. A series of small, protected rocky inlets fringe this section before the coast orients south-east and a sandy beach stretches uninterrupted to Sussex Inlet. On the south side of Sussex Inlet is a large rocky reef, followed south by another sandy beach to the entrance of Swan Lake marked by a reef on the southern side (Fig. 2.4).

Within 500 m offshore from the cliffs on both legs, depths varied but were generally between 20 m and 30 m. However, at some points the 20 m depth contour is less than 200 m from the coast e.g. Point Perpendicular. There were areas on both legs over sand where shallow gradients found the 10 m depth contour more than 1 km from shore, like some sites in the Bay.

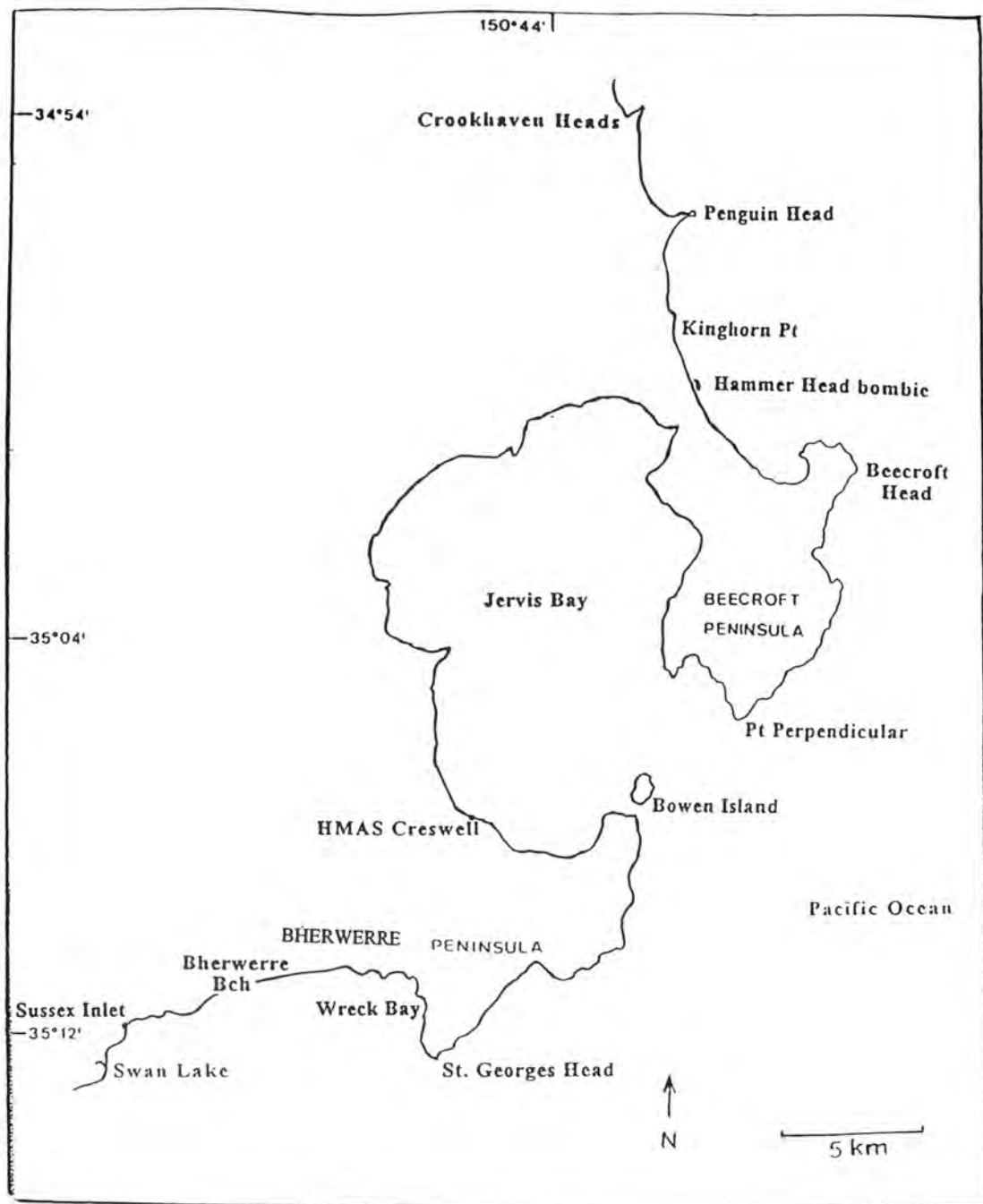


Figure 2.4: Regional Survey Locality Map

## 2.2 Observation Platforms and Equipment

All dolphin observations, unless otherwise stated, were made from a 4.3 m aluminium Quintrex boat, with half cabin, 50hp outboard motor and 25hp auxiliary motor. A JRC JFC-20 echosounder recorded the elapsed distance travelled (hereafter referred to as "log"), speed, water surface temperature and water depth immediately below the boat. It also produced a continuous LCD (liquid crystal display) image of the bottom which gave an indication of substratum type and this was verified, where necessary, using Self Contained Underwater Breathing Apparatus. The boat was fitted with a fixed bowl Plastimo magnetic compass to ascertain directions. A hand-held wind-speed indicator, called a Wind Wizard (Davis Instruments), was used to record wind speed.

An Autohelm, hand-held digital compass by Nautech Ltd, was used with charts to locate and map sightings and the beginning and end of each transect. This digital compass was also used to determine the angle of the animals from the transect line or search route, by focusing on the centre of the group(s) sighted. Field notes were taken on data sheets specifically designed for each of the three types of surveys conducted, i.e. nearshore surveys within and beyond the Bay and a Transect Survey.

A sextant, clinometer and binoculars were all trialed for measuring distances. However, this equipment did not prove functional due to the instability and low height of the observational platform (observer height above water was approximately 2 m only) and the intermittent surfacing patterns of the dolphins. Hence all distances were visually estimated, e.g. the animals' radial distance from the vessel and the vessel's distance offshore. This radial distance was checked using the echosounder log, after initial sighting data were collected, by travelling from the sighting position to the position where animals were first sighted. Whenever feasible the distance offshore was also verified, having marked the vessel's original position with a buoy. Bresser binoculars (10x50) were only used

to confirm distant sightings and their numbers, or to check individual identifications in the field.

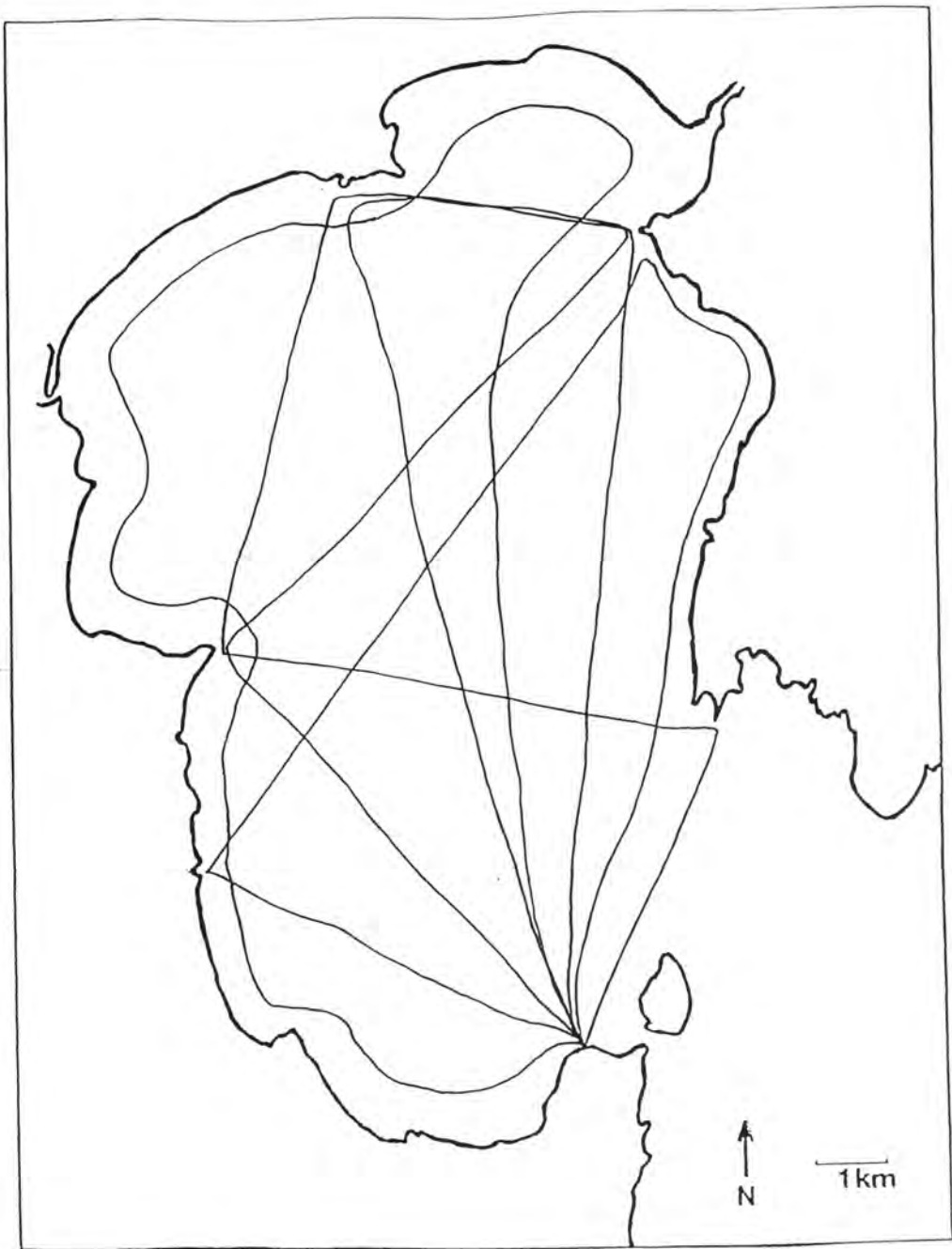
The Bay was divided arbitrarily into quadrants (divided along 35°04'S. and 150°44'E., see Fig. 2.1) for the purpose of analysis, i.e. northwest (NW), northeast (NE), southwest (SW) and southeast (SE) quadrants. The area of quadrants (see Table 2.2) and different depth categories for the whole of the Bay were calculated using a Summasketch digitizer and Chart Aus 193 (R.A.N., 1986).

Throughout the study approximately 2000 negatives were taken with a Canon AE-1 camera and 85-210 mm (f 1.4) lens. A 55 mm lens was rarely used. Initially, a range of films were used including: Kodak, Fuji, Agfa, Konica colour print (100, 200 & 400 ASA); Ektachrome, Kodachrome, Fujichrome colour slide (100 & 400 ASA); and Ilford XP1 and HP5 plus (400 ASA) for black and white prints. Ultimately Ilford HP5 plus was chosen and the majority of photographs were taken with this film, exposed at shutter speeds between 1/250 and 1/1000. On the Regional Survey when two additional vessels were used, photographs were taken with Ilford HP5 plus film and two 35 mm auto-focus Nikon cameras both fitted with a power winder and 75-300 mm lenses.

### **2.3 General Methods and Types of Surveys**

This research was conducted on a part-time basis. A three-month pilot study involving four surveys commenced in October 1989. These surveys were used to determine the boundaries of the study area, investigate observation techniques, develop data sheets and trial equipment (Fig. 2.5).

All surveys involved at least two observers, i.e. myself (the driver of the boat) and another. For the first year I had one assistant only, which ensured a certain level of repeatability in the data. For the last 18 months of the study and during all Regional Surveys, I operated a two- or three-day volunteer program, respectively. This meant that observer experience varied considerably. To compensate for this I



**Figure 2.5: Map of the routes of the four pilot surveys conducted in 1989 prior to the commencement of the project in 1990.**

usually organised a minimum of two volunteers to assist me. Prior to the commencement of surveys, volunteers were trained in boat safety procedures and equipment use. Subsequently, they were allocated search areas. When the first sighting of dolphins was made, time was taken to describe the visual cues and apparent behaviour observed, to improve the volunteer's ability to spot these animals.

During both Search and Encounter and Regional Surveys, observers were responsible for searching 90° port or starboard of the bow, with regular checks made beyond the stern of the boat. Survey effort was focused over the 180° in front of the bow because of the limitation driving placed on my searching abilities, the inexperience of some observers and, in the case of the Regional Survey, more difficult open-ocean conditions. Additional observers were requested to search the whole of this area as a double-check. The Transect Survey, however, required that the trackline and 180° to either side be searched. Hence, I searched the trackline, the two main observers searched the full 180° starboard or port and additional observers were requested to focus on 180° behind the stern, to ensure adequate coverage of this area.

Three different fieldwork approaches were developed for this study and are described in detail in their respective chapters, i.e. Search and Encounter (S&E) Survey (Chapter 3), Line Transect Survey (Chapter 4), and Regional Survey (Chapter 5). Whenever possible, attempts were made to record individual dolphins photographically (Chapter 6) and ancillary sighting and fisheries data were investigated where available (Chapter 7).

The period of data collection for each of my three types of surveys were:

1. Search and Encounter Survey: 4<sup>th</sup> January 1990 to 1<sup>st</sup> June 1992;
2. Transect Survey: 7<sup>th</sup> March 1991 to 6<sup>th</sup> June 1992; and
3. Regional Surveys: 20-22<sup>nd</sup> March 1992; 27-29<sup>th</sup> November 1992; and 2-4<sup>th</sup> April 1993.

On the Regional Surveys, each observer team was led by experienced observers whom I had trained previously, and, where possible, inexperienced volunteers joined the boat I was on. The minimum number of observers, not including the captain, on the extra two legs of this Survey was two, with a maximum of four.

During the total period (spanning 1186 days), a total of 107 days were spent conducting surveys in the field (excluding pilot and ancillary surveys, see Chapter 7) involving approximately 709 hours, travelling 6,626 km searching for dolphins, and approximately 110 hours directly observing animals.

## **2.4 Statistical Analyses**

Because of the differences in the sampling regimes between my three surveys and also between ancillary data sets, sighting data were not combined. Although this approach resulted in relatively small sample sizes for each data set, statistically significant results from analyses are not compromised, and any common trends across data sets can be viewed as separate lines of evidence.

The detailed statistical analyses of all data presented in this thesis are contained in Appendices 3-7. The results presented in Chapters 3 to 7 are summarised in tables at the end of each Chapter. Data analyses were conducted using SYSTAT and MYSTAT computer packages (Wilkinson, 1990). Generally the same analyses were used for all three types of Surveys. These statistical analyses are described below and for those frequently repeated, examples are presented in Tables 2.3-2.6.

### **Analysis of Variance (ANOVA)**

Analysis of variance was used for simultaneous examination of several means, which was only applicable to the Transect Survey, following the recommendations of Underwood (1981). The unbalanced nature of the survey design allowed only two separate forms of analysis of variance to be done when looking at interactions between water depth and substratum type. They were a one-factor ANOVA looking across all depths over sand only; and a two-factor ANOVA looking at only the two

shallowest depth classes (see Table 3.2) across all three substratum types. For examples of these analyses see Table 2.3.

### **Multiple Comparison of Means**

The program PERITZ (Martin & Toothaker, 1989) was used for pair-wise, multiple comparison of any means following a significant ANOVA (Day & Quinn, 1989), to identify the source of the significant difference, where possible. For examples of these analyses see Table 2.3.

### **Variance Homogeneity**

The variances of sets of replicate samples, for those variables which had a significant ANOVA result at  $\alpha=0.05$ , were tested for homogeneity with Cochran's test (as required to satisfy the assumption of equal variances among sets of replicate samples, see Underwood, 1981). If variances of raw data were found to be unequal then the data were transformed using the  $\log_{10}$  transformation.

Transformed data were re-tested by Cochran's test and any data that remained heteroscedastic following transformation were not analysed further. The variances of many variables associated with group composition could not be stabilised by this transformation. For examples of this analysis see Table 2.3. The homogeneity of the two sample variances obtained in Student  $t$ -tests was tested by the  $F$ -test (see below).

### **Students $t$ -test**

This was used to investigate pairs of means of continuous variables. If a significant result (at  $\alpha=0.05$ ) was found, the homogeneity of the two sample variances was tested by the  $F$ -test and, if significant heteroscedasticity was found, the data were then  $\log_{10}$  transformed and re-tested. For examples of this analysis see Table 2.4.

### **Contingency Tests**

These were used to investigate any associations between frequencies of ordinal and categorical variables. Although significant results were indicated (at  $\alpha=0.05$ ),

few tables had all “expected” cell frequencies equal to or greater than five, as a result of the small sample sizes. Even though categories were often combined, there was still a paucity of samples. In order to investigate possible trends in these data, significant results were accepted when expected cell frequencies were equal to or greater than one. Although it is recognised in the latter cases that significant tests are suspect, as a result of sparseness (Bailey, 1976). Following recommendations contained in Wilkinson (1990) different chi-square statistics were applied to contingency tables depending on the number of variables analysed. For asymmetric tables the chi-square test statistic with the “highest” probability was given using either the Pearson or Likelihood ratio statistic, i.e. the more conservative result due to significant tests being suspect, as a result of sparseness. For square tables (i.e.  $r$  columns  $\times$   $r$  rows) the McNemar Symmetry chi-square statistic was used. In the case of  $2 \times 2$  tables Yates’ corrected chi-square was found to be very similar to Fisher’s Exact test which calculates all possible outcomes exactly, and thus accounts for sparseness. The MYSTAT software performed Fisher’s Exact Test for grand total values up to 50 and thereafter used the Yates’ corrected chi-square statistic. For examples of these analyses see Table 2.5.

### **Chi-square Goodness-of-Fit**

This test was used to compare observed data with expected values, with significance set at  $\alpha=0.05$ , e.g. for the distribution of sampling effort of various variables for all three types of surveys. For examples of this analysis see Table 2.6.

### **Power Analysis**

This was pursued for all non-significant  $t$ -tests to establish whether these results indeed reflected a lack of an effect or difference, or indicated that the power of the statistical test was too weak to reach a conclusion. Where low power was determined, *post hoc* power analysis can be used to consider “...the ‘effect size’ to be detected, a more appropriate sample size and significance value for any test...” (Fairweather, 1991). The low power of most of the results analysed effectively

reflects the small sample sizes (see Table 2.4). Hence interpretation of trends in these data from this study, come only from the plotted data.

## **Density Estimates**

### **a) Estimates derived from Line Transect distance data**

Distance data (i.e. data which allows the perpendicular distance of observed animals from a trackline to be calculated, e.g. from radial distance and angle of animals from the vessel's heading) were investigated using the program DISTANCE (Laake *et al.*, 1993). The model chosen by the DISTANCE program to fit the data best was a half-normal model with two cosine adjustment terms (Laake *et al.*, 1993).

The Transect Survey was designed to allow for density estimates using the distance sampling technique, described by Buckland *et al.* (1993). However these authors recommend, "...as a practical minimum,  $n$  should usually be at least 60-80...If the population is clustered, the sample size...should be larger to yield similar precision for the abundance estimates of individuals...", where  $n$  = the number of clusters detected. Because the final sample size was too small ( $n=26$ ), the DISTANCE program did not prove useful.

### **b) Estimates derived from the surveyed areas (no. per sq. km)**

Where appropriate, estimates of dolphin and calf density (*Tursiops* and calves per sq. km) were calculated for the:

- \* whole study area per survey;
  - \* seasons per survey for the whole study area;
  - \* quadrants of the Bay per survey (per the area of each in waters  $\leq 10$  m in depth);
- and
- \* three substrata per sighting event (per the area of each in waters  $\leq 10$  m in depth). For examples of these analyses see Sections 3.3.7.2; 4.3.2.5; 4.3.4.7b; and 5.4.4.7b.

**TABLE 2.1: Estimated total areas of three different substrata in Jervis Bay, NSW.**

<b>Substratum</b>	<b>Area (sq. km)</b>	<b>Percentage of Bay (%)</b>	<b>Source</b>
Sand	110	89.8	Leadbitter, 1987
Seagrass	8.9	7.3	J. Fitzpatrick, CSIRO (unpub. data)
Rock	3.57	2.9	West, 1987
<b>Total</b>	<b>122.47</b>	<b>100</b>	

**TABLE 2.2: Areas of arbitrarily chosen quadrants of the Bay based on the digitisation of Chart Aus 193.**

	<b>Quadrant</b>				
	SW	NW	NE	SE	<b>Total</b>
<b>Area (sq. km)</b>	27.9	33.2	31.8	24.3	<b>117.2</b>
<b>% of Bay</b>	24	28	27	21	<b>100.0</b>

**TABLE 2.3: Examples of ANOVA applied to Transect Sighting data, the Peritz procedure and Cochran’s test for homogeneity of variances. (NB: individual table numbers indicate the Table in the Appendix where the analyses are presented).**

**Table A4.4c:** The total number of sighting events recorded at transects across all 6 depth classes but only over the substratum sand,  $n=162$ . A significant result was indicated but raw data were heteroscedastic (i.e. Cochran’s test critical  $C = 0.29$  at  $P = 0.05 < \text{observed } C = 0.54$ ) and variances were unable to be stabilised after  $\log_{10}$  transformation (i.e. observed  $C = 0.54$ ).

Source of Variation	<i>df</i>	Mean Square	F-ratio	<i>P</i>
Depth Classes	5	0.017	3.177	0.009
Error	156	0.005		

**Table A4.5a:** The total number of animals per sighting event across 3 substrata at the 2 depth classes where all substrata were present,  $n=174$ , indicated non-significant results for the main effects of depth and substratum, as well as their interaction.

Source of Variation	<i>df</i>	Mean Square	F-ratio	<i>P</i>
Substratum, S	2	46.688	2.029	0.135
Depth, D	1	34.679	1.507	0.221
Interaction, SxD	2	67.002	2.912	0.057
Error	168	23.005		

**Table A4.10s:** A one-factor Analysis of Variance of the total number of dolphins per pod,  $n = 35$ , across tidal state indicated a significant result and data were homoscedastic (i.e. Cochran’s test critical  $C = 0.56$  at  $P = 0.05 < \text{observed } C = 0.36$ ).

Source of Variation	<i>df</i>	Mean Square	F-ratio	<i>P</i>
Tidal State	3	106.57	5.806	0.003
Error	31	18.35		

**Table A4.10t:** The Peritz multiple comparison procedure for the mean number of dolphins per pod across tidal state, where  $\alpha = 0.05$ , S indicates a significant result, and NS a non-significant result.

Tidal State	Flood	Low	Ebb	High
Flood	-	NS	NS	S
Low	-	-	NS	S
Ebb	-	-	-	S
High	-	-	-	-

**TABLE 2.4: Examples of Students *t*-test analysis and *F*-test for the homogeneity of variances. (NB: individual table numbers indicate the Table in the Appendix where the analyses are presented).**

**Table A4.17e:** A *t*-test indicated no significant difference in the mean number of dolphins per pod, across the north or south of the Bay. Pooled variances  $t = 1.659$ ,  $df = 34$  and  $P = 0.106$ . Power = 0.41.

Half of Bay	N	Mean	SD
North	24	11.5	8.6
South	12	7.1	4.8

**Table A3.2a:** A *t*-test indicated a significant difference in the mean number of animals per sighting event, with or without calves and data were homogeneous (i.e. *F*-test critical  $F = 2.08$  at  $P = 0.05 > \text{observed } F = 1.47$ ). Pooled variances  $t = 3.151$ ,  $df = 47$  and  $P = 0.003$ .

Calves	N	Mean	SD
Absent	20	8.9	6.6
Present	29	15.8	8.0

**Table A4.20b:** A *t*-test indicated a significant difference in the mean pod size with or without calves but raw data were heteroscedastic (*F*-test critical  $F = 1.70$  at  $P = 0.05$  and observed  $F = 2.66$ ). Data were not significant after  $\log_{10}$  transformation. Pooled variances  $t = 1.983$ ,  $df = 87$  and  $P = 0.051$ . Power = 0.48

Calves	N	Log Mean	SD
Absent	55	0.764	0.303
Present	34	0.905	0.363

**TABLE 2.5: Examples of five different types of Contingency Tests (after Wilkinson, 1990). (NB: individual table numbers indicate the Table in the Appendix where the analyses are presented).**

**Table A3.4h:** No association was indicated between sighting substratum and the presence or absence of calves per pod by, Pearson chi-square = 0.049, *df* = 2 and *P* = 0.976.

Substratum	Calves		Total
	Absent	Present	
Sand	29	17	46
Seagrass	17	11	28
Rock	7	4	11
<b>Total</b>	53	32	85

**Table A4.22h:** No association was indicated between sighting substratum and the presence or absence of calves per pod, by Likelihood ratio chi-square = 3.275, *df* = 2 and *P* = 0.194.

Substratum	Calves		Total
	Absent	Present	
Sand	29	12	41
Seagrass	16	16	32
Rock	10	6	16
<b>Total</b>	55	34	89

**Table A3.8h:** An association was indicated between pod size (i.e. the total number of animals recorded per pod, divided into small, medium and large size classes) and the behaviour of each pod, by McNemar Symmetry chi-square = 13.571, *df* = 4 and *P* = 0.004.

Pod Size	Behaviour			Total
	Travel	Milling	Social/ Feed	
Small	17	11	11	39
Medium	22	5	10	37
Large	3	2	4	9
<b>Total</b>	42	18	25	85

**TABLE 2.5 contd.**

**Table A4.21h:** No association was indicated between depths when divided into shallow ( $\leq 11.5$  m) and deep ( $> 11.5$  m) waters and the presence or absence of calves, by Yates' corrected chi-square = 1.548,  $df = 1$  and  $P = 0.213$ .

	Depth Category		Total
	Shallow	Deep	
Calves			
Absent	18	5	23
Present	29	2	31
Total	47	7	54

**Table A5.3f:** No association is indicated between the total number of animals per sighting, divided into small (1-10 dolphins) and larger (11+) size classes and the presence or absence of calves, by Fisher's Exact Test  $P = 0.198$ .

	Calves		Total
	Absent	Present	
Sighting Size			
Small	7	4	11
Larger	3	8	11
Total	10	12	22

**TABLE 2.6: Examples of Chi-squared goodness-of-fit test. (NB: individual table numbers refer to the Table in the Appendix where the analyses are presented).**

**Table A3.1i:** Distribution of survey effort across nearshore ( $\leq 10$  m) and deeper waters,  $n = 1,771.5$  km, chi-square = 404.2,  $df = 1$  and  $P < 0.001$ .

	Depth (m)	
	0-10	>10
Observed	1308.9	462.6
Expected	885.75	885.75

**Table A5.4b:** Distribution of sighting events across three depth categories for the whole Bay when the area of each (see TABLE 3.3) is considered (i.e. used to calculate expected values),  $n = 22$ , chi-square = 19.73,  $df = 2$ , and  $P < 0.001$ .

	Depth Categories (m)		
	$0 \leq 10$	$10 < 20$	$> 20$
Observed	15	5	2
Expected	5.3	11.5	5.2

## CHAPTER 3: SEARCH AND ENCOUNTER (S&E) SURVEY

### 3.1 Introduction

This survey was initiated to ascertain the logistics of finding and observing dolphins from a single small boat in Jervis Bay. The route of all four pilot surveys conducted in 1989 was random throughout the Bay (see Fig. 2.5). Therefore, more time was spent proportionally in deep water, i.e. greater than 10 m in depth, than in shallower waters. However, sightings of bottlenose dolphins were only made in nearshore waters (for the purpose of this study defined as waters  $\leq 10$  m in depth or within approximately 500 m from shore). Hence, it was decided to conduct a survey which searched the perimeter of the Bay recording opportunistic sightings based on the hypothesis that animals spent a lot of, if not more, time in relatively shallow waters versus deeper areas of the Bay (Würsig, 1978; Hansen, 1983; Shane, 1987; Kenney, 1990). This survey was named the Search and Encounter Survey and is referred hereafter as the S&E Survey. As the primary focus of this research was the quantitative assessment of sightings with respect to the major habitats of the Bay defined by substrata and depth and a range of environmental variables, it was considered the S&E Survey may maximise the opportunity for finding dolphins as compared to the random transect survey approach (see Chapter 4). It was considered this survey was also likely to allow for longer observation periods at a closer distance than the transect survey and so was particularly important for collecting data on group size, the presence of calves, apparent behaviour and individual identification.

The ephemeral nature of both larger and many small sighting groups has long been recognised (Shane *et al.*, 1986). Bottlenose dolphin societies, however, may also include both fluid and stable associations between individuals based on sex and age classes (Wells *et al.*, 1987; Smolker *et al.*, 1992). To accommodate such variability this study only considered gross group composition, i.e. group size and the presence and absence of calves. These data were recorded in order to investigate if group composition varied in response to different habitats and

environmental variables such as season, sea conditions, tidal state, time of day, wind direction and sea surface temperature. The spatial pattern of groups and surface behavioural activities were also recorded and analysed with regard to habitat and these environmental variables. Individuals were photographed opportunistically to investigate the potential “residency status” of animals using the study area (see Chapter 6).

### 3.2 Survey Design

The S&E Survey was conducted twice monthly for the first year and then monthly, where possible, for the remainder of the project. This Survey involved varying the point of departure and route taken, to search the periphery of the Bay for dolphins. When searching, the boat was operated at approximately 15-20 km per hour. This speed was chosen because it was observed, when watching other vessels from land and the research boat, that dolphins were often not seen if the boat was travelling faster. This observation typically related to the behaviour in which the animals were involved at the time a boat passed. For example, if the animals were travelling at a moderate to fast speed typically some, but not necessarily all, would join the boat to ride the bow-wave. However, if the animals were engaged in other activities or travelling at a slower speed, they would often alter their diving pattern and remain beneath the surface for a longer period, and the craft would be at some distance before the animals re-surfaced.

A circuit of the Bay was commenced travelling at an average distance of 500 m from shore. The direction initially taken (i.e. clockwise or anti-clockwise) was dependent on weather and sea conditions. Most searches (68%) completed a circuit of the Bay unless weather conditions deteriorated or, in a few instances, following animals made this impractical (Fig. 3.1).

When animals were first seen, this was referred to as the “initial sighting” and marked the beginning of a sighting event. A sighting event ended when: it was determined as much information as possible had been collected; the animals

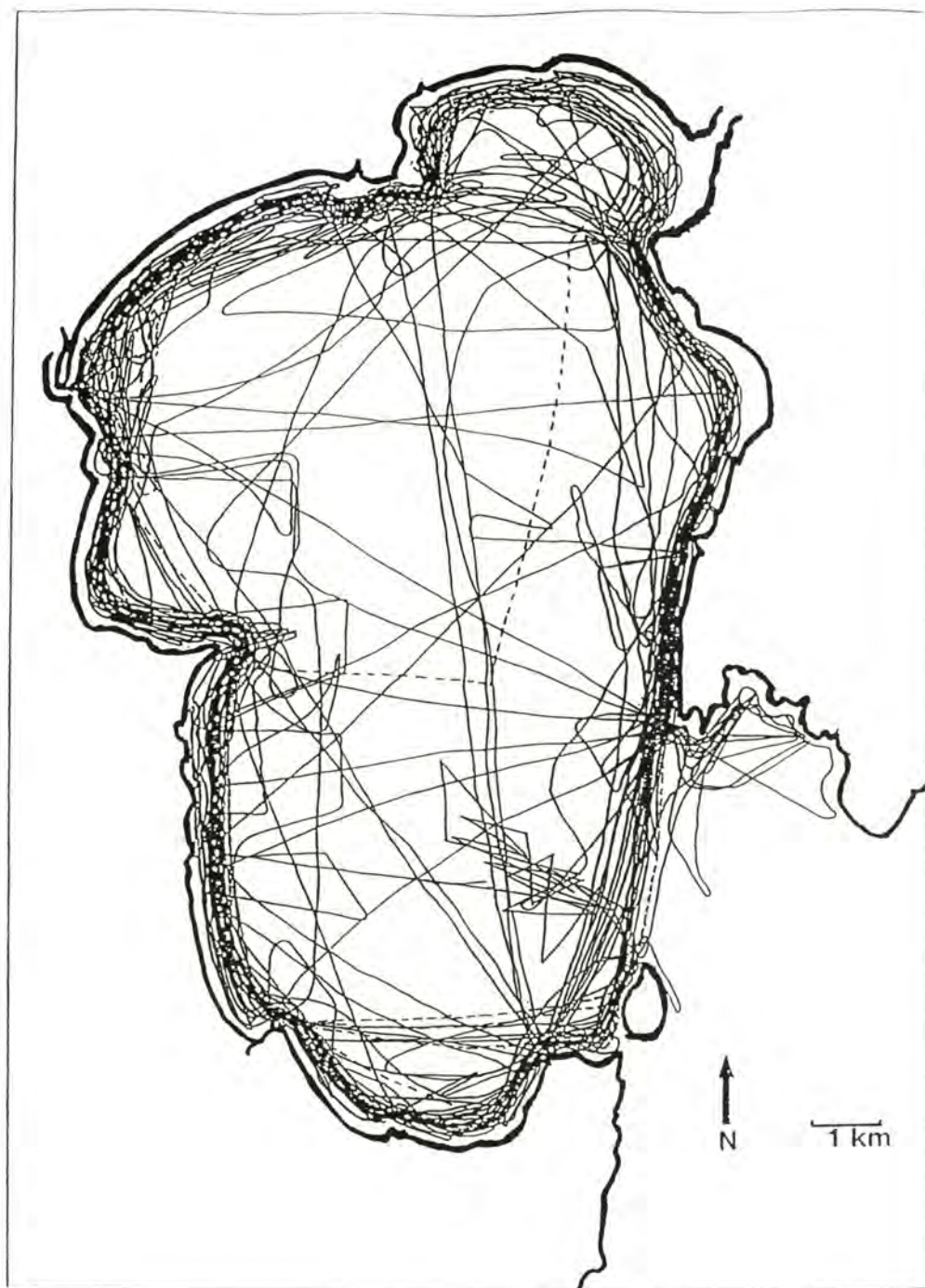


Figure 3.1: Map of survey routes for the Search and Encounter Survey.

repeatedly appeared to avoid the research boat; or they disappeared completely from the immediate area. Whether or not the encounter ended when the animals were still in view (as in the first two instances), there remained the chance that a group of the same or similar composition as those previously sighted may be resighted again during the same survey day.

The procedure for data collection was standardised using field data sheets, with five specific occasions for data to be initially collected. These were: at the beginning of a survey; at the time of an initial sighting; at the commencement of the observation period (i.e. for the purpose of standardising data collection “observation” began after initial sighting and environmental data had been collected and typically commenced five to ten minutes after the initial sighting); during the course of the subsequent encounter; and at the end of the survey. Some measurements and observations were recorded only once during a survey (e.g. date, departure point) or sighting (e.g. animals’ distance and angle from vessel), others were repeated at intervals during a sighting (e.g. time, wind speed and direction, total number sighted) and others were continuous, for certain periods (e.g. depth, substratum, behaviour). A description of all data and when it was collected is given below. It has been grouped into six categories for ease of presentation: survey, environmental and habitat data, sighting, group composition, behavioural and individual identification.

### **3.2.1 Survey Data**

At the commencement of each survey the date, time (which was transformed where necessary from daylight saving time to standard eastern time), departure point and direction of travel of the research boat were recorded. When the survey ended the return point, log, and time were noted. The Bay was divided arbitrarily into quadrants (see Fig. 2.1) which differed in area but not significantly (Tables 3.1a & b). The survey route taken, the approximate location of initial sightings and movements of observed animals were also recorded on a locality map (see Fig. 2.2).

**TABLE 3.1: Areas of arbitrarily chosen quadrants of Jervis Bay**

**Table 3.1a:** Areas of arbitrarily chosen quadrants of the Bay based on the digitisation of Chart Aus 193.

	Quadrant				
	SW	NW	NE	SE	Total
Area (sq km)	27.9	33.2	31.8	24.3	117.2
% of Bay	24	28	27	21	100.0

**Table 3.1b:** Area (sq km) of arbitrarily chosen quadrants of the Bay based on the digitisation of Chart Aus 193,  $n = 117.2$ , chi-square = 1.653,  $df = 3$ ,  $P > 0.05$ .

	Quadrant			
	SW	NW	NE	SE
Observed	27.9	33.2	31.8	24.3
Expected	29.3	29.3	29.3	29.3

These field records were later transferred to a base map, using Chart Aus 193 (R.A.N., 1986).

### **3.2.2 Environmental and Habitat (i.e. depth and substratum) Data**

At the commencement of each survey sea surface temperature, sea conditions, wind speed and direction, and weather (which consisted of three categories, i.e. clear - sunny with less than 50% cloud cover; overcast - greater than 50% cloud cover; and raining) were recorded. Cloud cover, weather and sea conditions were visually estimated by observers. Wind direction was determined using a compass, using the direction from which the wind was coming. Wind speed and temperature were measured using the instruments described in Section 2.2. Wind speed was later converted into the Beaufort (BF) scale (FSSC, 1989).

Initial sighting events were later categorised for tidal state and time of day. Four categories of tidal state were used (i.e. high, ebb, flood and low) based on tide charts (SMRA, 1989-1993). The five time of day categories used were: prior to 0600; morning = 0600-0959; midday = 1000-1359; afternoon = 1400-1759; and after 1800.

At the commencement of the observation period the depth, substratum, water temperature and wind speed were recorded. Occasionally when multiple pods of dolphins were present near the margin of a substratum, typically seagrass or rocky areas, it was necessary to move towards the more distant pods to record depth and substratum. The depths at which animals were initially recorded were divided into depth classes for the purposes of chi-square analysis. The classes are represented by 4, 8, 15, 20, 25 and 30 m, to match the depths of transect sites used on the Transect Survey (see Chapter 4), so as to allow for comparisons of results between Surveys. The boundaries of these classes are the depths at the middle of the interval between each class (Table 3.2). Depth, substratum, log and time were also regularly recorded during the encounter. If weather or sea conditions altered during the encounter, these measurements were repeated.

**TABLE 3.2: The nominal depths of transects used on the Transect Survey and the boundaries of the depth classes they represent. The boundaries of these depth classes are at the depths in the middle of the interval between each class.**

Nominal Transect Depths (m)	Boundaries of Depth Classes	
	Shallow (m)	Deep (m)
4	0	6.0
8	6.0	11.5
15	11.5	17.5
20	17.5	22.5
25	22.5	27.5
30	27.5	40

### 3.2.3 Sighting Data

When an initial sighting was made the time, log, vessel position, animals' distance from the nearest land point, the animals' direction of travel and "distance data" were recorded. Distance data used in line transect sampling (see Section 4.2) to estimate abundance were recorded on this survey for consistency of data collection procedures between different surveys. These data included: radial distance(s) from the point of sighting (or transect line) to the centre of the observed group(s); horizontal angle measurements made from the centre of the observed group(s) to the boats' heading at the time of the sighting (or trackline); and numbers of animals per "cluster" (Laake *et al.*, 1994).

Vessel position (i.e. geographic coordinates) was determined using three compass bearings to identified coastal landmarks and also visual estimation of the distance offshore from the nearest coastal point. The horizontal angle of the animals from the vessel was determined using a hand-held digital compass. The distance from the vessel to the centre of the group(s) was also visually estimated. The distance at which an initial sighting was made varied, depending on sea conditions, observer experience and the angle of the sun.

If the animals did not approach the research boat after distance data were collected, it was often necessary to approach them, to make more detailed observations. This marked the commencement of the observation period.

It was noted that the animals' initial response to the approach of the research and other vessels depended on the activity in which they were engaged and on the manner in which the boat was handled. That is, if animals were actively engaged in feeding or socialising, for example, they rarely altered this activity as a vessel approached. It also appeared that animals were more likely to alter the activity in which they were engaged if a boat approached at a faster speed relative to their movements and in an erratic manner. Hence, the research vessel was operated slowly and maintained a constant heading wherever possible.

The time, location, log, distance of animals from the vessel and from the nearest land point and their direction of travel were recorded again at the commencement of the observation period. The presence of other vessels and any response of the animals to these and the research vessel were also noted during the encounter.

#### **3.2.4 Group Composition Data**

Data collected on group composition included: total number of dolphins observed per sighting event; number of “subgroups”, referred to as pods; total number of animals per pod; absence or presence and number of calves.

For this study a pod was defined as “...the smallest number of dolphins observed to be closely associating...” (Wells *et al.*, 1980); and “...moving in the same direction and often, but not always, engaged in the same activity...” (Shane, 1990a). In this study the term pod does not suggest any definitive social associations between individuals, but simply a subgrouping of animals visible to the observer at the time of recording, based on the relative spatial arrangement of the dolphins present. This definition seemed reasonably functional in this study area as pods appeared to remain intact for the duration of most sighting events which probably reflects the relative brevity of most sightings versus pod stability.

Calves were defined as any animal approximately 1.5 m or less in length, a third of an adult’s body length, and/or associating closely with, or accompanied by, an adult. It was hoped these length estimations would include animals mainly one year or less in age, in order to estimate new season calves. However, it is recognised that a close association pattern between mother and calf may be maintained beyond the first year.

An assessment of the total number of dolphins, pod number and size, and the absence or presence and number of calves, at a sighting event was made at the commencement of the observation period. This assessment was delayed in order to

collect initial sighting and environmental data. In addition, some disturbance to the animals' activity often resulted from the research boat's approach (e.g. animals approached the boat, bow-wave riding, change in direction of travel or movement away from the boat). It was observed that after apparent investigation of the research vessel and possible recognition of the boat, the animals would re-group (it is not assumed necessarily into the same group(s) prior to our arrival) and pursue the direction of travel first recorded at the time of initial sighting. Bow-wave riding did not appear to be a prolonged option due to the boat's slow speed relative to the animals.

It was considered that our extended observation distance (an average of 30 m), as compared to some studies (e.g. Shane, 1990a; Smolker *et al.*, 1992; Slooten *et al.*, 1992) assisted our assessment of the total number of dolphins present. The duration of this count varied with the size of the group, their behaviour and the sea and weather conditions, but was typically less than five minutes and approximated an instantaneous scan sample (Altmann, 1974). Only one assessment of the total number of animals was made per sighting event, although occasionally animals would leave or join the group during the subsequent observation period.

As a result of small sample sizes and the resulting degree of sparseness for chi-square analysis, the four variables (total number of animals, total number of calves, pod number and size recorded per sighting event) have only been used in a small number of analyses. In most analyses the following grouping variables have been used. The total number of animals recorded per sighting and per pod were divided into "size classes". The arbitrarily chosen size classes are small (1-5), medium (6-14) and large (15+) and are referred to as "sighting size" and "pod size". In some analyses due to sparseness of the data, it was necessary to use just two sighting or pod size classes (i.e. small = 1-10 dolphins and larger = 11+). Three categories for the number of pods (i.e. one, two and three or more) were mainly used but in some analyses, due to sparseness of the data, it was necessary to use just two categories (i.e. one versus multiple pods).

### **3.2.5 Spatial Pattern**

Eight descriptive categories of dolphin spatial pattern, referred to by Shane (1990a) as the “two-dimensional geometry” of pods, were defined for this study (see Appendix 1). These were: clumped; spread; larger core group clumped + others spread; a number of clumped pods; linear; abreast; circular and not discernible.

Due to small sample sizes it was necessary to combine some spatial pattern categories, for the purpose of analysis. Unless otherwise stated three categories were used which consisted of “clumped” i.e. single or multiple clumped groups and circular arrangements; “spread” i.e. spread, linear and abreast patterns; and the “mixed” pattern of a core group clumped + others spread. However, in some instances it was necessary to use only two categories which consisted of clumped groups (as above) versus all other spatial patterns, referred to as “dispersed” spatial patterns.

Spatial pattern was recorded once during the observation period, after environmental, habitat and group composition information was collected, i.e. at least 15 minutes into the encounter. Spatial pattern was recorded using the technique of instantaneous scan sampling of groups (Altmann, 1974), for all animals and pods, if present, in view at the time.

### **3.2.6 Behavioural Data**

The direction dolphins were travelling was recorded at the time of the initial sighting. The animals’ direction of travel was recorded using nine categories, i.e. nil direction plus eight compass points. However, because of the small sample size data were combined into only five categories, i.e. nil and the cardinal compass directions for the purpose of chi-square analysis.

Eleven descriptive behavioural categories were defined for this study: “resting”; “travel - slow”, “moderate” or “fast”; “milling”; “socialising”; “feeding”; “social/travel”; “feed/travel”; “avoidance”; and “not discernible” (see Appendix 2). These well defined categories assisted in keeping sampling time brief (Altmann, 1974) and accommodated the limited experience of some observers. To aid interpretation of this material, specific behaviours such as leaping, surfing, head and tail slaps were also recorded.

Not all categories of behaviour were recorded every time and some were only recorded on a small number of occasions. Hence it was necessary to combine these data into three categories for the purpose of analysis. This involved combining the different speed behaviours into one “travel” category; resting and milling were combined into a milling category which functionally represented a non-directional, quiet activity mode; and the socialising, feeding, social/travel and feed/travel modes were combined into a single “social/feed” category.

It should be noted that animals were recorded as feeding or feeding/travel only in very specific cases. These consisted of: prey seen in the mouth of animals; fish leaping above the surface of the water away from apparently pursuing dolphins; or synchronised herding movements by dolphins (e.g. circling) with diving birds present. Hence some instances of foraging and indeed feeding, where potential prey were not observed, may have been unwittingly included in other categories.

Behavioural activity was recorded for the first time during the observation period after environmental, habitat and group composition information was collected i.e. at least 15 minutes into the encounter. This consisted of recording the overall activity of all animals and pods, if present, in view at the time by the instantaneous scan sampling of groups technique, described by Altmann (1974). In the early stages of this Survey, after the first behavioural record was made, instantaneous scan sampling was conducted on an irregular basis within and between encounters. Sampling was only later refined to include instantaneous records of behaviour every five minutes, as well as group size, depth and substratum over which the

animals were located. Because of the disjunct nature of this “continuous behavioural data set”, it is not presented here and only the one assessment of spatial pattern and behaviour per sighting event is analysed and discussed throughout this thesis.

### **3.2.7 Individual Identification**

These data are analysed in Chapter 6 and this category is mentioned here only to acknowledge its collection during the encounter phase. However it should be noted that photographic data were only collected opportunistically. Further, an encounter was not extended beyond the habitat, environmental, group composition and behavioural data collection periods, to ensure all individuals were photographed if the animals began to display avoidance activities or the time did not allow completion of a circuit of the Bay.

## **3.3 Results**

Appendix 3 contains the detailed statistical analyses of all data presented in this Chapter (TABLES A3.1 - A3.10). The results presented in this Chapter refer to Summary Tables located at the end of the Chapter (see Tables 3.8a-i). A line reference using roman numerals is included to assist referral to these Tables (e.g. Table 3.8a-lvi).

### **3.3.1 Survey Effort**

In 1990 25 surveys were conducted, with ten in 1991 and five during 1992 until June. Hence survey effort was not distributed evenly across years with 62.5% of all, and 61% of successful, surveys occurring in 1990 (Table 3.8a-li). In total 1,771.5 km were travelled (see Fig. 3.1) and 215 field hours spent in the S&E Survey. On this survey distance data were recorded at a mean distance of 170 m from the animals, depending on sea and weather conditions and took an average of five minutes to complete.

Animals were seen on 31 of the 40 surveys (77.5%) and 49 individual sighting events recorded (Fig. 3.2). An estimated 46 hours 12 minutes were spent observing dolphins, i.e. approximately 21% of the total time in the field during this survey was spent observing animals. Observations occurred at an average distance of 30 m from the animals. Observations lasted from a minimum of four minutes to a maximum of two hours and 58 minutes, with an average of 57 minutes. The distances travelled per sighting while observing animals also varied greatly, from 0 km to 9.9 km, with an average of 3.6 km.

Sampling effort ( $n=126$  quadrants) was distributed equally across quadrants of the Bay (Table 3.8a-*lii*). Survey effort ( $n=40$  surveys) was distributed equally across seasons (Table 3.8a-*liii*) with successful surveys ( $n=31$  surveys) also evenly distributed across season (Table 3.8a-*liii*). Sampling effort ( $n=215.3$  hours) was not distributed equally across the five time of day categories which the S&E Survey covered. Only one hour and 54 minutes occurred prior to 0600 and four hours and 55 minutes after 1800. When these categories were combined with morning and afternoon sightings to create three time of day categories, sampling effort remained unequally distributed (Table 3.8a-*liv*), with most sightings (47%) occurring at midday, i.e. between 1000 and 1359. Sampling effort ( $n=110$  tidal states) was equally distributed across the tidal states (i.e. based on three hourly intervals) which the S&E Survey covered (Table 3.8a-*lv*).

Survey effort was not distributed evenly throughout the Bay, with respect to depth (see Figs. 2.3 & 3.1). Whilst surveys regularly moved into deeper water, the greatest effort (74%) was in nearshore waters with an estimated 462.6 km (26%) searched, while travelling in waters >10 m in depth (Table 3.8a-*lvi*). This result reflects the decision to initiate searches by travelling around the periphery of the Bay, but was also influenced by animals typically remaining in shallow depths when followed.

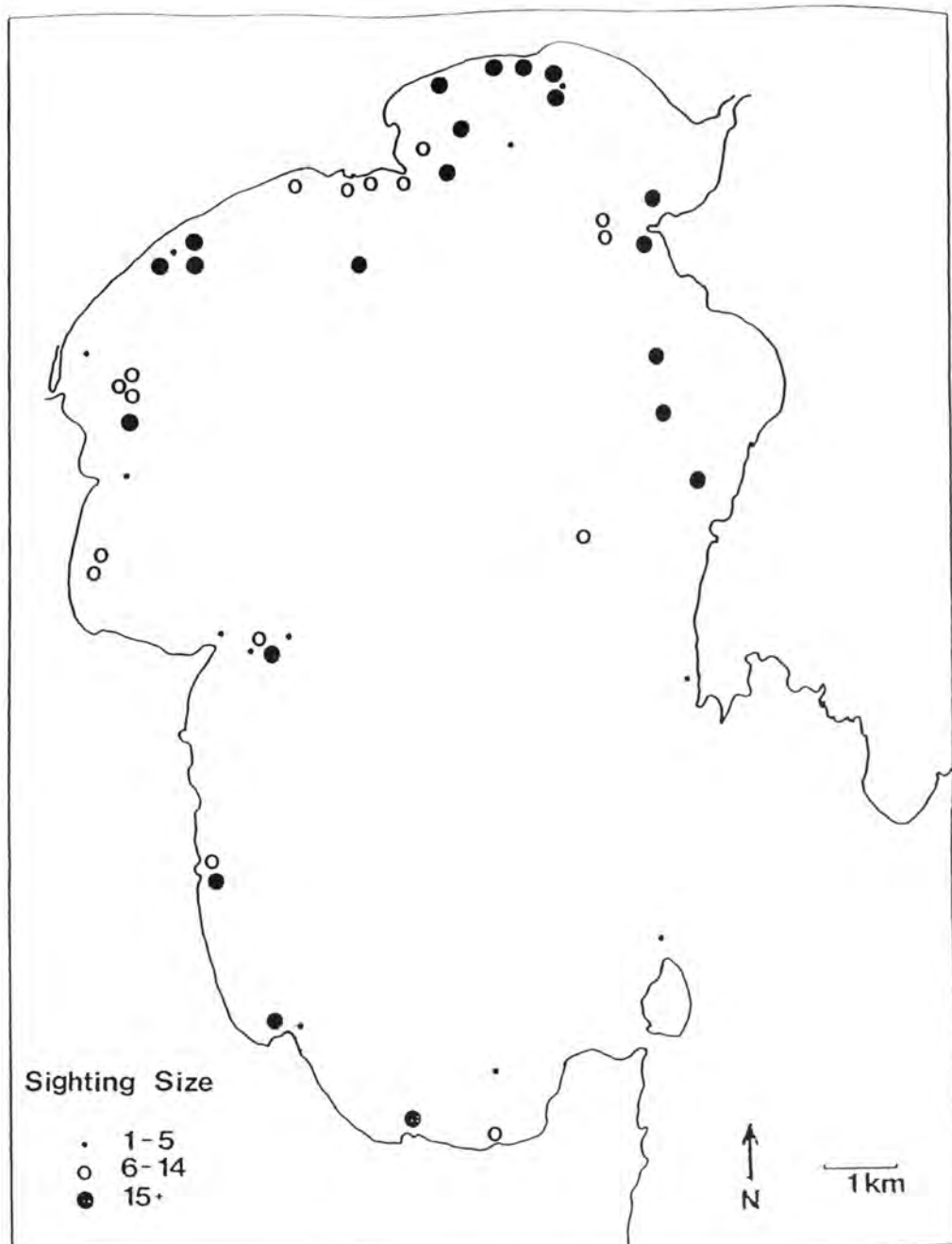


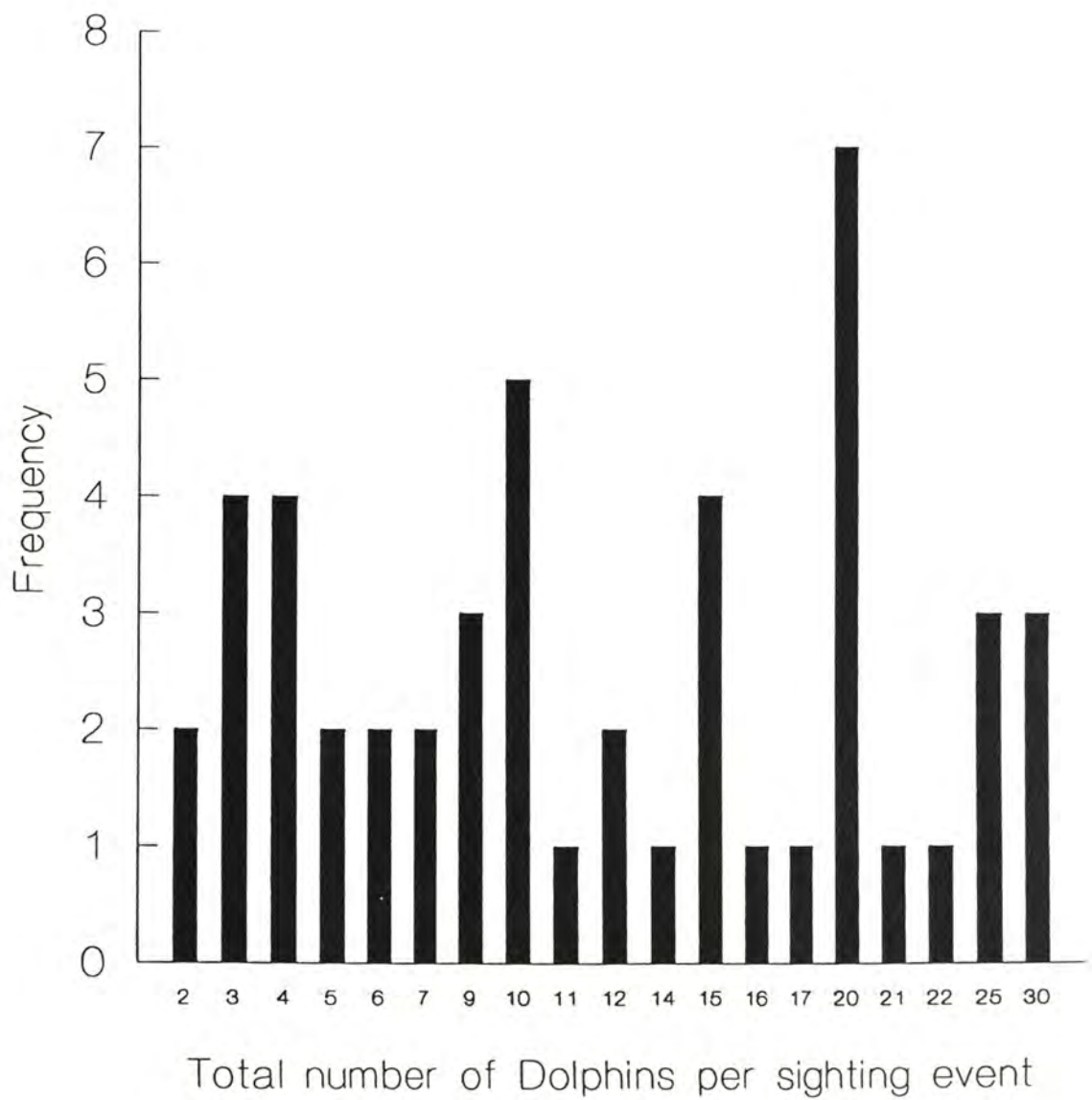
Figure 3.2: Map indicating the location and size of sightings (i.e. number of dolphins sighted), recorded on the Search and Encounter Survey.

For environmental variables which could fluctuate irregularly throughout the course of a single day in the field, such as sea surface temperature, weather, Beaufort sea state (BF) and wind direction, no attempt has been made to establish sampling effort across the whole survey. These variables are analysed where applicable with respect to sighting events only.

### 3.3.2 Group Composition

During the 49 sighting events a total of 635 individuals were recorded, the minimum number per sighting event was two and the maximum 30 (Fig. 3.3). The mean sighting and pod sizes were 13 (S.E. 1.16) and 7.5 (S.E. 0.55), respectively. On the 29 occasions where calves were observed, a total of 48 individual calves was recorded. Calves represented 7.6% of observed animals. The majority of calf sightings were of single calves in a single pod ( $n=17$ ); on some occasions there were two calves in a single pod ( $n=14$ ) but only on one occasion were there three calves in one pod.

It was necessary to use grouping variables for most analyses of the total number of animals, total number of calves, pod number and size recorded per sighting event, due to the small data set and degree of sparseness, for chi-square analyses (see Section 3.2.4). A *t*-test indicated that the mean number of animals recorded at each sighting event was significantly different when calves were present or absent (Table 3.8b-li). The mean number was larger, 15.8 (S.E. 1.48), when calves were present versus a mean group size of 8.9 (S.E. 1.47) when absent. An association was also found between the presence or absence of calves and sighting size classes (Table 3.8b-li), with calves mainly present in large sized sightings (i.e. 11+ dolphins). Also, a *t*-test indicated the mean number of dolphins per pod was significantly different when calves were present or absent (Table 3.8b-li). The mean number of dolphins per pod was larger, 9.7 (S.E. 0.87), when calves were present than when calves were not, 6.2 (S.E. 0.65). No association was found, however, between the presence or absence of calves and pod size classes (Table 3.8b-li).



**Figure 3.3: The frequency distribution of the total number of dolphins sighted per sighting event on the Search and Encounter Survey.**

A positive association was found between sighting size and the number of pods recorded at each sighting event (Table 3.8b-lii). The smaller the total number of animals recorded per sighting, the more likely it is to be a single pod, and conversely the larger the total number of animals recorded per sighting, the more likely multiple pods are to be present. No association was found between the number of pods recorded at each sighting event and the presence or absence of calves (Table 3.8b-li). No association was indicated between pod size and the number of calves per pod (Table 3.8b-liii).

### **3.3.3 Distribution of sightings across Habitats**

#### **3.3.3.1 Depth**

Sampling effort (km) was greater (74%) in nearshore waters (i.e.  $\leq 10$  m, Table 3.8a-lvi). When this unequal distribution was considered, the number of sightings in nearshore and deeper waters were as expected on the basis of this effort (Table 3.8c-li), i.e. more sightings in nearshore waters than in deeper waters.

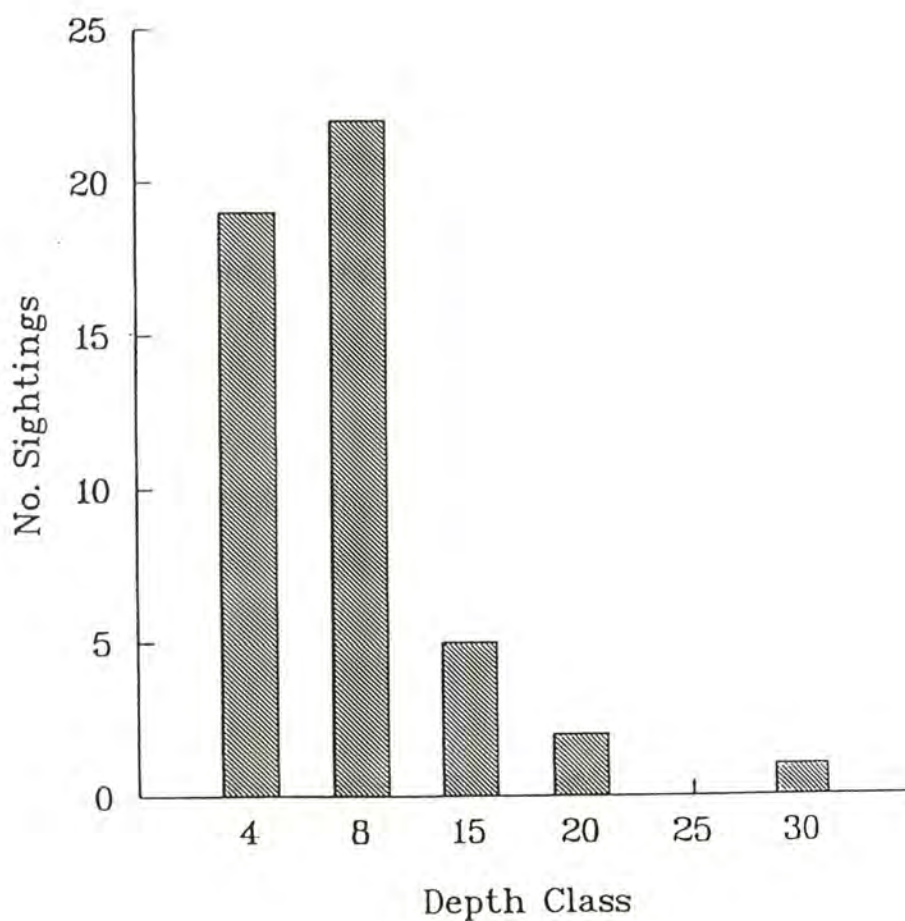
Furthermore, when the area of the Bay is separated into three depth categories (Table 3.3) the distribution of sightings across these is also found to be unequal (Table 3.8c-li). That is, 77.5% of sightings were made in waters of 10 m or less which represents only 23.9% of the Bay.

Sighting depths were divided into a shallow category (i.e.  $\leq 8$  m class) which has a maximum depth 11.5 m and a deep category (i.e.  $\geq 15$  m class) which includes waters greater than 11.5 m in depth (see Table 3.2). Of the total 49 sightings, 84% were initially sighted in waters 11.5 m or less (Fig. 3.4).

However, *t*-tests indicated that the mean number of animals recorded at each sighting event (Table 3.8c-lii), the mean size of pods (Table 3.8c-lv), and the mean sighting depths recorded when calves were present and absent (Table 3.8c-lvii), were not significantly different over shallow ( $\leq 11.5$  m) versus deep ( $> 11.5$  m) waters.

**TABLE 3.3: The area covered by three different depth categories in the Bay (sq km), estimated using Chart Aus 193 (R.N.A., 1986).**

Depth (m)	Area (sq km)	Area of Bay (%)
0-10	28.1	23.9
10-20	61.4	52.3
>20	27.8	23.7
<b>Total</b>	<b>117.3</b>	<b>99.9</b>



**Figure 3.4: Distribution of sightings across depth classes on the Search and Encounter Survey (i.e. 4m=0-6m; 8m=6-11.5m; 15m=11.5-17.5m; 20m=17.5-22.5m; 25m=22.5-27.5m; and 30m=27.5-40m).**

Furthermore there was no association between shallow versus deeper waters and sighting size (Table 3.8c-liii), the number of pods recorded per sighting (Table 3.8c-liv), pod size (Table 3.8c-lvi), the presence or absence of calves (Table 3.8c-lvii), and the presence or absence of calves per pod (Table 3.8c-lviii).

### **3.3.3.2 Substratum**

The areas covered by the three substrata investigated are listed in Table 2.1. The expected number of sighting events, calculated with respect to these areas, and the observed values were tested by the chi-square goodness-of-fit test. The probability value indicated that the null hypothesis ( $H_0$  = the distribution of sightings is independent of substrata) should be rejected, as there was a significant departure from what would be expected by chance (Table 3.8d-li). That is, almost 50% of sightings occurred over the rarer habitats which represented only approximately 10% of the area.

However, ANOVA indicated that the mean number of animals recorded at each sighting event was not significantly different across the three different substrata (Table 3.8d-lij). The mean number of animals recorded over sand, seagrass and rocky areas were 12.4 (S.E. 1.53), 13.6 (S.E. 2.03) and 13.7 (S.E. 4.3), respectively. Although sighting size was associated with substrata over which sightings were made (Table 3.8d-liii), i.e. most sightings over sand were of medium or large size, over seagrass mainly large groups were sighted and over rocky areas all group sizes were fairly evenly found. Also, unlike the large and medium groups, small groups were recorded fairly evenly over all substrata. In terms of the relative areas of substrata, these trends suggest the importance of seagrass beds. There was no association between the substratum over which sightings were recorded and group composition variables (Table 3.8d liv-lviii).

ANOVA indicated there was a significant difference between the mean sighting depth and substratum over which sightings were recorded (Table 3.8d-lix). That is, the mean sighting depths over sand, seagrass and rocky areas were 10.3 m (S.E. 1.06), 5.9 m (S.E. 0.29) and 6.0 m (S.E. 0.82), respectively. The Peritz procedure

indicated that sightings over sand were significantly deeper than sightings over seagrass and rock. These results probably reflect the fact that no seagrass and only a small area of rock is present at 11.5 m or deeper and hence mainly sand is found in 15 m or greater depth classes.

Indeed all seagrass and most rocky areas are in 10 m or less of water. Because this depth is where 77.5% of sightings were made ( $n=38$ ), it was decided to investigate the distribution of sightings across habitats within just this depth zone. The most important exception in terms of area is at Plantation Point (CSIRO, 1994) where approximately one half of the reef extends beyond 10 m (see Fig. 2.2). When the area of the three different substrata is derived for waters  $\leq 10$  m (Table 3.4), no significant difference was found in the distribution of these sightings corrected on the basis of these areas (Table 3.8d-li). Nor was there a significant difference indicated by ANOVA in the mean total number of dolphins sighted across substrata in waters  $\leq 10$  m in depth (Table 3.8d-liv). The mean total number of dolphins over sand, seagrass and rocky areas were 16.3 (S.E. 1.9), 13.6 (S.E. 2.03) and 13.7 (S.E. 4.25), respectively. However, a weak but significant association was found for sighting sizes over the different substrata (Table 3.8d-lviii), with large groups sighted more often over seagrass, medium size groups more frequently over sand, and small groups fairly evenly across all substrata. This pattern in waters  $\leq 10$  m in depth is similar to that found for sighting size across substrata, throughout the Bay (see Table 3.8d-lviii). There was no association between the number of pods in two categories in nearshore waters across the three substrata (Table 3.8d-lvi). ANOVA indicated no significant difference in the mean size of pods over the different substrata in nearshore waters (Table 3.8d-lv). Nor were there any associations between pod size classes, the presence or absence of calves per sighting or per pod across substratum in waters  $\leq 10$  m in depth (Table 3.8d lvi-lviii).

**TABLE 3.4: Estimated total areas of different substrata in waters of  $\leq 10$  m in depth.**

Substratum	Area (sq km)	Percentage of nearshore waters (%)
Sand	16.0	57
Seagrass	8.9	32
Rock	3.2	11
<b>Total</b>	<b>28.1</b>	<b>100</b>

### 3.3.4 Environmental Variables

Although surveys were distributed equally across quadrants (Table 3.8a-iii), sighting events ( $n=49$ ) were not. There was a significant difference in the distribution of sightings across quadrants when the expected number of sightings is adjusted for the different areas of each (see Table 3.1a) (Table 3.8e(1)-li). Seventy-one percent of sightings were made in the northern half of the Bay which, as arbitrarily defined, has a longer coastline and greater area than the southern half of the Bay. It also has a greater area of seagrass meadows and rocky areas and a greater proportion at shallower depths (see Fig. 2.3). Most sightings were in the NW quadrant (43%) and the least in the SE quadrant (see Fig. 2.1).

It was necessary to combine quadrant data due to sample sparseness, and so the two southern and two northern quadrants were combined, i.e. effectively the northern and southern halves of the Bay. A *t*-test indicated there was no significant difference between the mean number of dolphins per sighting event across the north and south of the Bay where sightings were recorded (Table 3.8e(1)-lii).

There were however, associations between sighting size and the number of pods using two categories, across the north or south of the Bay (Table 3.8e(1) liii & liv). That is, large and medium sized groups were more often sighted in the northern half of the Bay while small groups were seen across both north or south, fairly evenly. In the north, sightings most frequently consisted of multiple pods, while in the south mainly single pods occurred and single pods were sighted fairly evenly across the north and south of the Bay.

A *t*-test indicated there was no difference in mean pod size across north and south of the Bay. There was also no association between the size of pods and the presence or absence of calves (Table 3.8e(1) lv-lvii) across the halves of the Bay.

Dolphins were sighted in all months surveyed except January 1991 and May 1992 when only one survey was conducted in each month. Calves were sighted in all

months when sightings were recorded except April and February 1990 and September and November 1991. Although surveys ( $n=40$ ) were distributed equally across seasons, (Table 3.8a-iii), sighting events ( $n=49$ ) were not (Table 3.8e(1)-li). That is, almost 41% of sightings were made in summer, 29% in winter, 18% in autumn and 12% in spring. ANOVA indicated no significant difference in the mean total number of dolphins per sighting event across seasons (Table 3.8e(1)-lii). Nor was there a significant association between; seasons and sighting size (Table 3.8e(1)-lii); number of pods per sighting event using two categories (Table 3.8e(1)-liv); mean pod size (Table 3.8e(1)-lv) or size of pods (Table 3.8e(1)-lvi). There was, however, an association between season and the presence or absence of calves (Table 3.8e(1)-lvii) with the highest proportion of sightings with calves in winter.

Sixty seven percent of all sighting events occurred under clear weather conditions, i.e. sunny with less than 50% cloud cover. Also, of the nine surveys where animals were not seen, eight took place under clear conditions. Sightings were made at Beaufort sea state (BF) 5 or less with almost 80% of sightings recorded at BF 3 or less. On the nine surveys where animals were not seen the sea state ranged from BF 1-3. No significant associations were found between group composition data and when BF was divided into good (BF 0-3) and not good (BF 4+) sighting conditions (Table 3.8e(1) lii-lvii). There is no association between season and mean BF per survey, when divided into good (BF 0-3) and not good (BF 4+) sighting conditions (Table 3.8e(1)-lviii) and sighting events (Table 3.8e(1)-lix). That is, less than optimal conditions may occur across all seasons.

Sighting events were distributed evenly across the four tidal states (Table 3.8a-lv). No associations were found for tidal state and five group composition variables (Table 3.8e(2)) i.e. mean number of dolphins per sighting event (lii), sighting size (liii), number of pods per sighting event (liv), mean number of dolphins per pod (lv), and the presence or absence of calves (lvii). An association was found between tidal state and the size of pods (Table 3.8e(2)-lvi). Small pods were more frequently recorded at flood tide and medium sized pods at high tide while large

Pods were seen across all tidal states. Also, on ebb tides pods were mainly small and medium sized and at low tide mainly small.

No initial sightings were recorded on this survey prior to 0600 (i.e. the first time of day category) and only two sightings were recorded after 1800 (i.e. the last time of day category). Hence all initial sighting times were divided into three categories; morning = prior to 1000; midday = 1000-1359; afternoon = 1400 or after. Sighting events were distributed as expected across the three remaining categories when the chi-square goodness-of-fit test was applied, based on the uneven sampling of the S&E Survey. That is, as expected, almost 45% of sightings were recorded at midday (1000-1359) (Table 3.8e(2)-li). No association of time of day was found with five group composition variables (Table 3.8e(2)), i.e. mean number of dolphins per sighting event (lii), sighting size (liii), number of pods per sighting event (liv), pod size (lvi) and the presence or absence of calves (lvii). ANOVA indicated just a significant difference between time of day categories and the mean number of dolphins per pod (Table 3.8e(2)-lv). The Peritz procedure indicated that the mean pod sizes in the morning and midday, 8.8 (S.E. 0.97) and 7.2 (S.E. 0.78), respectively, were greater than in the afternoon, 5.0 (S.E. 0.83).

Wind direction was recorded at the time of sighting; however, the small sample size did not allow chi-square analysis across the nil wind category plus eight compass points recorded. Hence, data were combined into only five categories initially. Prevailing winds at the time of sightings were from the north (33%) and west (31%) with only four occasions when no wind was recorded. As only a small number of recordings were made under nil wind conditions, to reduce sparseness of the data set these were excluded from the final analyses. There were no associations between wind direction and five group composition variables (Table 3.8e(2)), i.e. mean number of dolphins per sighting event (lii), sighting size (liii), number of pods per sighting event (liv), mean number of dolphins per pod (lv) and the presence or absence of calves (lvii). An association was indicated between wind direction and pod size (Table 3.8e(2)-lvi). Most pods were recorded with winds prevailing from the north and west. The greatest number of small pods were

sighted under northerly wind conditions while medium sized pods were mainly seen in westerlies and large pods were sighted fairly evenly in all wind directions. When the winds came from the east mainly small pods were seen and when from the south any pod size may be found.

Wind direction and season were associated (Table 3.8e(2)-lix), with winds prevailing from the north in summer and from the west (i.e. offshore) in winter. However in this contingency table some expected values were less than one, and so this result is not considered further.

Recorded sea surface temperatures ranged between 14.1°C and 24.3°C ( $n=48$ ) with an overall mean of 19.5°C (S.E. 0.41). ANOVA indicated a significant difference between sea surface temperatures across season (Table 3.8e(2)-lix). The seasonal means were; winter 16.9°C (S.E. 0.67), spring 17.2°C (S.E. 0.94), summer 21.5°C (S.E. 0.41), and autumn 20.7°C (S.E. 0.24). The Peritz procedure indicated that there was no significant difference between summer and autumn mean temperatures but that these were greater than spring and winter. The minimum temperature was recorded in winter but the maximum in autumn, suggesting a seasonally delayed period for the study area waters to warm. Temperatures were only analysed with respect to sighting events and not per pod. A  $t$ -test indicated no significant difference in the mean total number of animals recorded per sighting when temperature was divided at the mean into cooler or warmer sea surface temperatures (Table 3.8e(2)-lii). Nor was there any association between sighting sizes when divided into two classes or the number of pods per sighting, and cooler versus warmer temperatures (Table 3.8e(2) liii-liv). A  $t$ -test indicated no significant difference in sea surface temperatures between calves being present or absent (Table 3.8e(2)-lvii).

### 3.3.5 Spatial Pattern

Seven of the eight descriptive categories for the spatial arrangement of animals with respect to each other were recorded in this survey (Table 3.5). The category not recorded was “not discernible”.

A *t*-test indicated no significant difference between the mean total number of dolphins per sighting for clumped and dispersed groups (Table 3.8f-lii). There was an association indicated between the overall spatial pattern of all animals observed and sighting size (Table 3.8f-liii) with larger sightings typically in clumped or mixed spatial patterns but small or medium sightings typically clumped and all sizes observed in spread spatial pattern. There was also an association indicated between the overall spatial pattern of all animals observed and the number of pods using only two categories (Table 3.8f-liv). The clumped pattern included single and multiple pods equally while the spread and mixed patterns involved mainly single and multiple pods, respectively.

There was however, no association indicated between pod spatial pattern, in terms of either clumped or dispersed patterns, and the mean number of dolphins per pod or pod size classes (Table 3.8f lv & lvi). There was also no association indicated between the absence or presence of calves and the spatial pattern of the whole group or pods (Table 3.8f lvii & lviii).

No association was indicated between the overall spatial arrangement of the whole group sighted and habitat variables (Table 3.8f lix-lxi), nor was any association indicated with environmental variables (Table 3.8f lxii-lxviii). No association was indicated between the spatial arrangement of each pod using the two general categories of clumped and dispersed, and the habitat variable depth when divided into shallow ( $\leq 11.5$  m) or deep ( $> 11.5$  m) waters (Table 3.8f-lx). However, using these two categories of spatial pattern an association was indicated with sighting substrata (Table 3.8f-lxi), where the greatest frequency of clumped groups were over sand, while most dispersed groups were sighted over seagrass. However, only

**TABLE 3.5: Frequency of spatial patterns for Search and Encounter sighting Events,  $n=49$ , and pods,  $n=85$ . Where na indicates not applicable and nil indicates the spatial pattern was not recorded.**

	Clumped	Spread	Core Group + others spread	Multiple clumped pods	Linear	Abreast	Circle
<b>Sighting</b>	16	6	10	15	1	1	nil
<b>Pod</b>	69	10	3	na	1	1	1

clumped pods were sighted over rock while over seagrass most groups had dispersed spatial patterns.

No association was indicated with the spatial pattern of each pod using clumped and dispersed categories and all seven environmental variables (Table 3.8f lxii-lxviii).

### **3.3.6 Behavioural Variables**

Eight of the eleven descriptive categories for behaviour were recorded for this survey (Table 3.6). The behavioural activities not recorded were “resting”, “avoidance”, and “not discernible”. For data analyses three categories of behavioural activities were used, i.e. travel, milling and social/feed (see Section 3.2.6).

Almost 50% of pods recorded were travelling, with milling and socialising equally represented by 21% of pods and only approximately 8% observed feeding (see Table 3.6). This low number of recorded feeding behaviours may reflect the very specific definitions of this category (see Appendix 2) and the inclusion of feeding in other categories (see Section 3.2.6).

It was not considered meaningful to analyse the overall behaviour of all animals sighted when in many instances pods were involved in different activities. Hence, primarily the behaviour of pods is analysed here, except for the overall spatial pattern of the whole sighting group and the general behaviour of the whole sighting group. For the overall spatial patterns of clumped versus dispersed, no association was found with behavioural activity of the whole group (Table 3.8g(1)-li). Nor was there any association between the behaviour of individual pods and their spatial pattern, using the same categories (Table 3.8g(1)-lii).

ANOVA indicated no significant difference in the mean number of dolphins per sighting event and sighting behaviour (Table 3.8g(1)-liv), nor for the mean number

**TABLE 3.6: Frequency of overall behavioural activities recorded per sighting event,  $n=49$  and per pod,  $n=85$ , where nil indicates the behaviour was not recorded.**

	Slow Travel	Mod. Travel	Fast Travel	Mill	Rest	Social	Feed	Feed/ Travel	Social/ Travel
<b>Sighting</b>	23	10	7	6	nil	1	1	1	nil
<b>Pod</b>	23	11	8	18	nil	1	3	4	17

of dolphins per pod and pod behaviour (Table 3.8g(1)-lvii). There was an association indicated between the behaviour of pods and their size, where small and medium sized pods were most frequently involved in travel and large pods involved in all activities. Milling behaviour mainly involved small pods and social/feed small and medium pods (Table 3.8g(1)-lviii). No association was found between the behaviour of pods and the absence or presence of calves (Table 3.8g(1)-lix).

ANOVA indicated no significant difference in the mean sighting depth and the behaviour of the overall group (Table 3.8g(1)-lx). An association was indicated between the behaviour of each pod and the habitat variable depth when divided into shallow ( $\leq 11.5$  m) or deep ( $> 11.5$  m) waters (Table 3.8g(1)-lxi). Most activity occurred in shallow waters but all behaviours were recorded in both, except for milling which was only seen in shallow waters. Travel was most frequently seen in shallow waters, and travel and social/feed evenly recorded in deep waters. No association was indicated between the behaviour of each pod and sighting substratum (Table 3.8g(1)-lxii).

Of the seven environmental variables analysed, three indicated an association with the behaviour of pods (Table 3.8g(2)). These were tidal state (li), time of day (lii) and wind direction (liv). Both travel and social/feed categories were fairly evenly distributed across all tidal states but peaked at flood tide. No milling behaviour was recorded at flood tide and this activity peaked at ebb tide. Most activities and the highest frequency of travel and milling sightings were recorded in the middle of the day (i.e. 1000 to 1400) when most hours were spent in the field. Particularly interesting then is the highest frequency of social/feed behaviour, which was recorded in the morning. The highest frequency of social/feed and travel activities occurred with winds recorded mainly from the north, and for the latter from both north and west. Milling was mainly recorded when winds were from the east.

Direction of travel of the animals was analysed using five categories, i.e. nil and the cardinal compass directions ( $n=48$ ). This variable was only recorded at 48 of

the 49 sighting events (Table 3.8g(2)). Only three environmental variables were considered applicable for analysis in terms of a potential influence on the dolphin's direction of travel, i.e. tidal state (li), time of day (lii) and wind direction (liv). Due to the small number of sighting events,  $n=4$ , with nil wind conditions these were excluded from analysis. No association was found between the dolphin's direction of travel and any of these three variables. Also, for all three contingency tables some expected chi-square values were less than one, hence these results were not considered further.

### **3.3.7 Abundance and Density Estimates**

#### **3.3.7.1 Abundance**

The total number of dolphins sighted ( $n=635$ ) varied significantly across the different quadrants of the Bay when these were adjusted for the area of each (Table 3.8h-li), with 78% of animals being recorded from the northern half of the Bay with the most and least being sighted in the NW and SE, respectively. In contrast, the total number of calves sighted ( $n=48$ ) did not vary significantly across the different quadrants of the Bay when these were adjusted for the area of each (Table 3.8h-lii).

There was a significant difference in the total number of animals sighted across seasons when survey effort was considered, with the highest number (almost 39%) of animals recorded in summer although this was less than expected (Table 3.8h-li). Winter, with the second highest number (28%), recorded a significantly higher number of dolphins than expected on the basis of survey effort. This result reflects the same pattern as for sighting events (Table 3.8e(1)-li).

There was also a significant difference in the total number of calves sighted across seasons when survey effort was considered. The highest number was recorded in winter (44%) and then autumn (25%) both above expectations (Table 3.8h-lii). Lower numbers of calves than expected on the basis of survey effort were recorded

in summer and spring. This result is in contrast to both the distribution of survey effort and sighting events, unlike for sightings above.

There was no significant variation in the total number of animals or calves sighted across the three years of the Survey when survey effort was accounted for (Table 3.8h li & lii).

The total number of animals sighted over sand, seagrass and rock were 322, 231 and 82 respectively. When sightings at depths beyond 10 m were excluded ( $n=38$ ), the highest number of animals sighted were then over seagrass (231), followed by sand (169) and fewest over rock (82). However, when the areas of each substratum in these waters were considered (see Table 3.4), more dolphins than expected were seen over seagrass and rock, and less than expected over sand (Table 3.8h-li). The total number of calves sighted over sand, seagrass and rock were 23, 19 and six. Even when sightings with calves at depths beyond 10 m were excluded ( $n=11$ ), most calves were sighted over seagrass (19), then sand (12) and fewest over rock (6). When the areas of each substratum in these waters were considered the same pattern as for total abundance was found for the distribution of calves (Table 3.8h-lii).

### 3.3.7.2 Density

The mean density estimate for the whole study area (117.2 sq. km) based on the total number of animals sighted ( $n=635$ ) per survey ( $n=40$ ) was 0.13 *Tursiops*/sq. km.

As this survey was focused on nearshore waters and the majority (77%) of sightings were located in waters of  $\leq 10$  m, dolphin density was estimated for these areas in each quadrant rather than the total area of each quadrant. The highest density occurred in the NW of the Bay with 0.69 *Tursiops*/sq. km and the lowest density was recorded in the SE quadrant with 0.11 *Tursiops*/sq. km. (Table 3.8i-li).

Seasonal density also varied in the study area for this Survey (Table 3.8i-iii) with the highest densities recorded in winter and spring at 0.17 and 0.15 *Tursiops*/sq. km, respectively. The lowest seasonal density was 0.11 *Tursiops*/sq. km, recorded in autumn. This density estimate highlights the possible increase in dolphins in the Bay in winter, as suggested by the abundance data (see Section 3.3.7.1).

Estimated dolphin density varied across the different substrata located in  $\leq 10$  m of water of the Bay when the area of each was considered, for this Survey. The highest density occurred over rocky complex areas with 4.24 *Tursiops*/sq. km and then seagrass and sand with 1.53 & 0.70 *Tursiops*/sq. km, respectively (Table 3.8i-iii). Estimated calf density varied across the different substrata located in  $\leq 10$  m of water of the Bay when the area of each was considered, for this Survey. The highest density occurred over seagrass with 0.10 calves/sq. km, followed by rocky complex areas then sand with 0.08 & 0.03 calves/sq. km, respectively (Table 3.8i-liv).

### 3.4 Discussion

The 40 searches that made up this S&E Survey were conducted over a 29 month period. This survey achieved the aim of maximising the opportunity for finding dolphins with animals sighted on 77% of Surveys. The focus by inshore “populations” of *Tursiops* on shallow waters has been reported in a number of studies. The dolphins in Hansen’s (1983) study area, along the open California coast “...tended to stay near the shore in 2-4 m of water... generally 60-100 m offshore...”. Würsig (1978) reported that animals along the coast of Argentina preferred a depth of 2-6 m, but did move into water 39 m deep. The maximum depth in Shane’s (1987) study off Sanibel Island, Florida was 8 m and at 1.6 km offshore the bottom reached a maximum depth of only 6 m; however, 80% of pods sighted were in waters  $\leq 4$  m in depth. In Jervis Bay waters  $\leq 10$  m in depth range between a minimum and maximum distance offshore of approximately 100 m at Dart Point and 2.3 km in Hare Bay (see Fig. 2.2).

While there was a significant difference in survey effort across years with most conducted in 1990, when this was accounted for, there was no significant variation in the total number of animals sighted across the three years of the Survey. This does not necessarily indicate that the same animals are using the study area, i.e. forming a “resident” group. Individuals or subgroups within the population (see Section 1.2.2.3) may move in and out of the Bay, resulting in a consistent number of sightings annually but different individuals or subgroups at any point in time (see Section 6.4.1).

There was also no significant variation in the total number of calves sighted across the three years of the Survey when survey effort was considered. This trend may suggest that the population using the Bay is stable. That is, if not all calves are sighted, at least the rate of calf sightings across years is consistent in this area of the population’s range.

The average encounter lasted almost an hour, which in most cases could have been extended. However, after the assessment of environmental conditions and behavioural activity were made, and as many photographs taken as considered possible without harassing the animals, the search was continued. Despite this approach, only 21% of the total time spent searching during this survey was actually spent observing animals which is low compared with the contact rate for some other studies, e.g. 51% (Shane, 1990a) or approximately 47% and 33% (Ballance, 1990 & 1992, respectively). Acknowledging that the duration of individual encounters reflects the aims of any particular study, there remains the possibility that the overall density of dolphins in my study area is lower than at the above study sites.

Shane *et al.* (1986) reviewed density estimates from studies along the coast of the United States and these ranged from 0.06 to 4.8 dolphins/sq. km. The mean density estimate across multiple seasons for the protected Sarasota, Florida embayment study area was 1.3 dolphins/sq. km (Irvine *et al.*, 1981). Hansen (1983) estimated that density varied in his study area off California, between 2.23 and 3.10

dolphins/sq. km. Shane (1977) recorded a seasonal minimum and maximum in a shallow pass off Texas of 1.4 and 4.8 dolphins/sq. km, in October (autumn) and January (winter), respectively. In the present study all density estimates are based on small sample sizes and should be regarded with caution. However, both the mean density estimate for the whole of Jervis Bay (0.13 dolphins/sq. km) and seasonal density estimates (0.11 to 0.17 *Tursiops*/sq. km) for this Survey, fall within the range of those recorded elsewhere, although at the lower end of this range. The unknown level of resightings within and between survey days, although considered to be low, would further reduce density estimates.

#### **3.4.1 Group Composition**

The 635 animals seen at the 49 sightings were clustered into 85 pods, i.e. 36 sightings involved multiple numbers of pods. The minimum and maximum numbers of animals at any one sighting event were two and 30. Both the mean sighting and pod sizes, of 13 and 7.5, respectively, fall within the most common “group” sizes (2-15) reported by Wells *et al.* (1980). The maximum number of calves sighted at any one sighting event and on a single survey day were three and six, respectively. Calves constituted only 7.6% of all dolphins observed.

A positive association was found between sighting size and the number of pods recorded at each sighting event. Generally in Jervis Bay animals are found in groups less than 14 in number and at larger sightings (15+ dolphins) multiple sub-groups are present, i.e. pods for the purpose of this study.

The majority of calf sightings were of single calves. Calves were more likely to be present at larger sighting events rather than smaller sightings, i.e. with means of 15.8 and 8.9, respectively. Furthermore the mean size of pods with calves was larger (9.7) than without calves (6.2). Hence, the smaller the total number of animals recorded per sighting, the more likely it is to be a single pod and the less likely that calves would be present. Conversely the larger the total number of animals recorded per sighting (15+), the more likely that multiple pods and calves

were present. Similarly Weigle (1990) reported that "...the number of calves per school was highest in the same areas where mean school size was highest...". These trends may be related to increased protection of calves within larger groups or the higher visibility of larger groups versus smaller.

#### **3.4.2 Habitat (i.e. depth and substratum)**

The distribution of sighting events in terms of the area of three different depth categories for the whole of the Bay was the only significant depth-related association in this Survey. That is, 77% of sightings were made in waters of 10 m or less which represents only 24% of the Bay. However, the distribution of effort was not equal with most, i.e. 74% survey effort (km) expended in nearshore waters, i.e.  $\leq 10$  m. When this unequal distribution of effort was accounted for, there was no significant difference in the distribution of sighting across waters  $\leq 10$  m or greater. Hence this survey is unable to ascertain whether more dolphins are found in shallow versus deeper waters. It should be noted, however, that dolphins were readily observable on both sides of the search path, i.e. at distances greater than 500 m offshore and therefore typically in waters greater than 10 m. Furthermore the dolphin's movement typically paralleled the coast with only a few observations of animals moving directly away offshore. As almost 80% of sightings occurred at BF 3 or less it is considered that had dolphins been present within 1 km of shore, at least, they would have been sighted.

More dolphins were sighted over sand, less over seagrass and least over rocky areas throughout the Bay (see Section 3.3.7.1, Fig. 3.2). However, when the total area of the three different substrata in the Bay is considered, almost 50% of sightings occurred over the rarer habitats of seagrass and rocky complex areas which only represent approximately 10% of the total Bay area (see Fig. 2.3). When sightings at depths beyond 10 m were excluded ( $n=38$ ), and the area of the three different substrata for these waters were considered there was no significant difference in the distribution of sighting events across different substrata. However, for both total abundance and calves sighted in water  $\leq 10$  m,

significantly more were observed over the rarer substrata and less than expected over sand. These results suggest from a conservation management perspective, the importance of seagrass and rocky complex habitats in water depths  $\leq 10$  m to bottlenose dolphins in Jervis Bay.

Sighting size was the only group composition variable to be associated with the substrata over which sightings were made, both throughout the Bay and in waters  $\leq 10$  m in depth. Both results yielded a similar variable pattern of association with a trend, in nearshore waters, towards more large groups over seagrass than across other substrata. Authors have suggested group size may be related to a number of factors such as habitat, season, activity and predation pressure (see Section 1.2.2.3). Sighting size was not significantly associated with any environmental variables in this study other than the half of the Bay in which the sightings occurred, see below. However, sighting size was associated with spatial pattern, and pod size with pod behaviour. Accepting that group size may vary for a range of reasons at any given time it is possible that in Jervis Bay variable group size may, at times, reflect different activity patterns or patterns of use of the three substrata.

The mean sighting depths differed across the different substrata with sand, seagrass and rocky areas being 10.3 m (S.E. 1.06), 5.9 m (S.E. 0.29) and 6.0 m (S.E. 0.82) deep, respectively. This result suggests that dolphins: while recorded along the surfline of sandy beaches, were mainly found beyond the surf zone; were mainly sighted in the middle of seagrass meadows, not along the deeper margins which extend to depths of approximately 8 m; and were mainly sighted around the margins of rocky areas in shallower waters, not over the deeper areas.

When densities were calculated for the different habitats in waters  $\leq 10$  m in depth, the mean values showed that the density of dolphins was greatest in rocky areas, less over seagrass and least over sand. Interestingly, Lear & Bryden (1980) also found, on the basis of an aerial survey of both open coastal and embayment waters off Queensland, that the density of dolphins was greatest in rocky shore areas, less

in ocean beach areas and least in bay shore areas. Lear & Bryden's (1980) density estimates were based on an area 218 km long and one kilometre wide. The authors inferred that water depth had some influence on the distribution of sightings, reporting "...significantly greater numbers of bottlenose dolphins were seen in rocky regions of coastline with deep water close to shore than in open coast or enclosed bay areas where the bottom is more gently shelved...". This interaction between deep water and shallow rocky areas is not reflected in the results of this survey. With the exception of one sighting along the rocky foreshore at Dart Point, where at one kilometre the water depth is approximately 20 m, all other rocky areas with sightings are where the water is  $\leq 15$  m in depth, at one kilometre from shore. If there is an influence at rocky locations of adjacent water depths, the results of this survey suggest it is rocky areas in shallow waters which are preferred by dolphins, in contrast to the above study. It must be remembered that Lear & Bryden (1980) were referring to animals in an open bay and inshore oceanic areas whereas this study was done in enclosed waters.

While the small sample size necessitates caution in interpretation of all density estimates, it is interesting to note that the pattern of estimated calf density across the different substrata located in  $\leq 10$  m of water varied from density estimates based on total numbers of dolphins. The highest density of calves occurred over seagrass, then rocky areas.

### **3.4.3 Environmental Variables**

The sampling regime of this Survey was evenly distributed across seasons, however, sighting events were not, with the highest number of sightings in summer (41%), then winter. Also, there was a significant seasonal variation in the total number of animals sighted when survey effort was considered. The highest number, almost 39% of animals, were recorded in summer with the second highest number (28%) in winter. However, the total number recorded in winter was higher than expected. The highest seasonal density throughout the Bay (per survey) was

recorded in winter also, suggesting a possible increase in dolphins in the Bay at this time.

The presence or absence of calves was the only group composition variable that was associated with season. A peak in calf sightings occurred in winter ( $n=12$ ), with similar numbers in summer ( $n=8$ ) and autumn ( $n=7$ ), and the lowest number of sightings in spring ( $n=2$ ). There was also a significant difference in the total number of calves sighted across seasons with the highest number of calves recorded in winter (44%) and then autumn (25%). This result reflects seasonal density estimates, but is in contrast with the distribution of sighting events and total abundance, for which the greatest numbers were both in summer.

No “live” newborns were sighted in this study, i.e. less than one month old with visible fetal folds, lead grey in colour and usually head-slapping when breathing, as defined by Shane (1990a). In this study the definition of calf (see Section 3.2.4) could incorporate animals up to a year old, at least. Hence, the peak in calf sightings in winter may reflect an increase in abundance and/or an increase in calf visibility. The latter may be associated with less avoidance behaviour exhibited by the mother and slightly older and larger calves. If this is the case, based on a 12 month gestation period (Tavolga & Essapian, 1963) these results may suggest a calving peak in autumn.

Würsig (1978) noted that “...higher ambient temperature, as in most terrestrial mammals and in pinnipeds and baleen whales may be of physiological advantage to the newly-born young...”. Although ambient temperatures were not recorded sea surface temperatures recorded in Jervis Bay by CSIRO (1994) were warmest from January to April typically ranging between 19°C to 25°C. During this Survey there was a significant difference between sea surface temperatures across seasons. The minimum temperature (14.1°C) was recorded in winter and the maximum (24.3°C) in autumn. This seasonal delay for the study area to warm coincides with a proposed calving peak in autumn. However, little can be said about the influence of sea surface temperatures on breeding activity of bottlenose dolphins in a Bay

which is vertically stratified by temperature for much of the year (see Section 2.1.1). Furthermore, Bay waters are apparently colder for most of the year than adjacent offshore waters (CSIRO, 1994), so associating any increase in females and calves in the Bay with warmer temperatures is also problematic.

Although surveys were distributed equally across Bay quadrants sighting events and the total number of animals were not. That is, 71% of 49 sightings and 78% of 635 dolphins were recorded in the northern half of the Bay. An association was indicated between both sighting size and pod numbers, and the occurrence of sightings in the north versus the south, of the Bay. That is, medium and large sightings made up mainly of multiple pods were most frequent in the north, and small sightings of single pods were recorded in either half of the Bay.

These differences may be related to the fact that the northern half of the Bay, as arbitrarily defined, has a longer coastline and greater area, i.e. approximately 53% and 55% of the total, respectively, than the southern half. Alternatively, such results may relate to habitat differences between the north and south. For example, the northern half of the Bay has the greater area of seagrass meadows and rocky reefs, and a greater proportion at shallower depths (see Fig. 2.3).

A difference in the number of sightings is also evident within the northern half of the Bay with nearly 43% of all sightings located in the NW quadrant and only approximately 29% in the NE quadrant. The NW quadrant also recorded the highest density in water  $\leq 10$  m in depth. The most apparent differences in habitat between the two northern quadrants are summarised in Table 3.7. The differences between the two quadrants is unlikely to be related to the length of each shoreline (NW=12 km and NE=13 km) or area (28% and 27%, respectively). The clockwise flow of water around the Bay reported by CSIRO (1994) is probably unlikely to result in major differences between the two northern quadrants either, as the inflow to the Bay is concentrated near the surface on the southern side of the entrance. Hence, I would suspect this current's influence to be markedly weakened by the time it reached the northern section (see Section 2.1.1). The exact nature and

**TABLE 3.7: Summary of some apparent differences between the arbitrarily determined NW and NE quadrants of the Bay.**

NE	NW
* approximately 75% of seagrass in the Bay (West, 1987)	* a relatively small area of seagrass, i.e. 2 sq km approximately (CSIRO, 1994)
* the longest stretch of rocky shoreline, 4 km approximately (R.N.A., 1986); and a total area of 40 ha of rocky habitat (West, 1987)	* the single largest intertidal rock platform in the Bay, and a total area of 161 ha of rocky habitat (West, 1987)
* the second largest estuary draining into the Bay is the only significant estuary in the NE	* the largest and deepest estuary entering the Bay plus three other sizeable estuarine water bodies (i.e. Moona Moona Ck, Wowly Gully and Callala Ck)
* slightly smaller area of shallower waters i.e. approximate areas (sq. km) at $\leq 10\text{m}$ , $10\text{-}20\text{m}$ , and $> 20\text{m}$ are 10.1, 19.5 & 2.2, respectively	* slightly larger area of shallower waters i.e. approximate areas (sq. km) at $\leq 10\text{m}$ , $10\text{-}20\text{m}$ , and $> 20\text{m}$ are 10.7, 21.9 & 0.6, respectively
* the NE has only minimal coastal development	* most of the NW shoreline is urbanised
* the orientation of the NE quadrant is towards the west and may be less effected directly by oceanic conditions, at least along the northern end of its margin	* the orientation of the NW quadrant is towards the east (i.e. the entrance to the Bay) and although furthest from the entrance may be exposed to more oceanic conditions, particularly with seasonally prevailing winds from the south and east

degree of the impact of these differences, in terms of the distribution patterns of dolphins and their prey are difficult to ascertain. However, such differences constitute different environmental conditions around the Bay's shoreline which might influence the dolphins' movement patterns.

Shane *et al.* (1986) concluded about short-term movements that "...dolphins move with concentrations of food, move into shallow safe areas, move with or against the tide and show some regular (but usually not strong) diurnal movement patterns. The overriding theme is variability...". Shane *et al.* (1986) also believed these animals "...know particular areas well and that they remember when and where the best chances for finding prey are likely to be...". In this study only a few associations with environmental variables that may affect the short-term movement of bottlenose dolphins in the study area were found. These were tidal state, time of day and wind direction, and all related to pod data ( $n=85$ ), not sighting event data ( $n=49$ ). These results possibly reflect the different sizes of the data sets and the need for larger sample sizes when considering these type of variables. For example, Shane (1990a) investigating five dolphin activities and a number of temporal and environmental factors, used a combined data set of three minute ( $n=6196$ ) instantaneous and converted duration records of focal-group activity which involved 310 hours of direct observation.

Survey effort and sighting events were evenly distributed across tidal state. The only association between this variable was with the size of pods, where small pods (1-5) were more frequently recorded at flood; medium size groups (6-14) at high tide; and larger groups (15+) across all tides. Hansen (1990), unlike this study, found significant variation in mean group size across tidal state with mean group size lowest (4) at the lowest tide, increasing to 28 at a flood tide, and decreasing to 17 at the highest tide. He indicated the reasons for this pattern were not readily evident but considered that feeding strategies were unlikely to be responsible for the variation in group size. Indeed in Jervis Bay, tidal currents are weak and make only a minor contribution to the dynamics of the Bay (CSIRO, 1994). Hence, tidal influence on the distribution of the dolphins' prey or the dolphins is likely to be

minimal. However, this does not necessarily eliminate localised movements of prey in association with tides at particular sites which may also vary over time, but which the dolphins may be aware of.

The mean number of dolphins per pod was the only variable that indicated a significant difference between time of day categories with mean pod sizes being the greatest in the morning and at midday and effectively decreasing through the afternoon. Most surveys ended between 1500 and 1600, hence any changes in group sizes toward dusk would be undetected on this survey.

There was an association between wind direction and size of pods and pod behaviour. Discussion of these results is problematic with respect to the circular character of the study area and the higher number of sightings along the north and western shoreline of the Bay. Under the recorded wind conditions, these areas are relatively protected.

#### **3.4.4 Spatial Pattern**

Shane (1990a) indicated that "...pod geometry is not random but has functional significance which varies depending upon the dolphin's activity...". Hence, the main purpose of recording spatial patterns and behaviour of sightings and pods was to investigate: a) how dolphin spatial arrangements and behaviour were associated in Jervis Bay; and b) if either or both of these varied across different habitats.

Not unexpectedly, overall group spatial pattern was associated with the size of sightings and pod number. That is, when sightings were of small or medium size they were clumped (equally in single or multiple pods) while larger sightings were either mixed or clumped (either single or multiple pods). The association of overall spatial pattern with pod number appears to reflect category definition. A spread spatial pattern made discerning subgroups problematic and so they were mainly recorded as single pods. Allocation into single or multiple pods for the mixed category was dependent on the distance between the core group and other animals

but they were typically recorded as multiple pods. The clumped spatial pattern which was readily identified represents the largest category, and was made up equally of single and multiple pods.

There was an association between pod spatial pattern across the three different substrata. That is, for the two categories of spatial pattern used, most pods (82%) were described as clumped versus dispersed. Clumped sightings were greatest over the most open substratum (sand), and decreased over more structurally complex substrata (i.e. seagrass and then rock). Dispersed pods were only recorded over sand and seagrass, not over rocky areas and were greatest over seagrass. Hence, this result may reflect an influence of the physical habitat on pod spatial pattern, as Shane (1990a) suggested for group size. However consideration of spatial arrangement alone without corresponding behavioural activity is unlikely to elucidate the nature of the influence of physical habitat on group spatial pattern (Shane *et al.*, 1986). That is, group spatial pattern is likely to primarily reflect behavioural activity which may directly determine the dolphin's locality and hence the character of the immediate physical habitat.

There was no association between spatial pattern and behaviour in this study. This may reflect the small sample size, the inappropriate definition and/or grouping, of categories.

### **3.4.5 Behaviour Variables**

Whilst behavioural data were collected in order to consider the exact nature of "usage" of different habitats, records were secondary to the search for dolphins, in order to record where they were. Hence, the duration of direct observation was limited (i.e. 46 hours 12 minutes). Also, by excluding all but the initial instantaneous sampling records of behaviour due to the *ad hoc* collection procedure in the early stages of this Survey (see Section 3.2.6), the resulting sample size is small. Consequently, more detailed behavioural data are necessary before possible differences in usage of different habitats can be considered.

Approximately 49% of all pod behaviour recorded at the time of the initial sighting was travel, approximately 21% were each socialising and milling, and approximately 8% was feeding. Pod behaviour was associated with group size classes, depth, tidal state, time of day and wind direction. Behavioural variables were grouped into three categories for these analyses whereby travel involved a variation in speed (49%); milling represented a non-directional, “quiet” mode of activity (21%); and social/feed included any pod involved in socialising or feeding be they travelling or not (29%).

Pods of less than 15 dolphins were mainly involved in travel but greater than this, were involved equally in all three behavioural categories. Social/feed groups were typically less than 15 dolphins, like the travel pods but milling behaviour mainly involved pods of 1-5 dolphins.

Most activity occurred in shallow water although all behaviours occurred in both depth categories, except for milling. Milling involving typically small clumped groups, was only reported from shallow waters, especially at ebb tide. This behaviour may represent resting activity which was reported by Shane (1977) to occur almost exclusively at ebb tide. However, Shane (1987) later determined this behaviour was in fact “against-current feeding”. If this was the case at Jervis Bay then the percentage representation of feeding would markedly increase, i.e.

approximately, travel = 49%; feeding = 29% and socialising = 21%.

Although Jervis Bay is not apparently strongly influenced by tides (CSIRO, 1994), this does not necessarily negate localised currents at estuary mouths where the movements of potential prey may be affected.

Survey effort was not equal across time of day with effort greatest at midday (i.e. 1000 - 1400 hours). Hence the highest frequency of travel and milling behaviours were recorded as expected, on the basis of effort, at midday, although there was an equally high record of travel and slightly more social/feed behaviours recorded in the morning. As a result of combining categories and the uncertainty of the

function of the milling category, these results are difficult to interpret. Bräger (1993) in a study off Galveston, Texas found similar "...diurnal and interseasonal changes in the frequencies of occurrence of the three main behaviors of feeding, travelling, and socializing..." between his and two previous studies along the Texas coast. These two studies (Gruber, 1981; Shane, 1990b) were conducted at different locations and used different methods of data collection and analysis. However, in all three studies Bräger (1993) reported that: feeding peaked in the morning and decreased during the day; socialising was highest in the second half of the day; travelling peaked in the afternoon or evening; and the same increase in feeding and concomitant decrease in socialising and travelling from summer to fall, were observed. However, diurnal patterns do appear to vary between locations with Würsig & Würsig (1979) reporting resting in the morning, feeding in deeper waters at noontime, and socialising and feeding in the afternoon off Argentina.

#### **3.4.6 Summary**

The dolphins in Jervis Bay appear to spend a lot of time in nearshore waters where all habitats appear important. In terms of substrata, however, these trends suggest the overall importance of seagrass meadows (particularly to calves) and also rocky areas, in the dolphin's pattern of distribution. Sightings indicate preferential use of different areas of the Bay which may relate to differences in habitats, the abundance of preferred prey items and/or possibly predation pressure. There appear to be seasonal differences in the number of animals in the Bay, with a peak in summer and a secondary peak in winter. The highest seasonal density estimate and calf abundance coincides with this secondary peak in winter. These results may suggest a single calving peak in autumn when sea surface temperatures are the warmest. There is evidence that group size and spatial pattern may be influenced by substratum; and behaviour by depth, tide, time of day and wind.

In terms of the objectives of the S&E Survey, i.e. maximising sighting opportunities particularly to record the more time-intensive data of individual identification and behavioural activity, the limitations of this survey relate to the:

1. decision to photographically identify individuals opportunistically and not to pursue “complete” photographic sighting records of every sighting event (see Chapter 6);
2. irregular sampling of behavioural activity, although the same procedures for data collection were used throughout the survey; and
3. use of different observers with variable sighting experience (Leatherwood & Show, 1980) in the later half of the survey (25% of surveys).

**TABLE 3.8: Summary Tables of Results from Analyses of S&E Survey Data**  
**In all tables below:** **na** = indicates analysis not applicable to data set; **ee** = derivation estimated elsewhere; **du** = data unavailable; **+ve** indicates a positive association; **assoc** means a statistically significant association was indicated (at  $\alpha = 0.05$  and where expected values from contingency tests were equal to or greater than one, see Section 2.4) but no positive or negative trend was apparent, this typically relates to categorical variables and the area of strongest association is indicated in the appropriate column (see relevant Results & Discussion sections, for details); **S** indicates a statistically significant result (at  $\alpha = 0.05$ ) with the “trend” indicated in the respective Table, in the LH margin; **NS** indicates a non-significant result or a significant result but where expected values from contingency tests were less than one is indicated by  $\diamond$ , see Section 2.4). Unless otherwise stated (i.e. as a result of missing data) sample sizes for “sighting event” analyses are  $n=49$ ; “pod” analyses are  $n=85$  and “survey” analyses are  $n=40$ . SS Temp. refers to Sea Surface Temperature. Sighting and pod size classes, i.e. small (1-5), medium (6-14) and large (15+) are indicated by sm, med, and lge; unless “2 Classes” are indicated, i.e. small (1-10) or large (11+). Line reference number is indicated in column **I**. For detailed analyses see Appendix 3: TABLES A3.1 - A3.10.

**Table 3.8a: Analyses of Survey Effort**

<b>I</b>		<b>Route</b> ( <i>n</i> =126)	<b>Survey</b>	<b>Successful Survey</b> ( <i>n</i> =31)	<b>Field Hours</b> ( <i>n</i> =215.3)	<b>Tidal State</b> ( <i>n</i> =110)	<b>Distance Searched (km)</b> ( <i>n</i> =1771.5)
<b>i</b>	<b>Year / most in 1990</b>	na	<b>S</b>	<b>S</b>	na	na	na
<b>ii</b>	<b>Quadrant</b>	NS	na	na	na	na	na
<b>iii</b>	<b>Season</b>	na	NS	NS	na	na	na
<b>iv</b>	<b>Time of Day/ greater at midday vs am &amp; pm</b>	na	na	na	<b>S</b>	na	na
<b>v</b>	<b>Tidal State</b>	na	na	na	na	NS	na
<b>vi</b>	<b>Depth/ greater in ≤10 m vs deeper</b>	na	na	na	na	na	<b>S</b>

**Table 3.8b:** Analyses of Group Composition

<b>I</b>		<b>Mean Total Number</b>	<b>Sighting Size Classes</b>	<b>Number of Pods</b>	<b>Mean Pod Number</b>	<b>Pod Size Classes</b>
<b>i</b>	<b>Pres/Abs Calves/ present in larger sightings and pods</b>	S	<b>assoc/ 2 Classes: present mainly in lge groups</b>	NS	S	NS/ 2 Classes
<b>ii</b>	<b>Number of Pods</b>	na	<b>+ve / more pods in larger groups</b>	na	na	na
<b>iii</b>	<b>Number of Calves per Pod</b>	na	na	na	na	NS/2 Classes

**Table 3.8c:** Analyses of Depth

<b>I</b>		<b>Survey Effort in ≤10m &amp; &gt;10m</b>	<b>Depth wrt three areas of Bay</b>	<b>Shallow (≤11.5m)/Deep (&gt;11.5m)</b>	<b>Mean Sighting Depth</b>
<b>i</b>	<b>Sighting Event/ greatest in area of the Bay ≤10m</b>	NS	S	ee	na
<b>ii</b>	<b>Mean Total Number</b>	na	na	NS	na
<b>iii</b>	<b>Sighting Size Classes</b>	na	na	NS	na
<b>iv</b>	<b>Number of Pods</b>	na	na	NS	na
<b>v</b>	<b>Mean Pod Number</b>	na	na	NS	du
<b>vi</b>	<b>Pod Size Classes</b>	na	na	NS	du
<b>vii</b>	<b>Pres/Abs Calves</b>	na	na	NS	NS
<b>viii</b>	<b>Pres/Abs Calves per Pod</b>	na	na	NS	du

**Table 3.8d: Analyses of Substrata**

<b>I</b>		<b>Substrata wrt area of each in Bay</b>	<b>Substrata</b>	<b>Substrata ≤10m</b>
<b>i</b>	<b>Sighting Event/ greater over rarer substrata</b>	<b>S</b>	<b>ee</b>	<b>NS (n=38)</b>
<b>ii</b>	<b>Mean Total Number</b>	<b>na</b>	<b>NS</b>	<b>NS</b>
<b>iii</b>	<b>Sighting Size Classes</b>	<b>na</b>	<b>assoc/ lge over seagrass; med &amp; lge over sand; sm over any; any size over rock</b>	<b>assoc/ lge over seagrass; med over sand; sm over any; any size over rock</b>
<b>iv</b>	<b>Number of Pods</b>	<b>na</b>	<b>NS</b>	<b>NS</b>
<b>v</b>	<b>Mean Pod Number</b>	<b>na</b>	<b>NS</b>	<b>NS (n=63)</b>
<b>vi</b>	<b>Pod Size Classes</b>	<b>na</b>	<b>NS</b>	<b>NS</b>
<b>vii</b>	<b>Pres/Abs Calves</b>	<b>na</b>	<b>NS</b>	<b>NS</b>
<b>viii</b>	<b>Pres/Abs Calves per Pod</b>	<b>na</b>	<b>NS</b>	<b>NS</b>
<b>ix</b>	<b>Mean Sighting Depth/ deeper over sand, then rock &amp; seagrass</b>	<b>na</b>	<b>S</b>	<b>na</b>

3.8e: Analyses of Environmental Variables

Table 3.8e(1)

I		Quadrant wrt area of each	Half of Bay (Nth & Sth)	Season	BF (good BF 0-3 & not good BF 4+)
i	Sighting Event/ greater in the NW & summer (then winter)	S	ee	S	na
ii	Mean Total Number	na	NS	NS	NS
iii	Sighting Size Classes	na	assoc/ sm in either; med & lge in north	NS	NS
iv	Number of Pods	na	assoc/ multiple in north; single in either; but mainly single in south	NS	NS
v	Mean Pod Number / decreased from am to pm	na	NS	NS	NS
vi	Pod Size Classes	na	NS	NS	NS
vii	Pres/Abs Calves	na	NS	assoc/ greatest proportion of sightings with calves in winter	NS
viii	Survey per Season	na	na	na	NS
ix	Sighting Event per Season	na	na	na	NS

3.8e: Analyses of Environmental Variables (contd)

Table 3.8e(2)

l		Tidal State	Time of Day	Wind Direction	SS Temp. (n=48)
i	<b>Sighting Event/ greater in the NW &amp; summer</b>	NS	NS	na	na
ii	<b>Mean Total Number</b>	NS	NS	NS (n=45)	NS
iii	<b>Sighting Size Classes</b>	NS	NS	NS (n=45)	NS/ 2 Classes
iv	<b>Number of Pods</b>	NS	NS	NS (n=45)	NS
v	<b>Mean Pod Number / decreased from am &amp; midday to pm</b>	NS	S	NS (n=80)	du
vi	<b>Pod Size Classes</b>	<b>assoc/ mainly sm at flood; med at high; lge across all</b>	NS	<b>assoc (n=80)/ mainly sm with winds from north; med from west &amp; north; lge under any winds</b>	du
vii	<b>Pres/Abs Calves</b>	NS	NS	NS (n=45)	NS
viii	<b>Survey per Season</b>	na	na	na	na
ix	<b>Sighting Event per Season / higher in summer &amp; autumn; than in winter &amp; spring</b>	na	na	S ♦ (n=45)	S

**Table 3.8f:** Analyses of Spatial Pattern

<b>I</b>		<b>Sighting Spatial Pattern</b>	<b>Pod Spatial Pattern</b>
<b>i</b>	<b>Sighting Event</b>	na	na
<b>ii</b>	<b>Mean Total Number</b>	NS	na
<b>iii</b>	<b>Sighting Size Classes</b>	assoc/ mainly lge clumped & mixed; med & sm clumped; all sizes spread	na
<b>iv</b>	<b>Number of Pods</b>	assoc/ single & multiple pods clumped; single spread; multiple mixed	na
<b>v</b>	<b>Mean Pod Number</b>	na	NS
<b>vi</b>	<b>Pod Size Classes</b>	na	NS
<b>vii</b>	<b>Pres/Abs Calves</b>	NS	na
<b>viii</b>	<b>Pres/Abs Calves per Pod</b>	na	NS
<b>ix</b>	<b>Mean Sighting Depth</b>	NS	na
<b>x</b>	<b>Shallow/Deep</b>	NS	NS
<b>xi</b>	<b>Substrata</b>	NS	assoc/ clumped most over sand then seagrass, least rock; seagrass mainly dispersed
<b>xii</b>	<b>Quadrant</b>	NS	NS
<b>xiii</b>	<b>Season</b>	NS	NS
<b>xiv</b>	<b>SS Temp.</b>	NS (n=48)	NS (n=82)
<b>xv</b>	<b>BF</b>	NS	NS
<b>xvi</b>	<b>Tidal State</b>	NS	NS
<b>xvii</b>	<b>Time of Day</b>	NS	NS
<b>xviii</b>	<b>Wind Direction</b>	NS (n=45)	NS (n=80)

**Table 3.8g:** Analyses of Behavioural Variables

**Table 3.8g(1)**

I		Sighting Behaviour	Pod Behaviour	Dolphin's Direction of Travel
i	Sighting Spatial Pattern	NS	na	na
ii	Pod Spatial Pattern	na	NS	na
iii	Sighting Event	na	na	na
iv	Mean Total Number	NS	na	na
v	Sighting Size Classes	na	na	na
vi	Number of Pods	na	na	na
vii	Mean Pod Number	na	NS	na
viii	Pod Size Classes	na	assoc/ mainly sm & med=travel; lge=any behaviour; social/feed=sm & med; mill=sm	na
ix	Pres/Abs Calves per pod	na	NS	na
x	Mean Sighting Depth	NS	na	na
xi	Shallow/Deep	na	assoc/ all behaviour in both depths except mill, in shallow only; shallow mainly travel; deep travel & social/feed	na
xii	Substrata	na	NS	na
xiii	Half of Bay (Nth & Sth)	na	NS	na
xiv	Season	na	NS	na
xv	BF	na	NS	na

**Table 3.8g:** Analyses of Behavioural Variables (contd)

**Table 3.8g(2)**

<b>I</b>		<b>Sighting Behaviour</b>	<b>Pod Behaviour</b>	<b>Dolphin's Direction of Travel</b>
<b>i</b>	<b>Tidal State</b>	na	assoc/ mainly at flood & high=travel; ebb=travel & mill; low=any; social/feed=any; mill=any except flood	NS ♦ (n=48)
<b>ii</b>	<b>Time of Day</b>	na	assoc/ across all Time of Day classes travel was highest; pm also=social/feed; midday also=mill	NS ♦
<b>iii</b>	<b>SS Temp.</b>	na	NS (n=82)	na
<b>iv</b>	<b>Wind Direction</b>	na	assoc (n=80)/ winds from north=travel & social/feed; east=mill; south=any; west=travel	NS ♦ (n=44)

**Table 3.8h: Abundance Patterns**

l		Quadrant per area	Season per survey effort	Year per annual effort	Substrata ≤ 10m per area
i	Total Number (n=635) greatest in the NW & summer; more over seagrass & rock	S	S	NS	S (n=482)
ii	Calves (n=48)/ greatest in winter; more over seagrass & rock	NS	S	NS	S (n=37)

**Table 3.8i: Density Estimates**

Estimated Dolphin density (no. per sq. km)					
l		Quadrant			
		SW	NW	NE	SE
i	Mean no./survey/area at depths ≤ 10m	0.53	0.69	0.57	0.11
		Season			
		AUT	SPR	SUM	WIN
ii	Mean no./survey / area of whole of Bay	0.11	0.15	0.12	0.17
		Substratum			
		Sand	Seagrass	Rock	
iii	Mean no./sighting event/area at depths ≤ 10m	0.70	1.53	4.24	
		Substratum			
		Sand	Seagrass	Rock	
iv	Mean no. of calves/sighting event/area at depths ≤ 10m	0.03	0.10	0.08	

## CHAPTER 4: LINE TRANSECT SURVEY

### 4.1 Introduction

The Transect Survey was vessel-based and used line transect methodology. This methodology has previously been used for aerial and large scale ship-based surveys (Leatherwood & Show, 1980; Smith, 1981; Hammond, 1986; Holt, 1987; Holt & Cologne, 1987; Cockcroft *et al.*, 1992). The primary aim of this Survey was to investigate the applicability of line transect methodology in local area studies of bottlenose dolphins in order to establish a survey approach which could accommodate detailed quantitative assessment of dolphin habitat use patterns. It was considered this may be possible given references in the literature to local populations' apparent use of preferred areas (Wells *et al.*, 1980; Irvine *et al.*, 1981; Shane *et al.*, 1986; Cockcroft *et al.*, 1992), i.e. that transect location could be stratified for habitat. Furthermore, if this approach was found to be viable in determining preferred areas, it may have important implications for conservation managers. Accordingly, this survey was designed to test the null hypothesis that dolphins are distributed equally over different habitats (i.e. defined by depth and substratum) throughout Jervis Bay, and to estimate the abundance of dolphins using the Bay during the Survey.

Hence the Transect Survey, unlike the Search and Encounter (S&E) Survey, was structured in terms of its effort and coverage of the Bay, although the individual routes were randomised. The effort involved in travelling between randomly sampled transects was offset by recording all sightings fortuitously made between transects. These incidental sightings, for which group composition, environmental and behavioural data were recorded as per the S&E Survey, were referred to as Non-Transect Sightings (NTS). Thus, the Line Transect Survey provided two data sets for analysis, sightings made from transects and those made in transit between transects.

## 4.2 Survey Design

### 4.2.1 Placement of Transects

Habitat was defined in this study by depth and bottom substratum, hence the placement of transect lines across the study area was stratified according to six depth classes (see Table 3.2) and the three main substrata in the Bay, i.e. sand, seagrass and rocky areas.

The investigation and determination of transect sites were made on seven ancillary surveys (i.e. not used in transect analyses). The beginning and end of each transect was marked by three compass bearings from coastal landmarks, detailed site descriptions of adjacent coastal features where visible, and noting substratum and depth. An established compass heading and visual coastal cues were used to maintain direction during the transect.

The six nominal depths chosen were 4, 8, 15, 20, 25 and 30 m. Transect sites were located so this depth was represented for at least 60% of their length. Boundaries of the depth classes represented by these six “transect depths”, were located at depths at the middle between each (see Table 3.2). A few transects, however, extended beyond class boundaries, although all sightings of dolphins from transect lines were estimated to be at depths within the representative class. For example, the transects over rocky complex substratum characteristically varied markedly in depth along their whole length. At 8 m rocky transect sites, only the mean depth of transects fell within the this depth class, i.e. both minimum and maximum depths were outside that class (6 m minimum and 11.5 m maximum). Other transects, over seagrass for example, began and/or ended near a “drop off”, where the depth gradient increased markedly. Furthermore, sampling of the shallowest depth class appeared affected by tides, not unexpectedly. Some replicates had minimum depths at low tide or maximum depths at high tide outside the nominated depth class. The maximum deviation was 0.9 m, except for one transect site along a sandy beach with a very steep depth profile which had a maximum deviation of +2.1 m.

Because two of the three main substrata investigated in this study, i.e. seagrass and rocky areas, were patchy and relatively small in total area, the length of each transect was limited to only one kilometre (of which a minimum of 600 m represented the nominated substratum). The topography of the shoreline and substrata did not allow for a systematic design using parallel transect lines, hence transects were located randomly with respect to direction within each strata. The two rarer substrata were only found in the first two depth categories (i.e. represented by 4 and 8 m transects) which necessitated from the outset an unbalanced survey design.

#### 4.2.2 Sampling Regime

A total of 41 transects were initially located throughout the study area (Fig. 4.1, Table 4.1a). Each of these sites was sampled in random order, using random number tables (Snedecor & Cochran, 1980), on three separate occasions. In the second phase of this survey, sampling effort was increased in the next two depth categories (i.e. 15 m and 20 m, Fig. 4.1) to the same level (six transects) as the first two strata, to reduce any bias in sightings related to differing sampling effort across depths. Hence 47 transects were sampled (Table 4.1b).

Buckland *et al.* (1993) recommend that if little is known *a priori*, the strata should be sampled in proportion to their size. Costs limited the extension of the second phase of the survey to the remaining two depth categories (i.e. 25 m and 30 m) and indeed dictated the total effort spent. This recommendation is, therefore, approximated only in the stratified sampling effort for the three substrata, not depths. The total number of transects per substratum type were rocky complex=5, seagrass=12, and sand=30 (Table 4.1b) and their estimated total area is listed in Table 2.1.



**Figure 4.1: Map of transect sites throughout Jervis Bay, indicating location of both Phase 1 and Phase 2 transects ( $n=47$ ); and the transects on which sightings were recorded indicated by (—■—).**

**TABLE 4.1: The number of transects available per depth/substratum combination.**

**Table 4.1a:** Phase 1 of Line Transect Survey

Substratum	Transect Depth (m)						Total
	4	8	15	20	25	30	
Sand	6	6	3	3	3	3	24
Seagrass	6	6	0	0	0	0	12
Rocky areas	3	2	0	0	0	0	5
Total	15	14	3	3	3	3	41

**TABLE 4.1b:** Phase 2 of Line Transect Survey

Substratum	Transect Depth (m)						Total
	4	8	15	20	25	30	
Sand	6	6	6	6	3	3	30
Seagrass	6	6	0	0	0	0	12
Rocky areas	3	2	0	0	0	0	5
Total	15	14	6	6	3	3	47

Transects were sampled randomly, within areas north and south of an arbitrarily chosen demarcation (35° 04'S., see Fig. 2.1). For example, if the first transect selected from a random number table was in the north, then northern transects were sampled first and southern transects later. This was done to reduce the extensive travel time between completely randomised transect lines. The total number of transects sampled over 15 months was 264 (see Table 4.2c). The effort involved in travelling between transects was offset by recording all sightings made in transit between randomly sampled transects (i.e. NTS).

#### **4.2.3 Sampling Methods**

The data and procedures for collection were the same on the Transect Survey as for the S&E Survey (see Section 3.2), for both sightings made from the transect line (TS) and Non-Transect Sightings (NTS), with the exception of additional data recorded at the beginning and end of each transect.

Additional data included sea surface temperature, sea conditions, wind speed and direction, weather, three bearings to confirm position, time and the vessel log recorded prior to the commencement of a transect (see Section 3.2.2). Each transect followed an established heading and while transect depth and substrata were considered constant across replicates, minimum and maximum depths were recorded for each "run". This enabled a check on location and the expected depth range of each transect. At the end of one kilometre, another set of bearings, time and the log were recorded. When a sighting was made, distance data were collected as per Section 3.2.3.

Each transect was run at an average speed of six kilometres per hour with a mean duration of ten minutes and thirty seconds to complete, and a recorded minimum and maximum duration of seven and fourteen minutes, respectively. This variation resulted from strong wind and surface currents which occasionally made maintaining a constant vessel speed difficult. The equipment used to conduct this Survey and observer effort are outlined in Sections 2.2 and 2.3.

## 4.3 Results

Appendix 4 contains the detailed statistical analyses of all data presented in this Chapter (TABLES A4.1 - A4.28). The results presented in this Chapter refer to Summary Tables located at the end of the Chapter (see Tables 4.6 - 4.9). A line reference using roman numerals is included to assist referral to these Tables (e.g. Table 4.8a-liii).

### 4.3.1 Survey Effort

Transect Survey effort was distributed evenly across years with 31 and 27 survey days in 1991 and 1992, respectively (Table 4.6-li). A total of 80 sightings recorded on 36 of the 58 Transect Survey days (62%), i.e. 26 sightings from transect lines and 54 NTS. Successful survey days (i.e. survey days on which sightings were made either from the transect line or elsewhere in the Bay) were also distributed equally across years, with 50% ( $n=18$ ) in both years. This Survey involved travelling approximately 2,908 km (Fig. 4.2) over approximately 353 hours.

Transect Survey effort was not distributed equally across seasons due to weather and logistical restrictions, with most surveys in autumn (48%) and least in spring (10%) (Table 4.6-lii). There was no significant difference in the overall search effort with respect to the quadrants of the Bay traversed ( $n=195$  quadrants, Table 4.6-liii). Survey effort (hours) was not distributed equally across the four time of day categories which the Transect Survey covered. Only 25 minutes occurred prior to 0600 and when this 'early morning' and the morning (0600-1000) categories were combined, to create three time of day categories, survey effort remained unequally distributed (Table 4.6-liv). That is, most survey effort occurred at midday (1000-1400), followed by the morning and least in the afternoon. Survey effort was equally distributed across four tidal states (i.e. based on three hourly intervals,  $n=164$  tidal states) for the Transect Survey (Table 4.6-lv). When the

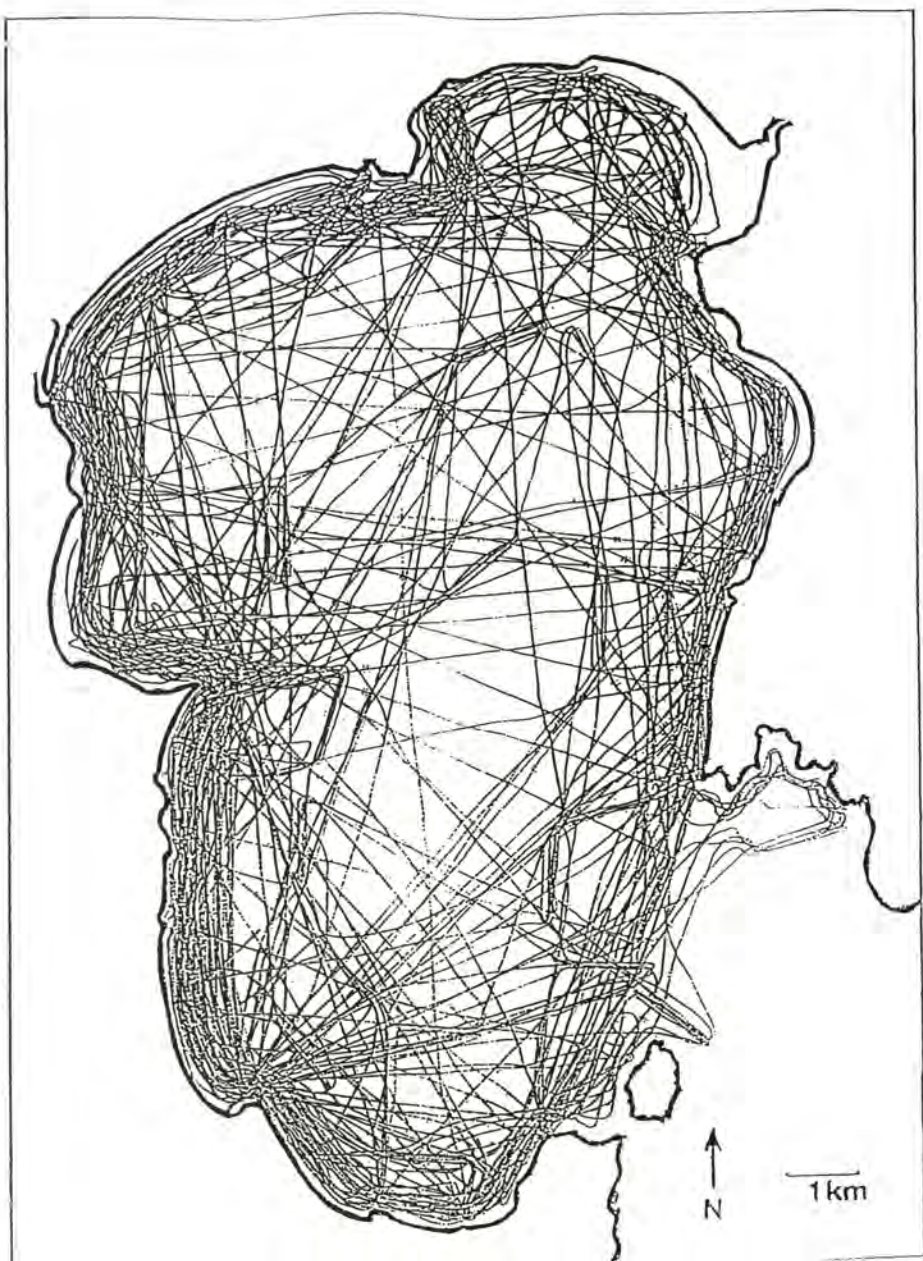


Figure 4.2: Map of Survey Routes for the Transect Survey.

percentage area of waters at depths  $\leq 10$  m or greater were considered (see Table 3.3), survey effort was not distributed evenly throughout the Bay (km searched), with respect to depth (Table 4.6-lvi, see Figure 4.2). Whilst surveys regularly moved into deeper water (41%), the greatest effort was in nearshore waters (59%), where two of the three substrata investigated were mainly found.

As in the S&E Survey, no attempt has been made to quantify sampling effort across the whole survey for environmental variables which could fluctuate irregularly throughout the course of a single day in the field (i.e. sea surface temperature, weather, Beaufort sea state (BF) and wind direction).

There was no significant variation in the total number of animals or calves recorded on the whole Transect Survey (i.e. TS and NTS) across the two years the Survey was conducted when survey effort was accounted for (Table 4.6 lvii & lviii).

The remainder of the Result Section is divided into three parts, with the results of analyses of Line Transect Sightings (TS) presented first (Section 4.3.2); then results from Non-Transect Sightings at Transect Sites (NTTS) (Sections 4.3.3), and finally, all Non-Transect Sightings (NTS) recorded on this Survey (Section 4.3.4).

## **4.3.2 Line Transect Sightings (TS)**

### **4.3.2.1 Sampling Effort**

The total number of transects completed in the first phase of the survey was 123 (Table 4.2a). The first two depth classes received a higher proportion of sampling effort because of the location of seagrass and rocky areas. In the second phase of the Transect Survey a total of 47 transect sites were sampled in random order three times at each site, hence the total number of transects completed on this part of the survey was 141 (Table 4.2b).

**TABLE 4.2: Total number of times each transect combination was sampled.**

**Table 4.2a:** Phase 1 of Line Transect Survey - Total number of times each transect combination was sampled. Where - indicates no transects were available.

Substratum	Transect Depth (m)						Total
	4	8	15	20	25	30	
Sand	18	18	9	9	9	9	72
Seagrass	18	18	-	-	-	-	36
Rocky areas	9	6	-	-	-	-	15
Total	45	42	9	9	9	9	123

**Table 4.2b:** Phase 2 of Line Transect Survey - Total number of times each transect combination was sampled. Where - indicates no transects were available.

Substratum	Transect Depth (m)						Total
	4	8	15	20	25	30	
Sand	18	18	18	18	9	9	90
Seagrass	18	18	-	-	-	-	36
Rocky areas	9	6	-	-	-	-	15
Total	45	42	18	18	9	9	141

**Table 4.2c:** The total number of times transect combinations, for the whole survey, were sampled. Where (-) indicates no transects were available.

Substratum	Transect Depth (m)						Total
	4	8	15	20	25	30	
Sand	36	36	27	27	18	18	162
Seagrass	36	36	-	-	-	-	72
Rocky areas	18	12	-	-	-	-	30
Total	90	84	27	27	18	18	264

On average four to five transects were run on the 58 survey days. Transect sampling was not distributed evenly across years with slightly more transects run in 1991 (138) than in 1992 (126), (Table 4.7a). On 18 days (31%) dolphins were sighted from the transect line. Of the 264 times transects were sampled, 26 sightings were made from the transect lines (see Fig. 4.1), i.e. TS occurred on only 9.85% of occasions.

There was no significant difference in transect sampling effort across the arbitrarily chosen quadrants of the Bay (Table 4.7a). Sampling effort was not evenly distributed across three time of day categories (i.e. morning = < 1000, midday = 1000 - 1359, afternoon = >1400) based on the time transects began. That is, more transects were run at midday, followed by the morning and then the afternoon (Table 4.7a). There was no significant difference in transect sampling effort across tidal state which was calculated retrospectively based on the time transects were begun (Table 4.7a). Sea surface temperatures recorded at the beginning of each transect ( $n=264$ ) ranged between a minimum of 13.3°C and a maximum of 23.5°C with an overall mean of 18.4°C. ANOVA indicated a significant difference between sea surface temperatures across season (Table 4.7a). The seasonal means were; winter 15.4°C (S.E. 0.19), spring 15.2°C (S.E. 0.21), summer 18.5°C (S.E. 0.17), and autumn 20.2°C (S.E. 0.12). The Peritz procedure indicated that the mean sea surface temperature in autumn was significantly greater than summer which were significantly greater than winter and spring. When the percentage area of waters at depths  $\leq 10$  m or greater were considered (see Table 3.3), as expected, sampling effort (see Table 4.2c) was not distributed evenly with respect to depth, with more effort in nearshore waters (Table 4.7a). Exact sighting depths were not recorded for sightings made from the transect line as the vessel did not depart from the trackline hence this result is an approximation, as 8 m transect boundaries extended beyond 10 m to 11.5m. When the percentage area of all three substrata throughout the Bay were considered (see Table 2.1), as expected, sampling effort (see Table 4.2c) was not distributed evenly with respect to substrata, with more effort over seagrass and rocky areas and less over sand (Table 4.7a). This uneven distribution pattern of sampling effort across substrata

was also repeated in waters  $\leq 10$  m in depth, when the area of substrata in these waters was considered (Table 4.7a). This result, however, is also an approximation as 8 m transect boundaries extended beyond 10 m to 11.5 m.

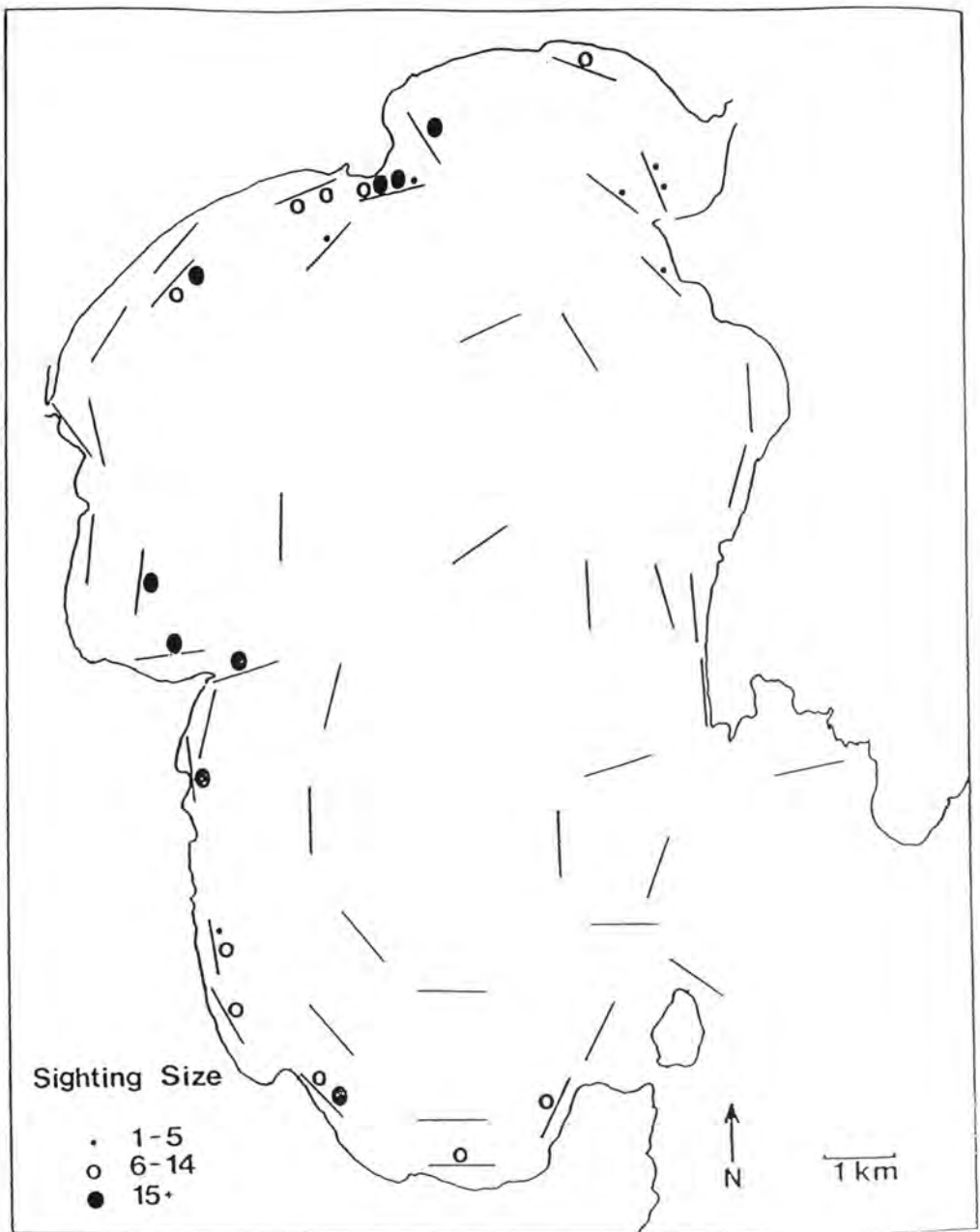
Only one sighting was made from a transect line on a survey day. However, multiple sightings occurred from six transects (Fig. 4.3). It is considered unlikely that resightings of the same groups occurred on the same survey day based on field observations such as the direction animals were travelling relative to the location of sampled transects. Also, multiple sightings only occurred on seven of the 18 days when animals were recorded. However, due to the dynamic nature of associations between individuals it may be that some members were recounted on these few multiple sighting days, although the level of any upward bias is considered likely to be minimal.

The mean observation period from the transect line was approximately three minutes. Due to the brevity of this observation period behavioural data were not analysed for TS.

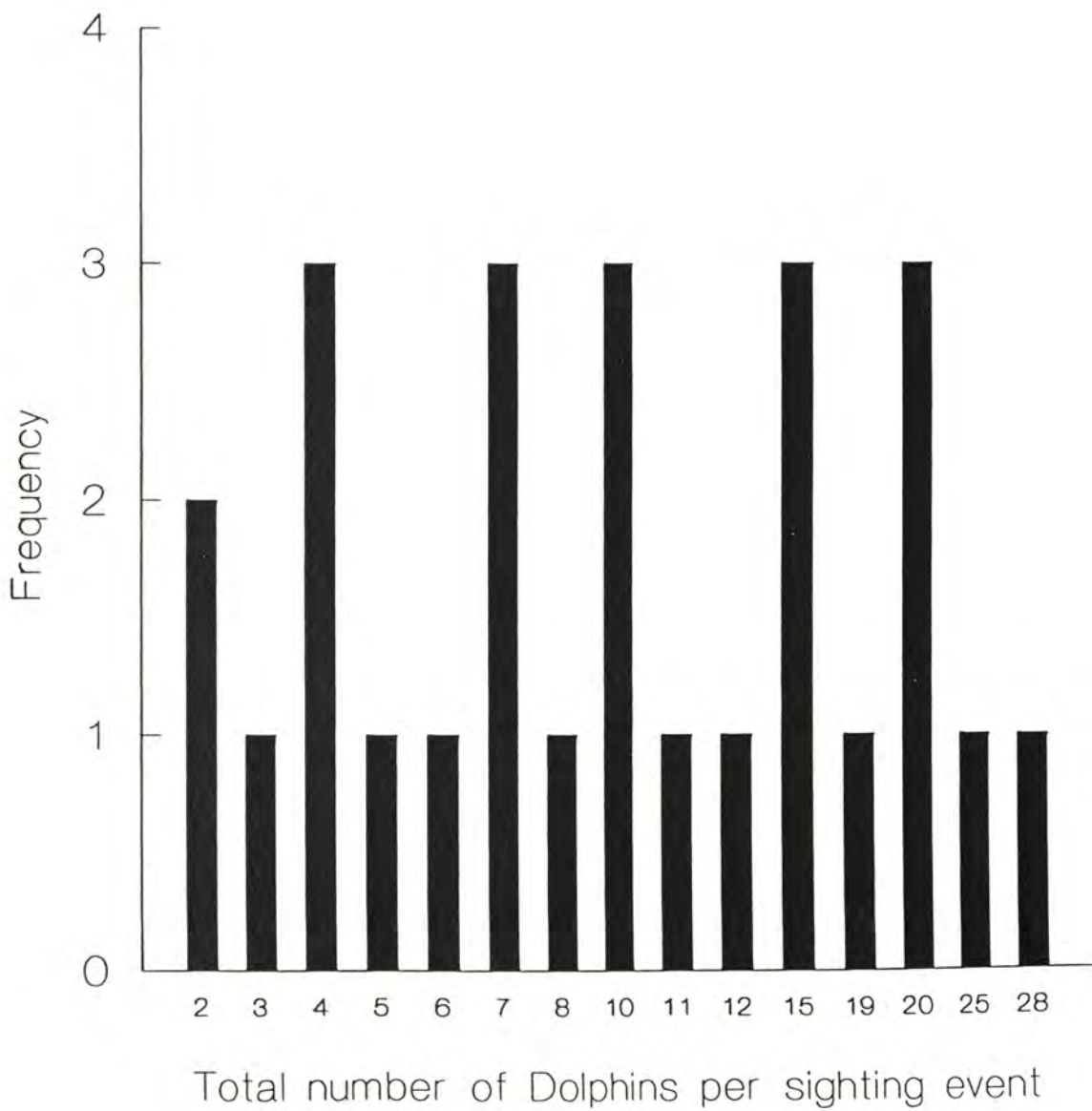
#### **4.3.2.2 Group Composition**

The 289 dolphins seen at the 26 sightings were clustered in 35 pods, i.e. nine sightings involved multiple numbers of pods. The minimum number of dolphins sighted was two and the maximum was 28, at a single sighting event (Fig. 4.4). Calves were observed at ten sightings. In total 14 calves were sighted. The maximum number of two calves per pod were recorded on three occasions, i.e. one sighting event included four calves. Calves represented 4.8% of observed animals.

As for the S&E Survey, it was necessary to use grouping variables for most analyses of the total number of animals, total number of calves, pod number and size recorded per sighting event, due to the small data set and degree of sparseness, for chi-square analyses (see Section 3.2.4).



**Figure 4.3: Map indicating the size of each sighting recorded from transects, on the Transect Survey.**



**Figure 4.4: The frequency distribution of the total number of dolphins sighted per transect sighting on the Line Transect Survey.**

A *t*-test indicated that the mean number of animals recorded at each sighting event was not significantly different when calves were present or absent (Table 4.7b-li).

An association was found between sighting size and the number of pods recorded at each sighting event (Table 4.7-lii). That is, most TS consisted of single pods which ranged from small to large in size, while sightings of multiple pods were only medium or large.

No association was found between sighting size and the presence or absence of calves (Table 4.7b-li) nor between the number of pods recorded at each sighting event and the presence or absence of calves (Table 4.7b-li). A *t*-test indicated no significant difference between mean pod size with and without calves (Table 4.7b-li). No association was indicated between the number of calves per pod and pod size (Table 4.7b-liii) and, even though only two categories for pod size were used, i.e. small (1-10) and larger (11+), expected values were less than one. Hence this result is not considered further.

#### **4.3.2.3 Distribution of sightings across Habitats**

All of the transect lines from which sightings occurred were at a depth of either 4 or 8 metres and were over all substrata: sand=11; seagrass=9; and rocky complex=6 (Table 4.3).

The distribution of dolphin sightings cannot be interpreted reliably without accounting for differences in sampling effort across different depths and substrata, and variability among replicate samples. ANOVA (Underwood, 1981) and the Peritz multiple comparison procedure (Martin & Toothaker, 1989) were used on all data (i.e. sightings and zeroes) to assess if such differences were significant over time and among sites. Due to the non-orthogonal survey design it was necessary to conduct two separate ANOVAs for a) all depth classes across sand only (1-factor ANOVA) and b) for all three substrata in only the two most shallow depth categories (2-factor ANOVA).

**TABLE 4.3: The distribution of transects from which sightings were made across habitats defined by depth and substratum. Where - indicates no transects were available.**

	Transect Depth (m)						Total
	4	8	15	20	25	30	
<b>Substratum</b>							
Sand	5	6	0	0	0	0	11
Seagrass	6	3	-	-	-	-	9
Rocky areas	1	5	-	-	-	-	6
<b>Total</b>	<b>12</b>	<b>14</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>26</b>

In total, 20 separate ANOVAs were calculated investigating: a) spatial variability across the Survey for two habitat and four group composition variables: and b) between site variability for two habitat and six group composition variables.

#### **4.3.2.3a Spatial Variability across the Survey**

##### **i) Six Depths over Sand**

There were no significant differences by the one-factor ANOVA across all six depth classes, for the total number of animals and calves, sighted over sand (Table 4.7c lii & liii).

Significant differences were found for the number of sighting events and total number of pods in the above analysis (Table 4.7c li & liv); however, these data were not homoscedastic by Cochran's test and when  $\log_{10}$  transformed, they remained heteroscedastic. When assumptions of the equality of variances are violated this increases the  $F$ -ratio which increases the risk of a Type I error (Underwood, 1981). If the significance level of the test was made more stringent, e.g. alpha reduced from 0.05 to 0.01, the test of the null hypothesis ( $H_0$ ) of no differences in sighting numbers, and the total number of pods across all six depths over sand, becomes more robust and may not be rejected in error.

In one case, the total number of sighting events across all six depth classes over sand, the extreme probability value of 0.009, would suggest that  $H_0$  should be rejected. Although it cannot be proven through  $\log_{10}$  transformation that this apparent significance is not related to differences in sample variances, such an extreme probability value still warrants consideration. Hence the Peritz procedure was used to make a multiple comparison of the means of each set of replicate samples in order to determine "...as many true differences as possible..." (Martin & Toothaker, 1989). The means for the total number of sighting events across the six transect depth classes (4, 8, 15, 20, 25 and 30 m) were 0.139 (S.E. 0.058) and 0.167 (S.E. 0.063), respectively and zero for the remaining four depth classes where no sightings were recorded. These results are not readily interpreted because they indicated that there was no significant difference in the mean number of

sighting events between 4 and 8 m, the only depths at which sightings were made. Nor were there any significant differences between 4 m and the remaining depths; however, there was a significant difference between 8 m and the 4 remaining depths.

## **ii) Shallow Depths and Three Substrata**

No significant differences were found by the 2-factor ANOVA in the total number of animals or pods sighted over the three substrata at the two shallower depths (Table 4.7c li & liv).

Significant differences for the interaction of depth and substratum were found for the number of sighting events (Table 4.7c-li); however, these data were not homogeneous by Cochran's test. When these data were  $\log_{10}$  transformed, they remained significant and heteroscedastic, and the probability values were not extreme enough to indicate likely significance in view of the variance assumption (Underwood, 1981).

The total number of calves was also significant across the interaction of substratum and depth (Table 4.7c-liv) but data were found again to be heterogeneous. After transformation this data remained significant but variances were again unable to be stabilised.

## **iii) Other analyses of Depth**

All transects from which sightings were made (i.e. 4 m & 8 m) were located in waters at  $\leq 11.5$  m depth and as indicated in Table 4.2c sampling effort was greatest in these shallow waters. Not unexpectedly, when the area of three depth categories across the whole Bay were considered (see Table 3.3) there were significantly more sightings in waters  $\leq 10$  m (Table 4.7d-li). These results are only an estimation, as noted earlier, because the boundary of the 8 m transect depth category was 11.5 m and hence some transects extended beyond 10 m in depth.

No association was indicated between sighting size and mean pod size across the two transect depths where sightings were recorded (Table 4.7d liii & lvi).

However, when pod size was divided into three size categories an association was indicated across the two transect depths (Table 4.7d-lvi) where sightings were recorded, i.e. more smaller pods at 8 m versus more medium pods at 4 m. There was no association between the presence or absence of calves per sighting event or per pod, across the two transect depths where sightings were recorded (Tables 4.8d lvii & lviii).

As sightings were only recorded from 4 m and 8 m transects, analyses of TS in shallow ( $\leq 11.5$  m) versus deeper ( $\geq 11.5$  m) waters was not applicable (Table 4.7d). Because the vessel did not leave the trackline when a sighting was made only transect depths were recorded. Hence analyses of mean sighting depths were also not made (Table 4.7d).

#### **iv) Other analyses of Substrata**

Because all sightings were made from transects located at 4 m and 8 m, there was no need to analyse the distribution of sightings with respect to substrata located in waters  $\leq 10$  m in depth separately, unlike for the S&E Survey. Transect sampling effort was unevenly distributed across substrata with more effort over seagrass and rocky complex areas (Table 4.7a). When the area of each substratum throughout the Bay is considered, not unexpectedly, there were significantly more sightings over the rarer substrata of seagrass and rocky areas. (Table 4.7e-li). There was no significant difference between the observed and expected distribution of TS across the three substrata in waters  $\leq 10$  m in depth when the area of each was considered (Table 4.7e-li).

Across transect substrata (Table 4.7e) no associations were indicated between sighting size (liii), mean pod size (lv), nor pod size classes (lvi). Nor were associations indicated between the presence or absence of calves per sighting (lvii) and per pod (lviii), across transect substrata (Table 4.7e). Mean sighting depths were not used in these analyses as these were not recorded for TS (Table 4.7e-lix).

#### 4.3.2.3b Between Transect Site Variability

ANOVA was used to analyse total sightings at each transect site using the variables: summed number of animals; of pods; and of calves; and the maximum number of animals sighted on that transect. Derived variables analysed were: sighting success (the number of times animals were sighted in terms of the number of times the transect was sampled, expressed as a percentage); and sighting frequency (the number of times animals were sighted on a transect).

##### i) Six Depths over Sand

There was no significant difference between transect sites located over sand and across all depths (Table 4.7f), for the summed number of animals (li); of calves (lii); and of pods (liii); and the maximum number of animals sighted on that transect (liv). ANOVA indicated significant differences for both sighting success and sighting frequency across the six depth classes (Table 4.7f lv & lvi). However, both variables were found to have heterogeneous variances and after  $\log_{10}$  transformation remained so.

##### ii) Shallow Depths and Three Substrata

A significant difference was found for the summed number of animals sighted across the interaction of the three substrata and two depths ( $P=0.018$ ) but data were found to be heteroscedastic (Table 4.7f li). When data were  $\log_{10}$  transformed, these remained significant and became homoscedastic. However the Peritz procedure did not find any significant differences between any of the means. Where the means for sand at 4 m and 8 m, seagrass at 4 m and 8 m, and rock at 4 m and 8 m, were 0.60 (S.E. 0.23), 0.42 (S.E. 0.23), 0.93 (S.E. 0.23), 0.41 (S.E. 0.23), 0.26 (S.E. 0.32) and 1.44 (S.E. 0.39), respectively. This indicates that the difference amongst the means that the ANOVA detected is not large enough for this less powerful, pairwise test to identify. Probably it is the change in the direction of trends, with the number of dolphins increasing with depth over rock compared with a decrease in numbers with increasing depth over the other two

substrata (Fig. 4.5), which causes the significant interaction. The summed number of calves were also found to vary in number significantly across the interaction of substrata and depth and data were found to be homoscedastic (Table 4.7f lii). When the Peritz procedure was performed on these data, the results were striking (Fig. 4.6) with the number of calves sighted in 8 m over rock significantly greater than any other depth and substratum combination. Furthermore no other significant differences amongst pairs of means were detected, i.e. the means for sand at 4 m and 8 m, seagrass at 4 m and 8 m, and rock at 4 m and 8 m, were 0.33 (S.E. 0.33), 0.50 (S.E. 0.33), 0.68 (S.E. 0.33), 0.17 (S.E. 0.33), 0.00 and 2.0 (S.E. 0.57), respectively. The summed numbers of pods and the maximum number of animals sighted, were not significantly different across the three substrata at the two shallowest depths (Table 4.7f liii & liv).

For both sighting success and sighting frequency (Table 4.7f lv & lvi), there were significant differences over the interaction of the three substrata and two depths. Neither variable was found to be homogeneous and after  $\log_{10}$  transformation only sighting success remained significant (interaction  $P=0.041$ ) but still proved to be heteroscedastic when tested. If the significance level was increased to the same stringent level adopted previously, i.e.  $P=0.01$ , then neither of these results could be considered significant.

#### 4.3.2.4 Environmental Variables

Although survey effort and transect sampling were distributed equally across quadrants (Tables 4.7-liii & 4.8a), TS were not. When the expected number of sightings is adjusted for the different areas of each quadrant (see Table 3.1a) the result remained significant (Table 4.7g(1)-li). That is 61.5% of sightings were made in the northern half of the Bay and 42.3% of all sightings were made in the NW quadrant. No association was indicated between the north or south of the Bay where sightings were made and group composition variables (Table 4.7g(1) lii-lvii).

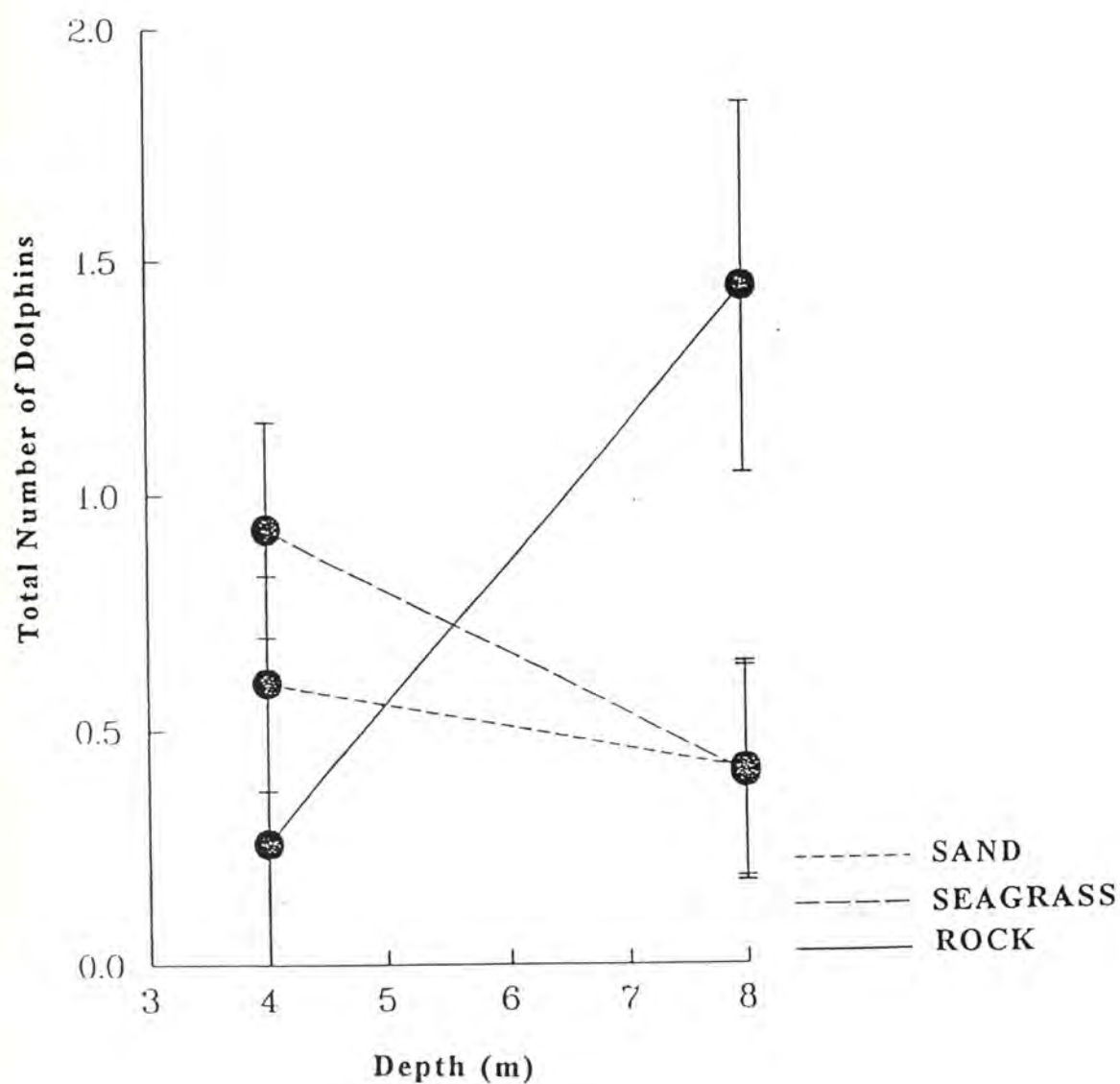


Figure 4.5: Means ( $\pm$ SE) of the total numbers of dolphins ( $\log_{10}$  transformed) sighted across three substrata and two depths.

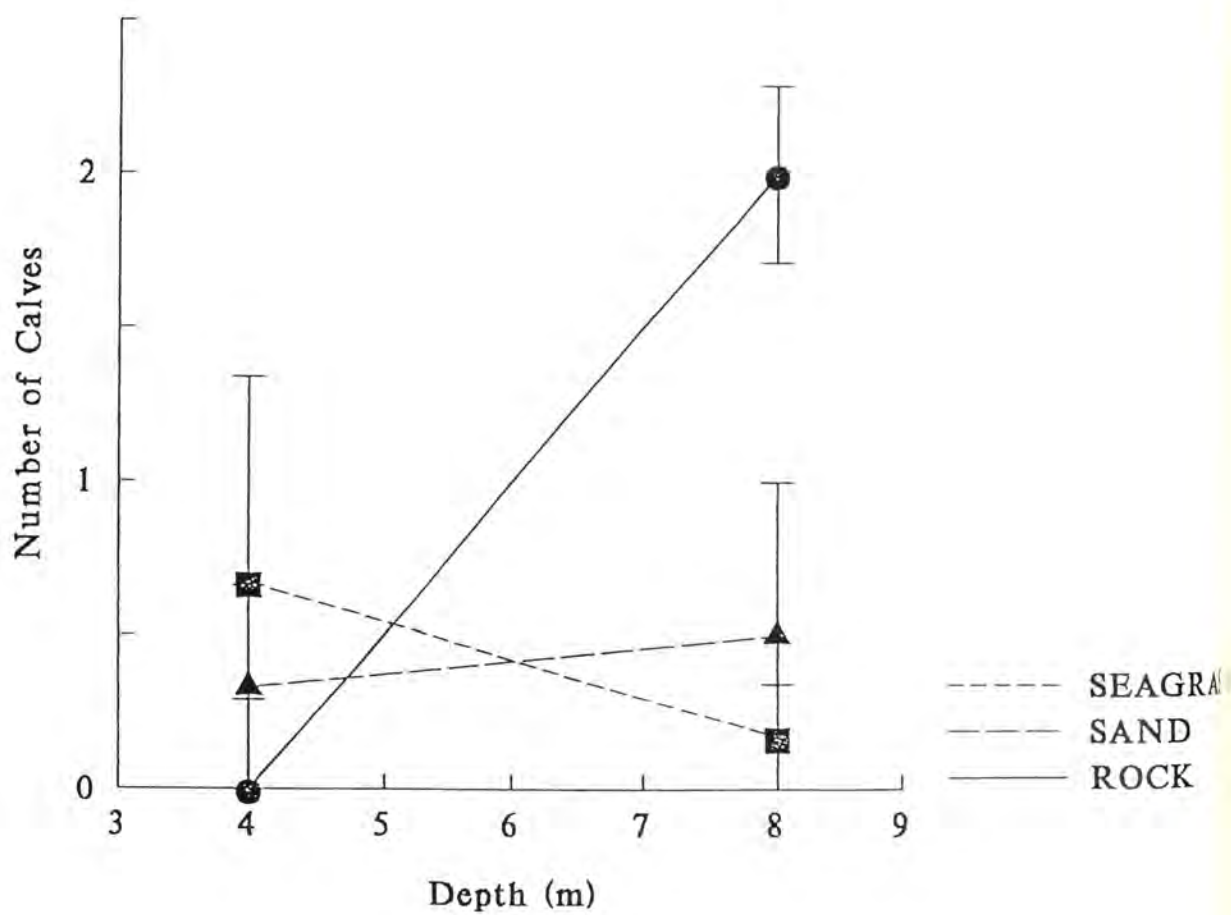


Figure 4.6: Means ( $\pm$ SE) of the total number of calves sighted across three substrata and two depths.

Surveys were not distributed equally across seasons (Table 4.6-*lii*). When the distribution of TS were considered using the chi-square goodness-of-fit test, with the expected distribution based on the uneven sampling, there was no significant difference (Table 4.7g(1)-*li*). That is, most sightings occurred in autumn when most surveys took place. There was no association between season and group composition variables and all contingency tests had some expected values less than one as a result of the sparseness of the data across seasons (Table 4.7g(1) *lii-lvii*).

Of the 264 times transects were sampled almost 70% were completed under clear weather conditions and nearly 80% of successful transects, i.e. those from which dolphins were seen, were also carried out under clear conditions. Transects were sampled at Beaufort 6 sea state or less with 88% being carried out in good sighting conditions, i.e. BF 0-3. All successful transects were in this range hence TS were unable to be divided into occurring in either good (BF 0-3) or not good (BF 4+) sighting conditions, as for the S&E Survey (Table 4.7g(1)). Accordingly it was not relevant to consider season and BF conditions, in terms of impacts on sightings, as for the S&E Survey.

All of the transects completed were distributed evenly across the four tidal states (Table 4.7a) as were TS (Table 4.7g(2)-*li*). ANOVA indicated no significant difference between the mean total number of dolphins sighted across tides (Table 4.7g(2)-*lii*). However, an association was indicated with sighting size when divided into small (1-10 dolphins) and larger (11+) size classes with smaller sightings recorded mainly at low and flood tides and larger groups recorded at high and ebb tides (Table 4.7g(2)-*liii*). An association was indicated between the number of pods per sighting event across tides (Table 4.7g(2)-*liv*). Mainly single pods were recorded and the greatest number of these at low tide while the few sightings of multiple pods were greatest across ebb and flood tides. There was a significant difference in the mean size of pods across tidal states (Table 4.7g(2)-*lv*) with mean pod size at high, ebb, low and flood being 15.4 (S.E. 2.38); 8.0 (S.E. 1.26); 7.1 (S.E. 1.57) and 5.89 (S.E. 0.90), respectively. The Peritz procedure indicated that pod size at high tide was significantly greater (almost double) than

at any other tidal state. There was also an association with the size of pods when these were divided into small (1-10 dolphins) and larger (11+ dolphins) size classes (Table 4.7g(2) lvi). Small pods were recorded mainly across ebb and flood tidal states, and larger pods most frequently recorded from low and high tides. There was no association between the presence or absence of calves across tides (Table 4.7g(2)-lvii).

No transects sampled ( $n=264$ ) were begun prior to 0600 or after 1800. Nor were they distributed evenly across the remaining three time of day categories (Table 4.7a) with 53% sampled in the middle of the day, i.e. 1000-1359. When the chi-square goodness-of-fit test was done on the expected distribution of TS based on the uneven sampling distribution of all transects there was, however, a significant difference (Table 4.7g(2)-li). More TS were recorded at midday than would be expected and less at both the morning and afternoon. No associations were found between any group composition variables and time of day when the single sighting event in the afternoon was excluded (i.e. only two categories morning and midday were analysed) (Table 4.7g(2) lii-lvii).

Wind direction was recorded at the time of sighting, however, the small sample size did not allow chi-square analysis across the nil wind category plus eight compass points. Hence data were combined into only five categories, i.e. nil and the cardinal compass directions. Prevailing winds at the time of sightings were from the north (42%) with both west and south equally represented (19%) and on only three occasions was no wind recorded. There was no association between group composition variables and wind direction and even though group composition variables were combined, where possible, some expected values of contingency tables were less than one (Table 4.7g(2) lii-lvii). It was not considered relevant to analyse the impact on sighting events of wind direction across seasons as done for S&E Survey data due to the uneven sampling effort and sparseness of data.

A *t*-test indicated no significant difference in the mean total number of animals recorded per sighting when temperature was divided at the mean into cooler or warmer sea surface temperatures (Table 4.7g(2)-lii). There was no association between sighting sizes when divided into two classes (Table 4.7g(2)-liii). However, an association was indicated between the number of pods and sea surface temperature with single pods recorded in warmer waters and multiple pods mainly in cooler (Table 4.7g(2) -liv). A *t*-test indicated no significant difference in sea surface temperatures when calves were present or absent (Table 4.7g(2)-lvii). Temperatures were only analysed with respect to sighting events and not per pod. ANOVA again indicated a significant difference between sea surface temperatures recorded at TS across seasons (Table 4.7g(2)-lviii). The seasonal means were; winter 14.6°C (S.E. 0.62), spring 14.9°C (S.E. 0.38), summer 20.8°C (S.E. 0), and autumn 19.9°C (S.E. 0.34). The Peritz procedure indicated that the mean sea surface temperature in autumn was not significantly different from summer (unlike mean sea surface temperatures recorded across all sampled transects, see Section 4.3.2.1). Both autumn and summer were significantly greater than winter and spring which was the case for temperatures recorded across all sampled transects (see Section 4.3.2.1). The latter two seasons were not significantly different from each other.

#### **4.3.2.5 Abundance and Density Estimates**

##### **a) Abundance**

Although both survey and sampling effort were equally distributed across quadrants (Tables 4.7-liii & 4.8a), the total number of dolphins sighted ( $n=289$ ) was not. When expected values were adjusted for the area of each quadrant, most dolphins were sighted in the NW (46%) followed by the SW (42%), then the NE (9%) and least in the SE (3%) (Table 4.7h-li).

There was also a significant difference in the total numbers of animals sighted across seasons when survey effort was considered with 74% of animals recorded in

autumn (Table 4.7h-li). All other seasons recorded significantly lower number of dolphins than expected on the basis of survey effort.

There was no significant variation in the total number of animals recorded at TS across the two years of the Transect Survey when survey effort was accounted for (Table 4.7h-li). There was, however, a significant difference in calf numbers at TS when survey effort was accounted for, with more calves than expected in 1991 and less in 1992 (Table 4.7h-lii).

The total numbers of animals sighted over sand, rock and seagrass were 119, 87 and 83, respectively. When transects with maximum depths beyond 10 m were excluded ( $n=21$ ), most TS remained over sand (119), then seagrass (69) and least over rock (42). However, when the areas of each substratum in waters  $\leq 10$  m in depth were considered (see Table 3.4) more dolphins than expected were seen over rock, and less than expected over seagrass and sand (Table 4.7h-li). As a result of the small number of calves sighted at TS ( $n=14$ ), analyses of abundance across quadrants, seasons and substrata were not conducted as for the S&E Survey.

#### **b) Density Estimates**

As all TS were made within 1 km from the transect line, the density estimate based on the 264 one kilometre long transects sampled throughout the Bay (i.e. 264 sq. km) and the total number of dolphins sighted ( $n=289$ ), is approximately 1.1 *Tursiops*/sq. km. This estimate is approximately 9x the mean density estimates for the whole study area (117.2 sq. km) calculated for the S&E (0.13 *Tursiops*/sq. km.) and the NTS data sets (0.12 *Tursiops*/sq. km). If the same approach is used as for these two surveys, i.e. the mean number of dolphins sighted per survey ( $n=58$ ) for the whole of the Bay (117.2 sq. km) the density estimate from the TS data set is 0.04 *Tursiops*/sq. km (approximately one third of the previous estimates).

Although transects were located throughout the Bay all TS were made from 4 m and 8 m transects, the majority (77%) of which had maximum depths of  $\leq 10$  m. Hence, dolphin density was estimated using the total number of dolphins sighted

from these transects ( $n=215$ ) and the area in each quadrant at  $\leq 10$  m in depth, rather than the total area of each quadrant. The highest density occurred in the SW of the Bay with 0.35 *Tursiops*/sq. km and the lowest density was recorded in the NE quadrant with 0.05 *Tursiops*/sq. km. (Table 4.7i-li).

Estimated dolphin density varied across the different substrata located in  $\leq 10$  m of water of the Bay, for this survey. The highest density occurred over rocky complex areas with 4.3 *Tursiops*/sq. km and then seagrass and sand, with 1.1 and 0.70 *Tursiops*/sq. km, respectively (Table 4.7i-lii).

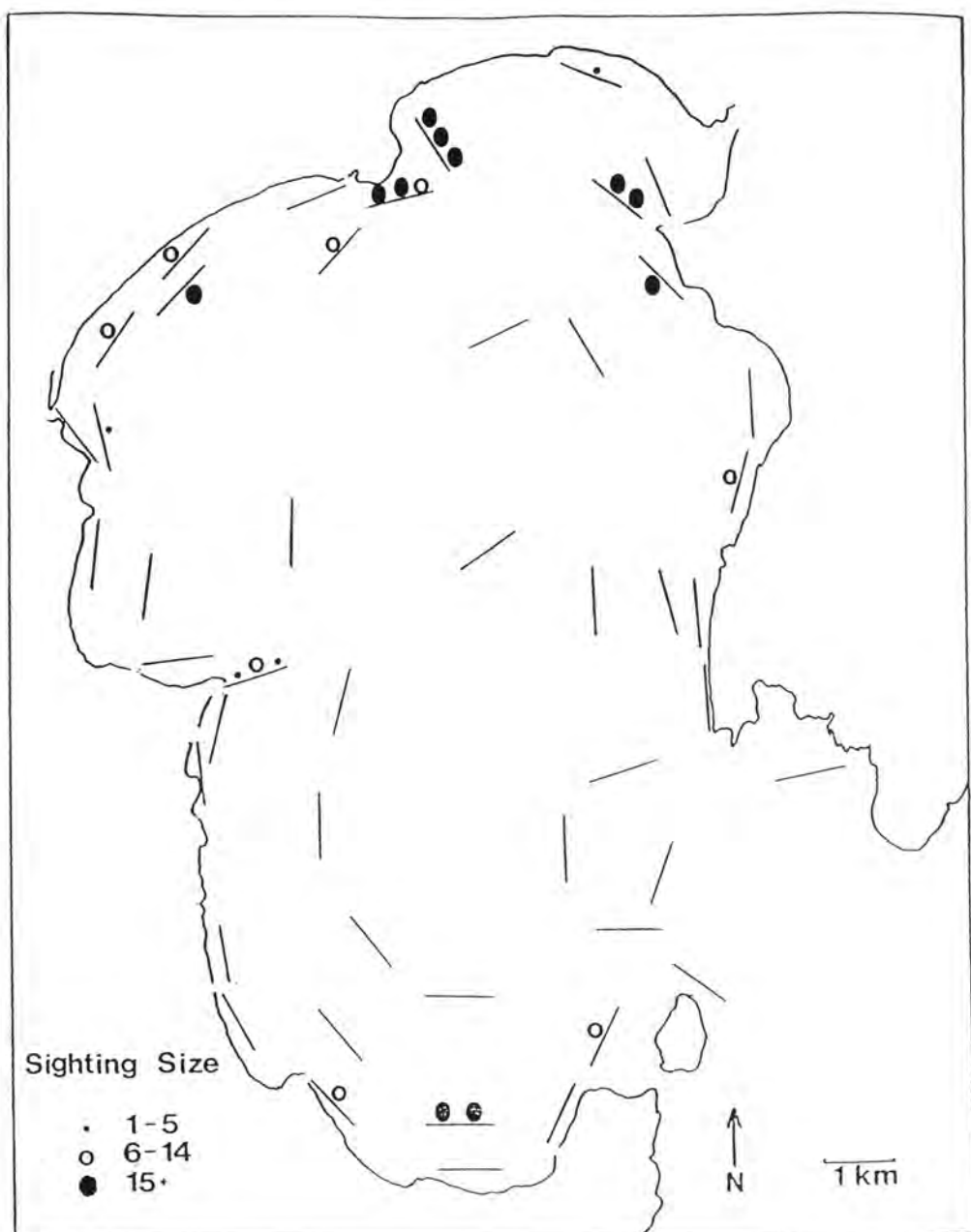
As a result of the small number of calves sighted at TS ( $n=14$ ), analysis of density across substrata was not conducted, as it was for the S&E Survey.

### **4.3.3 Non-Transect Sightings at Transect Sites only (NTTS)**

#### **4.3.3.1 Introduction**

Non-Transect Sightings from this Transect Survey can be viewed similarly to sightings made on the S&E Survey, that is they are accepted as opportunistic. However, it can also be argued that as a result of them occurring on a randomly selected route, unlike the S&E Survey, they represent another random survey of the Bay. As the sample size of TS was only small, it was considered important to analyse sightings which occurred at transect sites, but at the time were not being sampled, to compare with the findings of the former (see Section 4.3.2).

Of the total of 54 Non-Transect Sightings (NTS), there were 23 occasions when the dolphins were initially sighted at transect sites when they were not being sampled (Fig. 4.7). In some instances when animals were followed they subsequently crossed over other transect sites. On other occasions after an initial sighting not near a transect site, animals would then cross over one or more transect sites during the same encounter. For the purpose of the “transect-based” analysis below, only initial sightings at transect sites were used and also only one sighting from



**Figure 4.7:** Map indicating the location and size of “initial” non-transect sightings only, recorded at transect sites when these were not being sampled (see Section 4.3.3.1 for explanation).

any one encounter. This ensures a degree of independence for each sighting analysed as in the TS analyses (see Section 4.3.2). Using the initial sighting only also limits the influence of the research vessel on the animals' movements, and using only the one sighting per encounter restricts repeated reporting of the same group of animals.

On 19 of the 58 Transect Survey days animals were initially sighted at a transect site not being sampled. These 23 NTTS, do not allow assessment of spatial sampling bias nor replicate variability as for the planned component of the Transect Survey. At best, patterns within the data may be found and presented but the degree to which they do, or do not, reflect the "real" situation cannot be ascertained. Behavioural data recorded for NTTS are not presented in this section, as behaviour was not analysed for TS. These data are however, analysed with all NTS data in Section 4.3.4.

#### **4.3.3.2 Group Composition**

The 361 animals seen at the 23 sightings were clustered in 36 pods, i.e. 13 sightings involved multiple numbers of pods. The minimum number sighted was two animals and the maximum was 50 at a single sighting event, with a mean sighting size of 16 animals. In total 17 calves were sighted on 14 occasions with the maximum number of two per pod being recorded on three occasions. Calves represented 4.7% of observed animals.

As for the S&E Survey and TS, it was necessary to use grouping variables for most analyses of the total number of animals, total number of calves, pod number and size recorded per sighting event, due to the small data set and degree of sparseness, for chi-square analyses (see Section 3.2.4).

*T*-tests indicated that the mean number of animals recorded at each sighting event and per pod were not significantly different when calves were present or absent (Table 4.8a-li). No associations were indicated between remaining group

composition variables (Table 4.8a), i.e. sighting size and the presence or absence of calves (li); the number of pods recorded at each sighting event and the presence or absence of calves (lii); and the number of calves per pod and pod size (liii). Even though only two categories for pod size were used, i.e. small (1-10) and larger (11+), expected values were less than one. Hence this result is not considered further.

#### **4.3.3.3 Distribution of sightings across Habitats**

##### **a) Depth**

When the percentage area of three depth categories for the whole of the Bay was considered (see Table 3.3), sightings were not distributed equally across depth (Table 4.8b-li). That is, based on actual sighting depths recorded for NTTS, 87% of sightings occurred in waters  $\leq 10$  m in depth which represents less than 24% of the Bay. As indicated in Table 4.7a sampling effort was greatest in shallow waters on the Transect Survey.

There was no association between group composition variables across the three transect depths (i.e. 4, 8 and 15 m) where NTTS were recorded (Table 4.8b lii-lviii).

Analyses of NTTS located in shallow ( $\leq 11.5$  m) versus deeper ( $> 11.5$  m) waters were not conducted (Table 4.8b), because the shallow category incorporates both 4 m and 8 m transect sites, and only two NTTS occurred at greater than 11.5 m. Neither were mean sighting depths used in NTTS analyses, as these were not recorded for TS (Table 4.8b).

##### **b) Substratum**

There was a significant difference in the number of NTTS across substrata when the area of each substratum was considered (see Table 2.1), using the chi-square goodness-of-fit test (Table 4.8c-li). Sixty-five percent of sightings occurred over

seagrass and rocky areas, both more than expected, which cover only approximately 10% of the Bay.

There was no association between group composition variables and the three substrata over which NTTs were located (Table 4.8c lii-lviii). Mean sighting depths were not used in these analyses as these were not recorded for TS (Table 4.8c-lix). There was no association between the distribution of sightings across the three depths and three substrata (Table 4.8c-lx) where NTTs were recorded, and some expected values in the contingency table were less than one.

TS over substrata located in waters  $\leq 10$  m were not analysed separately as all sightings were made from transects located at 4 m and 8 m. However, for completeness, NTTs over substrata located in waters  $\leq 10$  m (i.e. representing 4 m and 8 m transect sites only) were analysed ( $n = 20$ ). There was a significant difference in the number of NTTs across substrata in  $\leq 10$  m depth when the area of each substratum was considered (see Table 3.4) using chi-square analysis (Table 4.8c-li). That is, more sightings occurred over seagrass and rock than expected (i.e. 70% of all sightings) and less over sand than expected.

There was no association between group composition variables and substrata in waters  $\leq 10$  m in depth (Table 4.8c), except for mean pod size (lv) and pod size classes (lvi). ANOVA indicated a significant difference between mean pod sizes across substrata with the largest pods recorded over rock = 13.8 (S.E. 4.5), then seagrass = 13.0 (S.E. 2.5) and the smallest over sand = 5.5 (S.E. 3.5). The Peritz procedure indicated that pod sizes over seagrass and rock were not significantly different from each other but were both significantly greater than pod sizes over sand. When pods were divided into two size classes, small (1-10 dolphins) and large (11+), only small pods were recorded over sand, while both small and large pods were found over seagrass and rock, reflecting the above result.

There was no association between the distribution of sightings across the two depths and substrata in  $\leq 10$  m depth (Table 4.8c-lxii) where NTTs were recorded.

#### 4.3.3.4 Environmental Variables

The Line Transect Survey was distributed equally across quadrants (Table 4.6-iii) as were NTTs when the different areas of each quadrant (see Table 3.1a), were considered (Table 4.8d(1)-li).

There was no association with any group composition variables and halves of the Bay when quadrants were combined into two categories, i.e. north and south (Tables 4.9d(1) lii-lvii).

The Line Transect Survey was not distributed evenly across seasons (Table 4.6-iii) and no significant difference in the distribution of NTTs, based on this uneven effort, was indicated (Table 4.8d(1)-li). That is, most sightings occurred in autumn when most surveys took place. There was no association between seasons and group composition variables (Tables 4.8d(1) lii-lvii).

Nearly all NTTs occurred under clear weather conditions, i.e. 21 of the 23 sightings, and all except one sighting occurred under good sea-state conditions (BF 0-3). Hence this data set, as for TS (see Section 4.3.2.4), was unable to be divided into good (BF 0-3) or not good (BF 4+) sighting conditions, unlike for the S&E Survey.

NTTs were evenly distributed across the four tidal states (Table 4.8d(2)-li), as was survey effort (Table 4.6-lv). ANOVA indicated no significant difference in mean sighting size across tides (Table 4.8d(2)-lii). There was, however, an association between the size of sightings when divided into small (1-10 dolphins) and larger (11+) size classes (Table 4.8d(2)-liii) with small sightings recorded mainly at ebb and flood tides, and larger groups mainly at high and low tides. There was no association between the number of pods and tidal state (Table 4.8d(2)-liv).

ANOVA indicated no significant difference in mean pod size across tides (Table 4.8d(2)-lv). However, an association was indicated between the size of pods when

divided into small (1-10) and larger (11+) size classes with small groups mainly at ebb and low tides, large groups mainly at high and low tides and small sightings mainly at flood tide (Table 4.8d(2)-lvi). The presence or absence of calves was also associated with tidal states (Table 4.8d(2)-lvii), with calves present at all tidal states but with peaks at low and ebb tides.

No NTTS were recorded prior to 0600 or after 1800. NTTS were distributed as expected across the three remaining categories, based on the uneven Transect Survey effort (Table 4.6-liv). Almost 61% of NTTS were recorded at midday (1000-1359). ANOVAs indicated no significant difference in the mean sighting and pod sizes across the three time of day categories (Table 4.8d(2) lii & lv). No associations were indicated between morning and midday categories only (i.e. when the two afternoon sightings were excluded,  $n=21$ , Table 4.8d(2)) and sighting size classes (liii), number of pods (liv), pod size classes (lvi) and the presence or absence of calves (lvii).

Wind direction was recorded at the time of sighting, but the small sample size did not allow chi-square analysis across the nil wind category plus eight compass points. Hence data were combined into five categories, i.e. nil and the cardinal compass directions for ANOVA, and four categories (i.e. excluding the nil wind category where only two sightings were recorded) for contingency tests. Prevailing winds at the time of sightings were from the north (30%), with both west and south equally represented (i.e. 22%). ANOVA indicated no significant difference in the mean number of dolphins sighted per sighting event and wind direction (Table 4.8d(2)-lii). There was no association between wind direction (Table 4.8d(2)) and sighting size classes (liii), number of pods (liv) and the presence or absence of calves (lvii). However, ANOVA indicated a significant difference in the mean pod size and wind direction (Table 4.8d(2)-lv). The mean pod size with no wind and under winds from the north, south, east and west were 10 (2.8), 6.3 (S.E. 1.5), 9.2 (S.E. 2.8), 9.3 (S.E. 3.4) and 17.4 (S.E. 2.9), respectively. The Peritz procedure indicated a complex result. There was no significant difference in mean pod sizes observed under nil, east, south and north winds; nor for nil and west winds,

however, pod sizes observed in westerlies were significantly greater than for the remaining three wind directions. An association was also found between pod size classes and wind direction (Table 4.8d(2)-lvi). When winds were from the north and south most pods were small (i.e. 0-5 dolphins), and when the wind was from the west mainly larger pods were recorded. Because no analysis on the impact of wind direction across seasons was done for TS this was not considered for NTTS.

Recorded sea surface temperatures at the time of NTTS fell within the range of temperatures recorded during the Transect Survey, with a slightly higher overall mean of 18.9°C. Temperatures were only analysed with respect to sighting events and not per pod. A *t*-test indicated no significant difference in the mean total number of animals recorded per NTTS when temperature was divided at the mean into cooler or warmer sea surface temperatures (Table 4.8d(2)-lii). There was no association between sea surface temperature divided into these two classes (i.e. cooler or warmer, Table 4.8d(2)) and sighting size (liii), and the number of pods (liv). A *t*-test indicated no significant difference in sea surface temperatures when calves were present or absent (Table 4.8d(2)-lvii). ANOVA indicated a significant difference in temperatures across seasons but variances were heteroscedastic and unable to be stabilised using log<sub>10</sub> transformation (Table 4.8d(2)-lviii).

#### **4.3.3.5 Abundance Patterns**

Although survey effort was equally distributed across quadrants (Table 4.6-liii), the total number of dolphins sighted ( $n=361$ ) was not. When expected values were adjusted for the area of each quadrant, most dolphins were sighted in the NW (55%) followed by the NE (22%), then the SE (17%), and least in the SW (6%)(Table 4.8e). Except for the NW there were fewer dolphins sighted than expected on the basis of survey effort.

There was also a significant difference in the total number of animals sighted across seasons when survey effort was considered with 76% of animals recorded in

autumn (Table 4.8e). All other seasons recorded significantly lower numbers of dolphins than expected on the basis of survey effort.

The total numbers of animals sighted over seagrass, sand, and rock were 156, 116 and 89. When transects with maximum depths beyond 10 m were excluded ( $n=16$ ), most NTTS remained over seagrass (116), then rock (78) and least over sand (46). When the areas of each substratum in these waters were considered (see Table 3.4) more dolphins than expected were seen over seagrass and rock and less than expected over sand (Table 4.8e).

As a result of the small number of calves sighted at NTTS ( $n=17$ ), analyses of abundance across quadrants, seasons and substrata were not conducted, as for the S&E Survey.

It was not considered useful to estimate annual abundance or densities from NTTS data because it represents only a subset of all NTS data, and these are analysed in Section 4.3.4.7.

#### **4.3.4 All Non-Transect Sightings (NTS)**

##### **4.3.4.1 Introduction**

The data set analysed in this Section, i.e. all NTS made on the Transect Survey, are viewed similarly to sightings made on the S&E Survey, that is they are accepted as opportunistic. The type and procedure for data collection for NTS was the same as for the S&E Survey, described in Section 3.2. Survey effort however, relates to Transect Survey Effort described in Section 4.3.1.

On 33 of the 58 Transect Survey days (57%), animals were sighted in transit between sampled transects. Animals were sighted on both the transect line and in between transects on 15 of these days, while on the remaining 18 days, dolphins were only sighted in transit between transect sites. On these 33 surveys a total of

54 NTS occurred (Fig. 4.8). Hence, the analyses below involve all NTS including the data subset used in NTTS, analysed in Section 4.3.3.

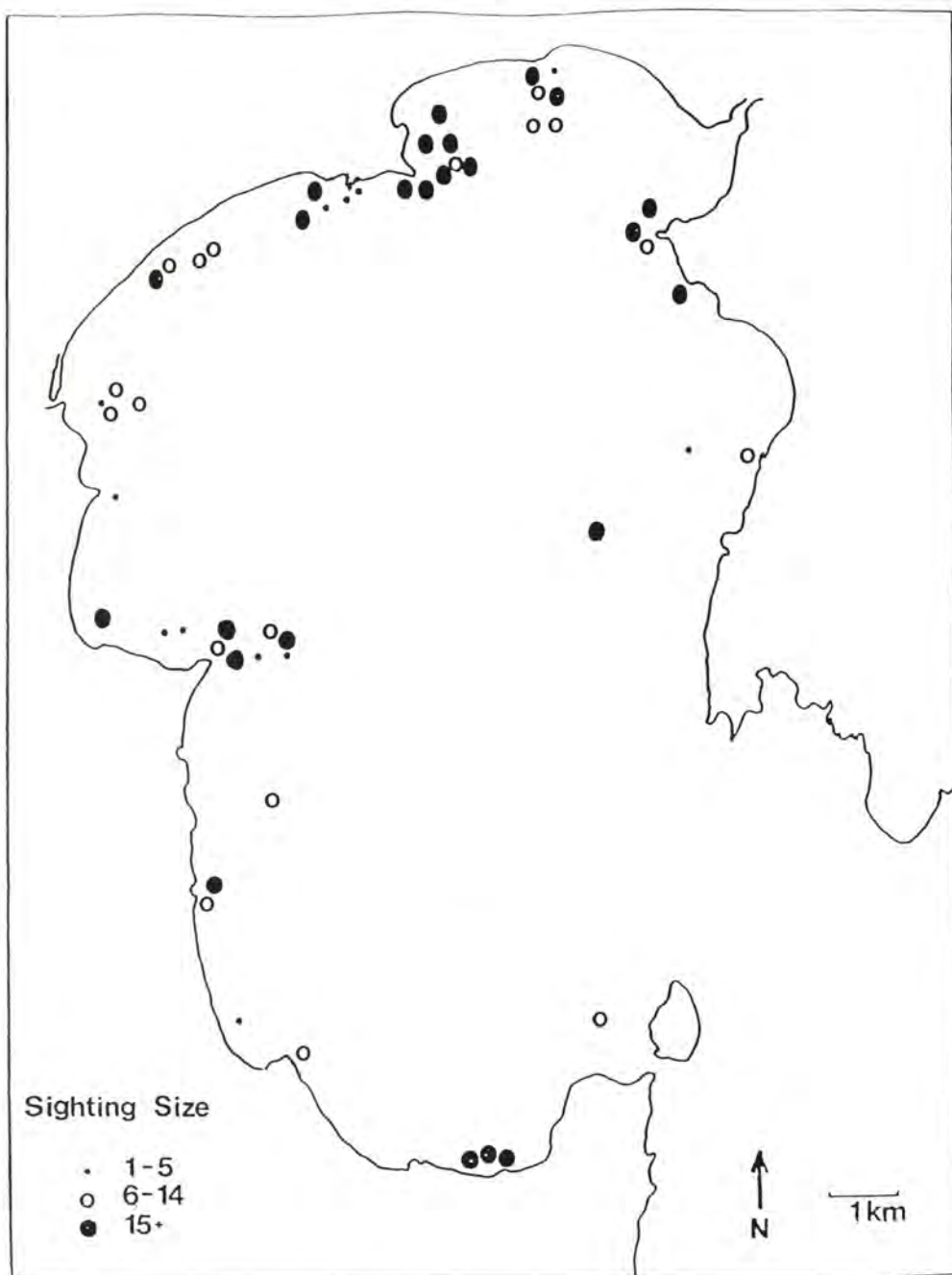
An estimated 41 hours 54 minutes were spent observing dolphins during NTS which represented approximately 12% of the time spent conducting the Transect Survey. Observations lasted from a minimum of four minutes to a maximum of two hours and 10 minutes, with an average of 47 minutes. The distances travelled per sighting while observing animals also varied greatly, from 100 m to 10 km, with an average of 2.6 km. Initial sightings were made at an average distance of 200 m from the animals, depending on sea and weather conditions.

#### **4.3.4.2 Group Composition**

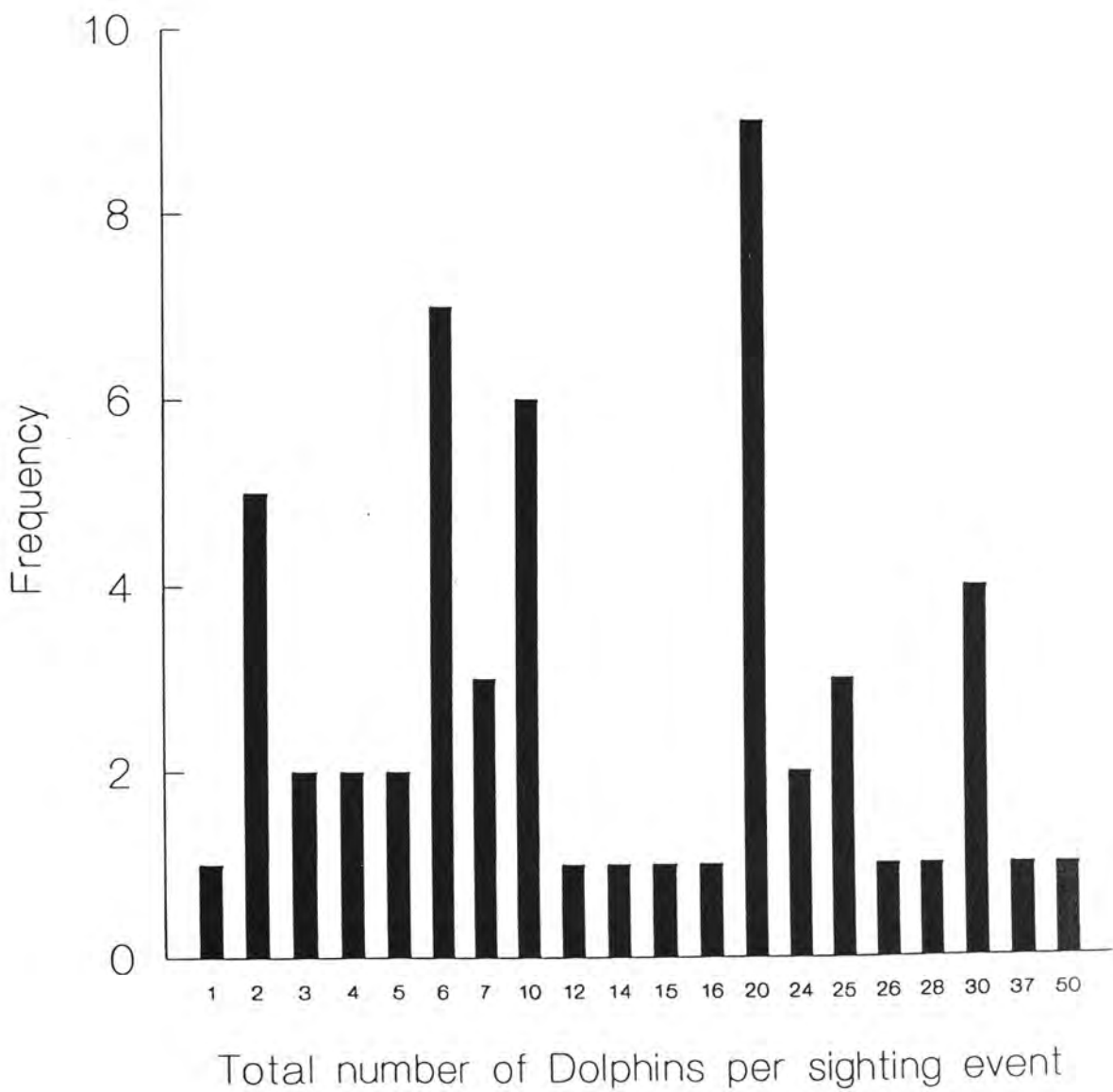
At the 54 sightings events a total of 779 individuals were recorded, the minimum number being one and the maximum 50 (Fig. 4.9). These 54 sightings were clustered into 89 pods, i.e. 35 sightings involved multiple numbers of pods. The mean sighting and pod sizes were, 14 (S.E. 1.5) and 8.7 (S.E. 0.75), respectively.

On the 31 occasions where calves were observed, a total of 45 individual calves were recorded. The maximum number of calves sighted at any one sighting event and on a single survey day were 3 and 4, respectively. Calves represented 5.8% of observed animals. The majority of calf sightings were of singular calves in a single pod ( $n=24$ ); on some occasions there were two calves in a single pod ( $n=9$ ) but only on one occasion were three calves in one pod.

Because of the small data set and the resulting degree of sparseness for chi-square analysis of four variables (total number of animals; total number of calves; pod



**Figure 4.8: Map indicating the location and size of all sightings recorded in transit between sampled transect sites, i.e. all Non-Transect Sightings.**



**Figure 4.9: The frequency distribution of the total number of dolphins sighted at Non-Transect Sightings on the Transect Survey.**

number and size recorded per sighting event), these data have only been used in a small number of analyses. Instead derived grouping variables are used which are described in Section 3.2.4.

A *t*-test indicated that the mean number of animals recorded at each sighting event was significantly different when calves were present or absent but raw data were heteroscedastic. After  $\log_{10}$  transformation variances were stabilised and the result remained significant (Table 4.9a-li). Calves were more likely to be present when the mean sighting size was larger (mean=18) versus smaller (mean=9.5). A *t*-test also indicated mean pod size was larger when calves were present but variances were heteroscedastic and after  $\log_{10}$  transformation the result was not significant (Table 4.9a-li). An association was found between and the presence or absence of calves and both sighting and pod size classes (Table 4.9a-li). Calves were mainly present in large sized sightings (i.e. 11+ dolphins), and in small pods (i.e. 1-10 dolphins).

No association was found between the number of pods recorded at each sighting event and the presence or absence of calves (Table 4.9a-li). An association was found between sighting size and the number of pods recorded at each sighting event (Table 4.9a-lii). Most sightings were of single pods and these were recorded at all sightings while only medium and large sightings consisted of multiple pods. No association was indicated between pod size and the number of calves per pod (Table 4.9a-lii).

#### **4.3.4.3 Distribution of sightings across Habitats**

##### **a) Depth**

As indicated in Table 4.2c, sampling effort on the Transect Survey was greater (66%) in waters  $\leq 11.5$  m than deeper. This effort is reflected in the distance travelled in waters  $\leq 10$  m in depth, approximately 59% (1,702 km) (Table 4.6-lvi). When this unequal distribution of effort was considered, using the percentage

distance travelled as for the S&E Survey analysis, the number of sightings in nearshore waters (83%) were significantly greater than expected (Table 4.9b-li). These waters represents less than 24% of the Bay.

When the percentage area of three depth categories for the whole of the Bay was considered (see Table 3.3), sightings were again not distributed equally across depth (Table 4.9b-li). All sightings occurred in waters  $\leq 20$  m in depth with a maximum recorded sighting depth of 17 m.

The depths at which dolphins were initially recorded were divided into six 'depth' classes based on transect depths. However in order to reduce sparseness of data for chi-square analysis only two depth categories were used, shallow ( $\leq 11.5$  m) or deep ( $> 11.5$  m) waters, as for S&E analyses. In total 47 sightings (87%) were recorded in shallow waters and only seven in deeper waters. There was no association between these two depth categories and any group composition variables (Table 4.9b lii-lviii). Also, a *t*-test indicated no significant difference in the mean of sighting depths recorded at the time of the initial sighting and the presence or absence of calves (Table 4.9b lviii).

#### **b) Substratum**

Sightings were recorded across all three substrata. When sighting events are calculated with respect to the area of each, and tested by chi-square goodness-of-fit, there is a significant departure from what would be expected by chance. Almost 63% of sightings occurred over the rarer habitats which only represent approximately 10% of the area of the Bay (Table 4.9c-li). Hence, the null hypothesis ( $H_0$  = the distribution of sightings is independent of substrata) should be rejected. In terms of the relative areas of these substrata these trends suggest the importance of seagrass and rock, as for the S&E Survey (see Section 3.3.3.2).

There was no association between the substratum over which NTS were recorded and group composition variables (Table 4.9c lii-lviii). ANOVA indicated a significant difference in the mean sighting depth ( $n=54$ ) across the three substrata

(Table 4.9c-lix) which probably reflects the location of seagrass and rock mainly in nearshore waters (i.e.  $\leq 10$  m). The mean sighting depths over the three substrata were sand 9.7 m (S.E. 0.83), seagrass 5.7 m (S.E. 0.32), and rocky areas 6.1 m (S.E. 0.71). The Peritz procedure indicated that the mean sighting depth over sand was significantly greater than over rock and seagrass, which were not significantly different from each other.

Because nearshore waters (i.e.  $\leq 10$  m) were where 83% of sightings were made ( $n=45$ ), the distribution of sightings across habitats within this depth zone was investigated. When the area of the three different substrata is derived for waters  $\leq 10$  m in depth (see Table 3.4), a significant difference was found in the distribution of these sightings (Table 4.9c-li), with more than expected over the rarer substrata of seagrass and rocky areas. However, no significant differences were found over the different substrata in nearshore waters (Table 4.9c) for the mean total number (lii), sighting sizes (liii), nor the number of pods (liv).

While ANOVA indicated no significant difference in the mean pod size across the three substrata (Table 4.9c-lv), an association was found between pod size classes with mainly small pods over all substrata but larger pods mainly over seagrass (Table 4.9c-lvi).

No association was indicated between the presence or absence of calves per sighting event and per pod across substrata (Table 4.9c lvii & lviii).

#### **4.3.4.4 Environmental Variables**

Although surveys were distributed equally across quadrants (see Table 4.6-liii), sighting events were not (Table 4.9d(1)-li). There was a significant difference in the distribution of NTS across quadrants when the expected number of sightings was adjusted for the different area of each (see Table 3.1a). Almost 65% of sightings were made in the northern half of the Bay and almost 43% of all sightings were made in the NW quadrant. There were no associations between the

halves of the Bay when quadrants were combined into two categories (i.e. north and south) and group composition variables (Table 4.9d(1) lii-lvii).

Dolphins were sighted in all months surveyed, except December 1991 when only one survey was conducted. Calves were sighted in all months surveyed except December 1991 and June 1992, also when only one survey was conducted. Surveys were not distributed equally across seasons (Table 4.6-iii). When the distribution of sightings were considered using the chi-square goodness-of-fit test with the expected distribution based on uneven sampling effort, there was no significant difference (Table 4.9d(1)-li). That is, most sightings occurred in autumn when most surveys took place. There was no association between season (Table 4.9d(1)) and mean total number (lii), sighting size (lii), mean pod size (lv), pod size classes (lvi) and the presence or absence of calves (vii). An association was found between the number of pods recorded per sighting and season (Table 4.9d(1)-liv). Both single and multiple pods were mainly recorded in autumn with a second peak in winter for single pods. In summer and spring the highest frequency of sightings were single and multiple pods, respectively.

Almost 78% of all sighting events occurred under clear weather conditions. Sightings were made at Beaufort sea state 6 or less with 94% of sightings recorded at BF 3 or less. Hence, it was not useful for this data set to be divided into sightings occurring under good (BF 0-3) or not good (BF 4+) sighting conditions, as for the S&E Survey (see Section 3.3.4).

Like Survey effort (Table 4.6-iv) NTS were distributed evenly across the four tidal states (Table 4.9d(2)-li). No associations were found between tidal state (Table 4.9d(2)) and the mean number of dolphins per sighting event (lii); small (1-10 dolphins) and large (11+) sightings (liii); and the number of pods per sighting (liv). ANOVA indicated a significant difference in the mean size of pods across tidal state. However, data were heteroscedastic and when  $\log_{10}$  transformed the result did not remain significant (Table 4.9d(2)-lv). An association was indicated when pods were divided into small (1-10 dolphins) and larger (11+) size classes

(Table 4.9d(2)-lvi). Larger pods were fairly evenly distributed across tides but the lowest number was recorded at ebb tide when a peak in smaller pods occurred. At low and flood tides mainly smaller pods were sighted while both pod sizes were evenly recorded at high tide. There was no association between tidal state and when calves were present or absent (Table 4.9d(2)-lvii).

No NTS were recorded prior to 0600 or after 1800. Hence three time of day categories were used in these analyses; morning=prior to 0959; midday=1000-1359; afternoon=1400 or after. Sighting events were distributed as expected across the three categories when the chi-square goodness-of-fit test was based on the uneven sampling of the Transect Survey (Table 4.6-liv). Almost 57% of sightings were recorded at midday (1000-1359) when the greatest survey effort occurred (Table 4.9d(2)-li). No association was indicated between time of day categories and any group composition variables (Table 4.9d(2) lii-lvii).

Wind direction was recorded at the time of the initial NTS. The small sample size did not allow chi-square analysis across the nil wind category plus eight compass points. Hence data were combined into only five categories, i.e. nil and the cardinal compass directions. Prevailing winds at the time of initial sightings were from the north and south equally (28%) and on only five occasions was nil wind recorded. Hence, the nil wind category was excluded in the following analyses of wind direction and group composition variables ( $n=49$ ). There was no association between the four remaining wind direction categories (Table 4.9d(2)) and mean total number (lii); sighting size (liii); number of pods (liv); and the presence or absence of calves (lvii). The exclusion of NTS under nil wind conditions resulted in 74 pods for which wind direction was recorded being available for analyses. ANOVA indicated no significant difference in the mean pod size across the four categories of wind direction (Table 4.9d(2)-lv). Nor was there an association between wind direction and pod size classes (Table 4.9d(2)-lvi). There was also no association between wind direction and season (Table 4.9d(2)-lviii) and for this contingency test some expected values were less than one.

Recorded sea surface temperatures at the time of NTS ranged between 12.2°C and 22°C with an overall mean of 18.5°C (S.E. 0.15). For the purpose of chi-square analyses sea surface temperature was divided into cooler or warmer temperatures at the survey mean (i.e.  $n=264$ ). Temperatures were only analysed with respect to sighting events and not per pod. A *t*-test indicated no significant difference in the mean total number of dolphins recorded per sighting when temperature was divided at the mean into cooler or warmer sea surface temperatures (Table 4.9d(2)-lii). Nor was there any association between sighting sizes when divided into two classes and the number of pods per sighting, and cooler or warmer temperatures (Table 4.9d(2) liii & liv). A *t*-test indicated no significant difference in sea surface temperatures when calves were present or absent (Table 4.9d(2)-lvii).

ANOVA indicated a significant difference between sea surface temperatures across season (Table 4.9d(2)-lviii). The seasonal means were: winter 14.9°C (S.E. 0.55), spring 15.1°C (S.E. 0.36), summer 19.2°C (S.E. 0.38), and autumn 20.3°C (S.E. 0.24). The Peritz procedure indicated winter and spring mean temperatures were not significantly different but they were significantly less than the summer mean which was significantly less than autumn. The minimum temperature was recorded in winter and the maximum in autumn suggesting a seasonally delayed period for the study area to warm, as also indicated in the S&E Survey (see Section 3.3.4).

#### **4.3.4.5 Spatial Pattern**

Of the seven descriptive categories for the spatial arrangement of animals with respect to each other, five were recorded for NTS events and only four for pods (Table 4.4). It was necessary to combine categories for the purpose of analysis which resulted in three (i.e. clumped, spread and mixed), or where indicated, two categories (i.e. clumped and dispersed) (see Section 3.2.5).

A *t*-test indicated no significant difference between the mean number of dolphins per sighting for clumped and dispersed groups (Table 4.9e-iii). There was an association indicated between the overall spatial pattern of all animals observed

**TABLE 4.4: Frequency of spatial patterns for Non-Transect Sightings,  $n=54$ , and pods,  $n=89$ . Where na indicates not applicable and nil indicates the Spatial Pattern was not recorded.**

	Clumped	Spread	Core Group + others spread	Multiple clumped pods	Linear	Abreast	Circle
Sighting	22	10	5	16	nil	nil	1
Pod	69	14	5	na	nil	1	nil

and sighting size (Table 4.9e-liii). Most sightings were clumped but were mainly recorded for medium and large sightings while spread and mixed spatial patterns were recorded fairly evenly for all sized groups. No association was indicated between the overall spatial pattern of all animals observed (Table 4.9e) and the number of pods (liv); or the presence or absence of calves per sighting (lvii).

A *t*-test indicated no significant difference in the mean number of dolphins per pod between clumped or dispersed spatial patterns (Table 4.9e-lv). No associations were indicated between pod spatial pattern (Table 4.9e) and the size of pods (lvi); or the presence or absence of calves per pod (lviii).

No associations were indicated between the overall spatial arrangement of the whole group sighted and habitat variables (Table 4.9e), i.e. shallow or deeper waters (lx); and substrata (lxi). No associations were indicated between the overall spatial arrangement of the whole group and environmental variables (Table 4.9e), i.e. quadrants of the Bay (lxii); seasons (lxiii); sea surface temperature (lxiv); BF sea state (lxv); tidal state (lxvi); and wind direction (lxviii). An association was indicated between the overall spatial arrangement of the whole group and time of day (Table 4.9e-lxvii). Sightings were mainly clumped in the morning and at midday while in the afternoon groups were either clumped or dispersed. There was a peak in both clumped and dispersed spatial patterns of sightings at midday, which probably reflects greater survey effort at this time (Table 4.6-liv). No associations were indicated between the spatial arrangement of pods and habitat variables (Table 4.9e lx & lxi), nor with environmental variables (Table 4.9e lxii-lxviii).

#### **4.3.4.6 Behavioural Variables**

Of the nine descriptive categories for behaviour, a total of eight were recorded for NTS (Table 4.5) and where behaviour was not discernible data were not included for analysis. For data analyses three categories of behavioural activities were used, i.e. travel, milling and social/feed as for the S&E Survey data (see Section 3.2.6).

Fifty-one percent of pods recorded were travelling while almost 23% were socialising and 16% were milling (Table 4.5). Only 10% of pods were observed feeding. This low number of recorded feeding behaviours may reflect the very specific definitions of this category and thus the inclusion of feeding in other categories (see Section 3.2.6).

It was not considered meaningful to analyse the overall behaviour of all animals sighted when subgroups, (i.e. pods) were involved in different activities in many instances. Hence, primarily the behaviour of pods is analysed here, except for the overall spatial pattern of the whole sighting group and the general behaviour of the whole sighting group. For the overall spatial pattern using clumped and dispersed categories, no association was found with behavioural activity of the whole group (Table 4.9f(1)-li). Nor was there any association between the behaviour of individual pods and their spatial pattern, using the same categories (Table 4.9f(1)-lii).

ANOVA indicated no significant difference in the mean number of dolphins per sighting event and three categories of sighting behaviour (Table 4.9f(1)-liv), nor for the mean number of dolphins per pod and pod behaviour (Table 4.9f(1)-lvii). There was no association indicated between the behaviour of pods (Table 4.9f(1)) and their size (lviii), nor the absence or presence of calves per pod (lix).

ANOVA indicated no significant difference in mean sighting depths across three categories of behaviour for the whole sighting group (Table 4.9f(1)-lx). No association was indicated between the behaviour of each pod and depth when divided into shallow ( $\leq 11.5$  m) or deep ( $> 11.5$  m) waters (Table 4.9f(1)-lxi). An association was indicated, however, between the behaviour of each pod and sighting substrata (Table 4.9f(1)-lxii). Most categories of behavioural activity were recorded over sand except milling which was not recorded over this substratum and was mainly seen over seagrass. Travel and social/feed were evenly recorded over sand and seagrass while travel was mainly observed over rock.

**TABLE 4.5:** Frequency of overall behavioural activities recorded per sighting event,  $n=53$  and per pod,  $n=88$ . Where nil indicates the behaviour was not recorded.

	Slow Travel	Mod. Travel	Fast Travel	Mill	Rest	Social	Feed	Feed/ Travel	Social/ Travel
<b>Sighting</b>	25	9	5	7	1	3	2	1	nil
<b>Pod</b>	33	8	4	9	nil	6	5	9	14

Beaufort sea state was not analysed due to 94% of NTS being recorded under good sighting conditions, i.e. BF 0-3. Of the six remaining environmental variables analysed (i.e. north or south of Bay, season, tidal state, time of day, sea surface temperature and wind direction), only one, the area of the Bay where animals were sighted, indicated an association with the behaviour of pods (Table 4.9f(1)-lxiii). Most sightings occurred in the northern half of the Bay where the highest frequencies of all behaviours were reported. Although social/feed was fairly evenly recorded in both the north and south of the Bay.

The direction dolphins were travelling at the time of the initial sighting was analysed using five categories, i.e. nil and the cardinal compass directions. Only three environmental variables were considered applicable for analysis in terms of a potential influence on the dolphin's direction of travel, i.e. tidal state, wind direction and time of day. No association was found between the animals' direction of travel and tidal state (Table 4.9f(2)-li). An association was found between the animals' direction of travel and wind direction (i.e. excluding the small number of nil wind conditions,  $n=5$ ). However some expected chi-square values were less than one, hence this result is not considered further (Table 4.9f(2)-liv). An association was found between the animals' direction of travel and time of day when the small number of afternoon ( $>1400$ ) sightings were excluded ( $n=5$ ). Most sightings (74%) in the morning involved animals heading north or west (i.e. deeper into the Bay) while at midday most dolphins (73%) observed were heading either north or south (Table 4.9f(2)-lii). Under nil and east wind conditions the dolphins' direction of travel was equally distributed between morning and midday categories.

#### **4.3.4.7 Abundance and Density Estimates**

##### **a) Abundance**

Survey effort was distributed equally between quadrants (Table 4.6-liii). However, the total number of dolphins sighted ( $n=779$ ) varied significantly across the different quadrants of the Bay when these were adjusted for the area of each (see

Table 3.1a). Sixty-five percent of the animals recorded were in the northern half of the Bay. The highest number sighted were in the NW (42%) with the next highest in the SW (23%) (Table 4.9g-li). All quadrants other than the NW recorded less dolphins than were expected.

The total number of calves sighted ( $n=45$ ) also varied significantly across the different quadrants of the Bay when these were adjusted for the area of each (Table 4.9g-lii). Sixty-two percent of the calves recorded were in the northern half of the Bay. The highest number sighted were in the NW (49%), the next highest in the SW (31%) and the remaining quadrants recorded fewer than was expected.

There was also a significant difference in the total number of animals sighted across seasons when survey effort was considered. The highest number of animals was recorded in autumn (60%) and the next highest in summer (19%) (Table 4.9g-li), while in winter and spring significantly lower numbers of dolphins were recorded than expected. There was also a significant difference in the total number of calves sighted across seasons when survey effort was considered. Seasonal calf abundance reflected the seasonal pattern for total abundance, i.e. the highest number of calves was recorded in autumn (60%), followed by summer (22%) and lower numbers of calves were recorded in winter and spring than expected (Table 4.9g-lii).

There was no significant variation in the total number of animals or calves recorded at NTS events across the two years of the Transect Survey when survey effort was accounted for (Table 4.9g li & lii).

The total number of animals sighted over sand, seagrass and rock were 294, 347 and 138. When sightings at depths beyond 10 m were excluded most animals remained sighted over seagrass (347), then sand (160) and fewest over rock (132). However, when the areas of each substratum in these waters were considered (see Table 3.4) more dolphins than expected were seen over both seagrass and rock, and less than expected over sand (Table 4.9g-li). The total number of calves sighted

over sand, seagrass and rock were 16, 22 and 7. When sightings with calves at depths beyond 10 m were excluded most calves sighted remained over seagrass (22), then sand (10) and fewest over rock (5). However, when the areas of each substratum in these waters were considered the same pattern as for total abundance was found (Table 4.9g-lii).

#### **b) Density**

The mean density estimate for the whole study area (117.2 sq km) based on the total number of animals sighted in transit between transects ( $n=779$ ) per survey ( $n=58$ ) was 0.12 *Tursiops*/sq. km.

As 83% of NTS were made in waters  $\leq 10$  m, dolphin density was estimated for these areas in each quadrant rather than the total area of each quadrant. The highest density occurred in the NW of the Bay with 0.59 *Tursiops*/sq. km and the lowest density was recorded in the SE quadrant with 0.34 *Tursiops*/sq. km. (Table 4.9h-li).

Seasonal density also varied in the study area for this survey (Table 4.9h-lii) with the highest densities recorded in summer and autumn at 0.21 and 0.14 *Tursiops*/sq. km, respectively. The lowest seasonal density was 0.05 *Tursiops*/sq. km, recorded in spring.

Estimated dolphin density varied across the different substrata located in  $\leq 10$  m of water of the Bay for NTS. The highest density occurred over rocky complex areas with 3.7 *Tursiops*/sq. km and then seagrass and sand with 1.8 & 0.8 *Tursiops*/sq. km, respectively (Table 4.9h-liii). Estimated calf density also varied across the different substrata located in  $\leq 10$  m of water of the Bay for NTS. The highest density occurred over seagrass with 0.09 calves/sq. km and then rocky complex areas and sand with 0.06 & 0.02 calves/sq. km, respectively (Table 4.9h-liv).

## **4.4 Discussion**

The following discussion is primarily concerned with results that were similar and or significantly different among four data sets, firstly between sightings from the transect line (TS) and Non-Transect Sightings at Transect Sites (NTTS); and secondly between all Non-Transect Sightings (NTS) and Search and Encounter (S&E) Survey data sets. This approach has been adopted primarily because of the small sample sizes of all data sets which raises concerns about the biological significance of the results. The focus on concordant findings between different sampling methods (in the first instance) and independent surveys (in the second case) allows at least the apparently “strongest” or most consistent trends to be highlighted.

### **4.4.1 Transect Sightings (TS) and Non-Transect Sightings at Transect Sites (NTTS)**

TS were made on 18 days and the total number of dolphins sighted was 289. A total of 361 dolphins were recorded during NTTS over 19 days. Sightings were made from both sampled transects and NTTS on nine days. The maximum number of sightings on such days was four and this occurred on two survey days (i.e. the remaining seven days consisted mainly of two sightings per day, one from each data set). The total numbers of dolphins recorded from these two days were 52 and 35. The level of resightings on the Transect Survey within and between field days is not known and may or may not be significant but is unable to be determined without individual identification data.

The similarity of the two data sets when collected on different days suggests there may be a significant resighting component between Survey days. Although, from field observations resighting levels are considered negligible within a field day because of the timing of the sighting, direction of travel of the animals and the survey route. That is, for nine days when only TS were made the total number of animals sighted was 126 and the mean sighting size was 11. While for the ten days

when NTTS were made only, the total number of animals sighted was 175 and the mean sighting size was 15. Alternatively, the similarity of the two data sets may suggest different groups of bottlenose dolphins in Jervis Bay show similar patterns of occurrence, group size and numbers of calves.

Results that were significant and/or similar for both data sets were:

#### **Group Composition**

- \* mean sighting and pod sizes are similar to the most common mean “group” sizes (2-15) for bottlenose dolphins at other locations (Wells *et al.*, 1990) (TS=11 & 8; NTTS=16 & 10 dolphins, respectively); and
- \* calves represented 4.8% (TS) and 4.7% (NTTS) of observed animals.

#### **Habitat Variables**

- \* the majority of sightings were found in the shallowest, i.e  $\leq 10$  m, of three different depth categories for the whole of the Bay (TS=100%; NTTS=87%); and
- \* a significantly higher proportion of sightings were made over the rarer substrata of seagrass and rock combined which cover only approximately 10% of the Bay, as compared to sand, when the area of each substratum was considered (TS=58%; NTTS=65%, respectively).

#### **Environmental Variables**

- \* the majority of sightings and highest number of dolphins, were recorded from the northern half of the Bay (TS=62% & NTTS=70%; TS=55% & NTTS=76%, respectively);
- \* the highest number of sightings and highest number of dolphins, were in the NW quadrant (TS=42% & NTTS=48%; TS=46% & NTTS=55%, respectively);
- \* the highest seasonal abundance of dolphins in the Bay was recorded in autumn (TS=74% & NTTS=76%);
- \* there were associations indicated between tidal state and sighting size classes but the patterns differed between data sets; and
- \* there were associations indicated between tidal state and pod size classes but the patterns differed between data sets.

Sampling effort was not equally distributed across all depths with 62% of transects in waters  $\leq 11.5$  m in depth. The remaining 38% of transects were located in waters  $>11.5$  m to a maximum depth of 40 m. The degree to which this sampling bias affects the rate of sightings is not known but the bias has been corrected for in most analyses.

The maximum sighting depth of any sighting was 15 m (NTTS). Also, when the maximum depth of a transect from which sightings occurred and the recorded sighting depths for NTTS were combined, only 6% of all sightings were recorded at depths  $>11.5$  m. Hence, the great usage of relatively shallow waters by dolphins in Jervis Bay was indicated from both data sets. Although sample sizes are small and effort was unequal across depth, this is suggested to be representative of these animals' "real" patterns of distribution.

Abundance patterns and density estimates were only considered for TS. All TS were within 1 km from transect lines. Hence the density estimate for 264 sq. km, based on the total number of dolphins sighted from transect lines and the 264 occasions transects were sampled was 1.1 *Tursiops*/sq. km. The difference in this estimate (approximately 9x larger) and those calculated for the whole Bay from the S&E and NTS data sets (see Section 4.4.2) relates primarily to differences in survey methodology. The main reason for using the line transect survey approach in this study was to investigate sightings of *Tursiops* in relation to different habitats. Hence the location of transects and sampling effort were designed to meet this objective, not to ascertain the density of dolphins in the study area. This density estimate is considered to reflect the increased effort of the Transect Survey in shallow waters where all sightings occurred. That is, 60% of sampled transects occurred in waters  $< 11.5$  m in depth as a result of two of the three substrata being restricted to these depths. The density estimate for the whole Bay based on TS, using the same approach as for the S&E and NTS data sets (i.e. the mean number of dolphins sighted per survey) is 0.04 *Tursiops*/sq. km. This estimate is approximately a third less than estimates based on the other two data sets. This is not surprising since all sightings made during a S&E survey were recorded, and all

those made in transit between sampled transect sites were recorded for the NTS data set. However, TS were restricted to those made on randomly sampled transects which only included, on average, four to five transects per survey day. Due to the Transect Survey design the use of TS data to estimate density for the whole study area, including seasonal density estimates, is not considered useful and is not discussed further. Density estimates within nearshore waters are calculated, as per the larger two data sets.

When sightings from transects with maximum depths beyond 10 m were excluded ( $n=21$ ), most TS were over sand (119), then seagrass (69) and least over rock (42). However, when the areas of each substratum in these waters were considered more dolphins were sighted over rock than expected, and less over both seagrass and sand. Also, density estimates for substrata in waters  $\leq 10$  m in depth indicated the density of dolphins was greatest in rocky areas, less over seagrass and least over sand, reflecting the S&E and all NTS data sets (see Section 4.4.2).

Sea surface temperatures recorded during the Transect Survey ranged between a minimum of 13.3°C and a maximum of 23.5°C with an overall mean of 18.4°C. The autumn high in sea surface temperatures for the Transect Survey period was reflected in TS data but not the NTTS data set. As in the S&E Survey, the minimum sea surface temperature recorded during the Transect Survey was in winter and the maximum in autumn, suggesting a seasonally delayed period for the study area to warm.

As discussed in Section 3.4.3 the reasons for the association between sighting and pod sizes and tidal state are not readily apparent, nor are the reasons for the variable nature of these association patterns.

The significant results from ANOVA (which could only be carried out on TS data) found:

- \* the mean number of animals over rocky areas increases from 4 to 8 metres in depth while over both sand and seagrass the mean number decreases from 4 to 8m; and
- \* significantly more calves were sighted in 8 m over rocky complex areas than for any other depth and substratum combination.

These results may give some insight into the interaction of depth and substratum in terms of dolphin distribution and possible usage patterns. The first result may reflect environmental conditions, the distribution of prey resources, and/or social factors. For example, rocky reef topography may make manoeuvring in 4 m difficult which may reduce accessibility of prey, or preferred food resources may be more abundant at the margin of rocky areas. In contrast, the nearshore environment over seagrass beds is an open habitat, protected from wave action which may make it attractive for larger groups. Such groups typically consist of multiple pods. The S&E Survey suggested that, in shallow depths, larger pods may be involved in a range of activities, and all behaviours were recorded, particularly milling and travel. Alternatively, different depths may result in the availability of different prey species which may require different foraging strategies and hence differences in dolphin group sizes. Very shallow waters over seagrass in some areas of Jarvis Bay are close to the sand margin along adjacent beaches. CSIRO (1994) indicated these areas yielded the greatest number of prey species and individuals including rarer species, baitfish and juveniles, compared to other shallow sandy beach habitats in the Bay. Very shallow waters over sand in Jarvis Bay are typically open beach habitats. While relatively protected compared to beaches along the coast, most are affected to varying degrees by sea swell. Jarvis Bay is known for its water clarity, but wave action and hence turbidity is likely to be more marked at 4 rather than 8 metres in these environments. It is difficult, however, to imagine what factors may influence group size between 4 and 8m, in these relatively uniform environments.

The second result explains to some degree the first finding that more animals are going to be sighted at 8 versus 4 metres over rocky areas because a component of

the local population, mothers with calves, display this preference. This result relates specifically to two locations in the study area, Callala Point and Plantation Point (see Fig. 2.2). A similar finding was indicated for NTTS with 41% of calves sighted at these two Points. These findings may suggest the importance of these two rock platforms specifically, which in turn may reflect the conclusions of a study on rocky reefs in the Bay which found "...that reefs within Jervis Bay fulfil ecological functions which vary from reef to reef..." (Lincoln Smith *et al.*, 1992).

Why calves are sighted more frequently in 8 m over rocky areas may relate to environmental and accessibility factors mentioned above, and/or the high energy requirements of a lactating female. These habitats, the margins of rocky areas, may provide a diverse and/or abundant food supply. Cockcroft & Ross (1990b) found a trend toward greater numbers of prey species in the stomachs of lactating females which they suggested may reflect the increased energetic cost of lactation and the need to take "any prey presenting itself". The margin of rocky areas may also be suitable for individual or small group foraging strategies by providing, for example, opportunities for herding against higher relief areas otherwise unavailable in more open habitats. Hence, such habitats may be particularly useful for mothers with calves which may need to spend more time foraging than other members of the population (Cockcroft & Ross, 1990b). These authors also noted that off the Natal coast, shallow inshore reefs constitute the nursery areas for several fish species, one of which predominated in the "restricted" diet of calves. Alternatively, it may be that the close proximity of Callala and Plantation Points to areas of seagrass is a reason for their apparent importance to calves (and their mothers). If the proximity to seagrass is a factor, this may relate to the provision of protected waters for calving and suckling, a variety of food resources in close proximity for weaned calves, and/or a variety of prey size classes. The latter reflects the "fish nursery" character of seagrass habitat (Bell & Pollard, 1989) which may be of value to weaning calves. It is recognised that without knowing exactly where dolphins feed in Jervis Bay the most, these points remain speculative.

However, it is interesting that no significant and homoscedastic results were found for the other ANOVAs investigating the interaction of depth and substratum. Possibly, the distribution of sightings is linked only with substratum type and not with depth. Thus, if particular substrata were found in shallow or deeper waters it may not affect their preferential use. In this study I was only able to look at the distribution of sightings over one substratum (i.e. sand) across shallow and deeper waters. No doubt shallow versus deep water over sand provides different habitats and hence probably supports different species assemblages, but the results indicate a preference by dolphins for shallow waters over this substratum.

The exact nature of these trends are not able to be resolved from these small data sets at one study site. Hence the reasons for these patterns remain points of conjecture and may relate to prey distributions or some other important ecological requirements associated, for example with mating, calving, rearing young, or predator avoidance.

#### **4.4.2 All Non-Transect Sightings (NTS) and Search and Encounter (S&E) Survey sightings**

The S&E Survey traversed shallow waters around the periphery of the Bay, that is 74% of the total distance searched was in waters  $\leq 10$  m in depth. The Transect Survey randomly sampled sites throughout the whole Bay and also recorded 'opportunistic' sightings in transit between sampled sites. Survey effort was also greater on the Transect Survey in nearshore waters with 59% of the total distance searched in waters  $\leq 10$  m depth. Hence, while differences in survey methodologies do not allow direct comparison of results, it is possible to consider similar trends produced by these two different types of surveys, based on the opportunistic character of the subset of NTS from the Transect Survey.

The S&E Survey was conducted over 29 months with the Transect Survey running concurrently in the last 15 months. The level of resightings within and between survey days is unknown. While no overlap occurred between the two different

Survey days, there was similarity in gross sighting data. On 33 days, the total number of dolphins sighted at NTS was 779. These animals were recorded at 54 separate sighting events and had a mean sighting size of 14. On the 31 occasions where calves were observed, a total of 45 individual calves were recorded. On 31 days on the S&E Survey, 635 dolphins were recorded. These animals were sighted at 49 separate sighting events and had a mean sighting size of 13. On the 29 occasions where calves were observed, a total of 48 individual calves were recorded.

The mean duration of observation was a little less for NTS (47 minutes) than those made on the S&E Survey (57 minutes). This results from my decision to terminate these encounters earlier in order to complete the maximum number of transects possible each survey day. The total time spent observing animals during NTS represented approximately 12% of the time spent conducting the Transect Survey which is considerably lower than for the S&E Survey (approximately 21% of the total search time). I suggest this difference reflects the shorter duration of individual observations as well as the greater time spent in deeper waters on the Transect Survey. The value of longer contact rates available on the S&E Survey, as a result of the smaller area surveyed and the greater survey effort and costs associated with random sampling of transect sites across the whole Bay, must be evaluated in terms of the aims of the study (see Section 4.4.3).

Results that were similar and/or significant for both data sets were:

#### **Group Composition**

- \* the mean sighting and pod sizes fall within the most common mean group size range (2-15) reported by Wells *et al.* (1990)(S&E=13 & 7.5; NTS=14 & 8.7 dolphins, respectively);
- \* the smaller the total number of animals recorded per sighting, the more likely it is to be a single pod while medium to large sightings are more likely to consist of multiple pods;
- \* calves are more likely to be present when the mean number of animals recorded per sighting is larger versus smaller;

- \* the majority of calf sightings were of a single calf per pod (S&E=59%; NTS=77%);
- \* the maximum number of calves sighted at any one sighting event was three for both data sets; and on a single survey day was six (S&E) and four (NTS); and
- \* the total number of calves observed represented 7.6% (S&E) and 5.8% (NTS) of the total number of observed animals.

### **Habitat Variables**

- \* significantly more sightings were made over the rarer substrata of seagrass and rocky complex areas, which only cover approximately 10% of the Bay, when the area of each substratum was considered (S&E=50%; NTS=63%);
- \* the majority of sightings were recorded in waters  $\leq 10$  m in depth which cover approximately 24% of the Bay (S&E=77%; NTS=83%); and
- \* the mean sighting depths were greatest over sand, then rock and shallowest over seagrass (S&E=10.3 m, 6.0 m & 5.9 m; NTS=9.7 m, 6.1 m & 5.7 m, respectively).

### **Environmental Variables**

- \* the majority of sightings were made in the northern half of the Bay (S&E=71%; NTS=65%) and these were mainly in the NW quadrant, 43% of all sightings from both data sets;
- \* the majority of calf sightings were made in the northern half of the Bay (S&E=69%; NTS=62%) but distribution patterns between quadrants varied between data sets;
- \* there was an association between tidal state and the size of pods but the patterns differed between data sets; and
- \* an association was indicated between seasons and sea surface temperatures with cooler temperatures recorded in winter and spring and warmer temperatures in summer and autumn.

### **Abundance Patterns**

- \* across both data sets there was no single month surveyed when dolphins were not sighted, i.e. some dolphins can be found in the Bay throughout the year;
- \* there was no significant variation annually in the total number of dolphins sighted, when survey effort was considered for both data sets;

- \* the total number of animals sighted across seasons were significantly different for both data sets when survey effort for each was considered; however, the patterns differed. The highest numbers were recorded in summer (39%) on the S&E Survey and in autumn (60%) for NTS. The second highest numbers were recorded in winter (28%) on the S&E Survey and in summer (19%) for NTS;
- \* the majority of animals sighted were in the northern half of the Bay (S&E=78%; NTS=65%) and these were mainly in the NW quadrant (41 & 42%);
- \* animals were more abundant over seagrass (48 & 54%), then sand (35 & 25%) and least over rock (17-21%) in waters  $\leq 10$  m in depth for the S&E Survey and NTS, respectively;
- \* significantly more dolphins were sighted over the rarer substrata of seagrass and rocky complex areas in waters  $\leq 10$  m, when the area of each substratum was considered;
- \* across both data sets there was no single month surveyed when calves were not sighted, i.e. calves can be found in the Bay throughout the year;
- \* there was no significant variation annually in the total number of calves sighted, when survey effort was considered for both data sets;
- \* the total numbers of calves sighted across seasons were significantly different for both data sets when survey effort was considered; however, the patterns differed. The highest numbers were recorded in winter (44%) on the S&E Survey and in autumn (60%) for NTS. The second highest numbers were recorded in autumn (25%) on the S&E Survey and in summer (22%) for NTS;
- \* calves were most abundant over seagrass (59 & 52%), then sand (28 & 32%) and least over rock (13 & 16%) in waters  $\leq 10$  m for the S&E Survey and NTS, respectively; and
- \* significantly more calves were sighted over the rarer substrata of seagrass and rocky complex areas in waters  $\leq 10$  m, when the area of each substratum was considered.

### **Density Estimates**

- \* a relatively low density of dolphins (Shane *et al.*, 1986) in the Bay (S&E=0.13 *Tursiops*/sq. km; NTS=0.12 *Tursiops*/sq. km);

- \* the density of *Tursiops* was highest in the NW quadrant for both data sets but density patterns varied between data sets across the remaining three quadrants;
- \* the density of *Tursiops* was greatest in rocky areas, less over seagrass and least over sand in waters  $\leq 10$  m in depth; and
- \* the highest density of calves in  $\leq 10$  m of water occurred over seagrass, then over rocky complex areas and least over sand.

### **Spatial Pattern**

- \* there was an association indicated between the overall spatial pattern of all animals observed and sighting size, although the patterns were slightly different for both data sets. Generally larger groups consisted of either single or multiple clumped pods versus dispersed spatial arrangements.

### **Behaviour**

- \* for both data sets approximately 50% of pods sighted were travelling and 21% were socialising. Milling was recorded on 10% & 21% of occasions and feeding on 16% & 8%, for the NTS and S&E data, respectively.

Many of these findings have been discussed with respect to the S&E Survey results in Chapter 3, Section 3.4, hence I will not refer to all of the above results in detail here. I simply note that some of the trends discussed previously for the S&E Survey results have been repeated in the NTS.

As for the S&E Survey, there was no significant variation in the total number of animals sighted across the two years of the Transect Survey, or for the NTS data set when survey effort was considered. As noted in Section 3.4, for the S&E Survey, this does not necessarily indicate that the same animals use the study area, i.e. a resident group. This trend alternatively may suggest that individuals or subgroups within the population (see Section 1.1) move in and out of the Bay, resulting in a consistent number of sightings annually but different individuals or subgroups being sighted at any point of time (see Chapter 6). This trend may suggest that the Bay, and more specifically its resources, have a limited carrying capacity for these large mammals. Cockcroft *et. al* (1991) suggested dolphins off the south coast of Natal may have to forage farther from shore due to a reduction

in the productivity of the inshore region and hence a reduction in the carrying capacity of any given area within that region. Alternatively, these individuals or subgroups may range between more “suitable” but geographically separated habitats (Krebs, 1985), where “suitability” as Krebs suggested (1985), may relate to factors other than just food supply, such as shelter, the presence of predators or the density of individuals. Cockcroft & Ross (1990b) suggested that, off the Natal coast where bottlenose dolphins have been observed more frequently along particular regions, “...they probably exert continuous pressure on available food resources in these areas...”. These authors also suggested that “...inshore dolphins may have adapted socially and behaviorally to alleviate intraspecific competition for food. These behavioral adaptations may include partitioning of the school into subgroups and the use of different foraging ranges or different prey sizes and species by these subgroups...”. Some populations of *Tursiops* are known to form separate sex and age class groups (Wells, 1986; Smolker *et al.*, 1992) and the density of such sub-groups at any point of time may also influence the suitability of the Bay for other dolphins.

As for the S&E Survey, there was no significant variation for NTS in the total number of calves sighted annually. As noted in Section 3.4, this trend may suggest that the population using the Bay is stable. The repetition across both data sets of: the range of calf counts per sighting event (i.e. 0-3); the maximum number of calves sighted at any one sighting event (3); and the similar range for the maximum number of calves sighted on a single survey day, i.e. 6 (S&E) and 4 (NTS), all suggest that if the same individuals aren't being sighted, then at least the overall rate of calf sighting across years is consistent in this area of the population's range

The variation in seasonal abundance peaks across both data sets does not indicate a single seasonal peak in total abundance but rather suggests higher numbers in the Bay during both autumn (i.e. NTS data), and summer with a possible influx in winter (i.e. S&E data). Also, no clear seasonal patterns in calf abundance are apparent across both data sets. Hence the suggestion that a single breeding peak

may occur in autumn, based on the S&E data (see Section 3.3.3), remains speculative. The pattern of seasonal density estimates for the total number of dolphins per sq. km in the Bay also varies across both data sets. As noted previously all density estimates are based on small sample sizes and should be regarded with caution. Furthermore the unknown level of resightings within and between field days would further reduce these estimates.

The contact rates (i.e. the proportion of the total search time actually spent observing the animals) for these data sets are both low compared to other studies as discussed in Section 3.4 suggesting the possibility that the overall density of dolphins in my study area is lower than at other sites (Shane *et al.*, 1986). This relatively low density of dolphins in the Bay also suggests there may be limiting factors in terms of the number of animals using the Bay at any one time and or the duration of stay of individuals in the study area. As noted previously, these may relate to the carrying capacity of the Bay in terms of food resources and/or the social structure and dynamics of the population.

Interestingly, although more time was spent in deeper waters on the Transect Survey than on the S&E Survey, a greater proportion of sightings was recorded in shallower waters from the former (83%) than the latter (77%). These results strongly suggest that *Tursiops* spend much of their time in shallow waters in Jervis Bay, although adjacent protected deep waters, relative to the open coast, are available. Saayman & Taylor (1973) described large coordinated schools of bottlenose dolphins frequenting deep water far out to sea as well as penetrating the surf zone to a depth of about one metre. These authors noted that "...Hunting in dispersed groups in the surf zone, over reefs, and off rocky outcrops, however, appeared to require more sustained activity than did the capture of pelagic fish...". Saayman & Taylor (1973) concluded "...Thus, these large schools of *Tursiops* may well represent a successful social adaptation to the exploitation of both the inshore and the more prolific pelagic food supply..". The use of different foraging and feeding strategies in different habitats, for different prey species by *Tursiops* has been well documented subsequently (for example, Shane, *et al.*, 1986; and Shane,

1990b). In Jervis Bay dolphins were observed infrequently entering deeper waters (i.e. >20 m), and on those occasions were rarely seen feeding. When feeding was observed, it took place mainly (80%) in waters  $\leq 10$  m in depth (see Section 7.3).

I am unaware of any systematic, quantitative studies of differential habitat use in nearshore waters by *Tursiops* being undertaken elsewhere. However, a number of authors have noted the presence and/or probable importance to the abundance of *Tursiops* of such habitats as: mangroves (Shane, 1987; Van Waerebeek *et al.*, 1990); seagrass (Wells *et al.*, 1980; Shane, 1987, 1990; Scott *et al.*, 1990a); rocky areas (Saayman & Taylor, 1973; Lear & Bryden, 1980); kelp beds (Hansen, 1990); and estuarine ecosystems (Hansen, 1990; Ballance, 1992). As in this study, Lear & Bryden (1980) found that the density of dolphins in the Moreton Bay region of south-eastern Queensland was greatest in rocky shore areas. However, in contrast to the above study in an open bay, the results of my surveys done in an enclosed bay suggest it is rocky areas in shallow waters versus adjacent to deep waters which are preferred by *Tursiops* in this study area. Unlike the S&E Survey, the Transect Survey included the deep rocky shorelines which characterise Point Perpendicular and the northern end of Bowen Island at the entrance to Jervis Bay (see Fig. 4.2), yet no sightings of *Tursiops* were recorded in these areas. In terms of the number of sighting events and dolphin abundance the results from both the S&E Survey and NTS data sets indicate the importance of seagrass and rocky areas in Jervis Bay to bottlenose dolphins.

The evidence from S&E Survey and NTS data sets concerning the greater number of sighting and abundance of dolphins in the northern versus the southern half of the Bay and specifically the NW quadrant reinforces the results of the smaller data sets described earlier, i.e. TS and NTTS data sets. The distribution pattern of sightings with respect to habitat is also different between the two northern quadrants for both the S&E and NTS data sets. Table 3.7 summarised the apparent differences between the NW and NE quadrants. Figures 3.2 & 4.8. show sightings in the NW quadrant are clustered over seagrass and rocky areas around Callala Point but also spread along the length of sandy beaches (see Figs. 2.2 & 2.3, for

maps indicating locations and substrata). In the NE, however, there is a cluster of sightings over seagrass adjacent to the rocky reef at Green Point with the remainder spread over sand in deeper water. These data suggest the importance of seagrass and rocky reefs but may also explain the seemingly disproportionate number of sightings in the NW as compared to the NE. Essentially Hare Bay, with its adjacent seagrass, rocky reef and protected sandy beaches, is probably the area with the richest variety of prey resources in the Bay for the bottlenose dolphin. South of Hare Bay, the NW shoreline probably has more potential foraging areas than the NE shoreline. The NW has the entrance of three of the four major creeks including the largest, Currumbene Ck, and three large rocky reef areas. I suggest dolphins are distributed along the total length of the NW quadrant's shoreline primarily as a result of the distribution of prey resources. That is they are foraging along sandy beaches and adjacent to estuaries and travelling between important foraging sites of known prey abundance, e.g. Plantation Point and Callala Point/Hare Bay. This distribution pattern does not appear to be directly related to predation threats, presumably from sharks (see Section 8.3) because of the sightings of dolphins in slightly deeper waters along the NE shoreline. In the NE quadrant dolphins may be expected to be more vulnerable to shark attack, as it is closer to the entrance of the Bay with a steeper contour gradient along the shoreline. Unfortunately the limited behavioural analyses from this study provide little clarification of habitat usage by dolphins, probably due to the small sample sizes.

The positive association of sighting size with the number of pods in the S&E, NTS and TS data sets is generally explained by these animals' tendency to group in "larger" aggregations which are typically ephemeral in nature but which may have sub-groups that are relatively stable (Connor *et al.*, 1992; Smolker *et al.*, 1992). However, the definition of pod used in this study (i.e. a sub-grouping of animals visible to the observer at the time of recording, based on the relative spatial arrangement of the dolphins present) does not suggest any definitive social associations between individuals. The implication of this definition in the interpretation of some results is highlighted in analyses of the presence or absence

of calves. In the S&E data calves were present when both the mean size of groups and pods were larger versus smaller. This result was only reflected in NTS data for sighting groups, not pods. For the S&E data, pods with calves had a mean size of 9.7 dolphins. However no association was found between the presence or absence of calves and two pod size classes (i.e. small (1-10) and large (11+)). In contrast, for the NTS data there was no significant difference in mean pod sizes with and without calves but an association was indicated with pod size classes, i.e. calves were mainly present in small pods. These results may indicate inappropriate size class categories where, for example, the most common pod size with calves overlaps between the arbitrarily chosen small and large size classes. Alternatively, the inclusion of pods in this study which have no definitive social associations and consequently may be only temporary groupings, may confound such analyses. These results also highlight the importance of providing definitions for such terms as group, pod, party, sub-group, herd or school and some consideration of their biological relevance in any particular study.

Smolker *et al.* (1992), in their Shark Bay population study, reported a mean "party" size of 4.8 dolphins, markedly lower than the mean pod size of both data sets (i.e. S&E=7.5; NTS=8.7). This may be related to differences in definitions or the inclusion of foraging assemblages in my analysis which were excluded by Smolker *et al.* (1992), for their investigation of association patterns. However, the latter was represented by only a small number of observations in my study and the differences in definition are not obvious. These authors reported that of the 869 parties where the sexes of all members were known, a significant difference in association patterns between the sexes existed. They found 49% of these parties contained both male and female non-calf members, 27% only non-calf females, and 24% only non-calf males. Mother-calf associations were found to be consistent for the first four years after which considerable individual variation was reported. Female-female associations usually consisted of pairs, but each were linked into a single network by associations with other females. Unfortunately no data were given on the nature of association patterns specifically of females with calves. However, why calves should be reported most frequently in larger groups in this

study (particularly without knowing the sex composition of these groups) is difficult to ascertain. This apparent trend may relate to the greater visibility of larger groups versus smaller and/or the successful avoidance of the research vessel by small groups of females with calves. Alternatively, larger numbers of females may associate in sub-groups or larger mixed-sex groups may be more prevalent in Jervis Bay than Shark Bay. This pattern may relate to a need for increased protection of calves in Jervis Bay versus other sites. It has been suggested that such protection may be afforded by larger groups (Würsig, 1978; Wells *et al.*, 1980). However, this study only suggests gross group composition patterns, the implications of which remain speculation until a detailed investigation is conducted of the social organisation of the dolphins in Jervis Bay.

The highest density of *Tursiops* in waters  $\leq 10$  m in depth in Jervis Bay was over rocky areas. Over this substratum the results from TS indicated that the mean number of animals increased with depth and that more calves were seen over rocky areas at 8 m than any other depth/substratum combination. Hence the group composition trend for larger groups to include calves may also reflect habitat usage patterns. However, in both the S&E and NTS data sets the highest abundance of calves was recorded over seagrass, and density estimates for calves in waters  $\leq 10$  m in depth were slightly higher over seagrass than over rocky areas. These apparently conflicting findings are probably due to different survey methodologies. The TS results relate to only two reef sites, both of which recorded higher sightings of calves than any other rocky area. While the S&E and NTS data sets relate to sightings over different substrata throughout waters  $\leq 10$  m and are not site specific. Effectively these results highlight the importance of these two reefs particularly and seagrass generally, to the distribution of calves in Jervis Bay.

Shane (1990a) suggested that the size and spatial pattern of a group varies with the dolphin's activity. Hence the association found in both data sets between overall spatial pattern and group size, is not surprising. The data sets are too small, however, to make any definitive assessment of these variable patterns. Furthermore, because no associations were found between behaviour and spatial

pattern, further behavioural investigations are required to identify any functional significance of these spatial arrangements.

It is difficult to compare behavioural data between studies when definitions and sampling methodologies vary and there is a need to combine different categories for analysis, as in this study, due to sparseness of data. However, most of my definitions of behavioural activities (see Appendix 2) are based on definitions presented by Shane (1990a) in a study of dolphin activities off Sanibel Island, Florida. Five categories of behavioural activity (i.e. travel, feed, socialise, travel/feed and social travel) were analysed by Shane (1990a) based on instantaneous scan sampling of focal groups ( $n=3,866$ ). Shane (1990a) did not include a “milling” category in this analysis. If these categories are combined as I did (i.e. including mixed categories of “travel/feed” into “feed” and “social travel” into “social”) then the percent occurrence of the remaining three activities are travel 46%; socialising 17%; feeding 38%. As indicated previously, in this study the occurrence of the main four activities of pods are similar across both the S&E and NTS data sets, i.e. approximately travel 50%; socialising 21%; milling 10% & 21%; and feeding 16% & 8%. Interestingly, the proportions of time spent in “travel” (probably the least contentious activity definition) and socialising are similar between these two studies located in very different environments and based on very different-sized data sets. An obvious difference between these two studies is the small number of feeding records from my study which may relate to the: specific nature of my definitions (see Section 3.2.6 and Appendix 2); possibility that milling represents against-current feeding (see Section 3.4.5); possibility that animals are feeding outside this study area; or uneven sampling effort across time of day categories. That is, feeding peaks in the morning, as suggested in this study, and possibly secondary evening peaks, as reported elsewhere (Shane *et al.*, 1986; Bräger, 1993) could have been missed.

#### 4.4.3 Suitability of Line Transect Methodology for local “population” studies of *Tursiops*

The Transect Survey had two primary aims, to test the null hypothesis that dolphins are distributed equally over different habitats (i.e. depth and substratum) throughout Jervis Bay, and to estimate the abundance of dolphins using the Bay during the Survey.

The small number of TS ( $n=26$ ) represented approximately 10% of my sampling effort which is quite comparable to some small vertebrate trapping rates in terrestrial surveys (e.g. Friend *et al.*, 1989). However, this small sample size limited analysis. In terms of investigations of habitat usage this resulted in TS effectively operating as independent supporting evidence for trends in the data derived from opportunistic sightings.

The sample size, in this case the number of groups or “clusters” detected, was too small ( $n=26$ ) to allow density estimates using the distance sampling method described by Buckland *et al.* (1993): “...As a practical minimum,  $n$  should usually be at least 60-80...If the population is clustered, the sample size...should be larger to yield similar precision for the abundance estimates of individuals...”. As acknowledged by these authors, “...cetacean surveys may need to be large scale to yield adequate sample sizes; in the eastern tropical pacific, dolphin surveys carried out by the US National Marine Fisheries Service utilise two ships, each housing a cruise leader and two teams of three observers, together with crew members, for 4-5 months annually. Even with this effort, sample sizes are barely sufficient for estimating trends over 8 or more years with adequate precision, even for the main stock of interest...”. This suggests that vessel-based line transect surveys aimed at calculating density estimates, are not likely to be useful for cetacean populations below a certain minimum, nor for species which do not aggregate in large numbers.

Cockcroft *et al.* (1992) concluded, after a study of abundance and undercounting in aerial surveys of bottlenose dolphins off the coast of South Africa, that "...in view of the imprecision and cost of aerial survey estimates, it may be profitable to undertake intensive fieldwork, relying on photographic identification of individuals and modified mark-recapture techniques to estimate stock levels...in addition to continuation of regular aerial assessments...". It is this combination of survey approaches I also advocate as the most practical strategy to obtain abundances and density estimates for populations of inshore *Tursiops*.

In the absence of aerial surveys to estimate and monitor abundance of *Tursiops* stocks in NSW waters, however, there is a need for some practical, quantitatively rigorous survey methods which can be applied at the local or regional scale. This is important for the conservation of local populations of inshore *Tursiops* whose habitat and resource requirements remain largely unknown and particularly where coastal habitats are threatened by alteration and degradation.

Hence the efficiency of a single, vessel-based transect survey needs to be questioned in the context of the specific aims of any local population study, of bottlenose dolphins. In terms of assessing local or regional abundances and densities of *Tursiops* off the south coast of NSW, such a survey appears limited. Factors mitigating against its usefulness may include the:

- \* size of the study area;
- \* likelihood of a relatively low overall population density throughout the study area;
- \* likelihood of variable density patterns in different parts of the study area; and
- \* probable group size, i.e. the typical small cluster pattern exhibited by this species in inshore waters.

However, in this study, I regard the transect survey approach as very useful in achieving the first aim of this Survey, i.e. quantitatively analysing dolphin's patterns of use of different habitats as defined here, by depth and substratum. The patchy character and small area of two of the three substrata in this study area

exacerbated the problems of using such an approach to survey highly mobile animals. These habitat characteristics restricted the length of transects to one kilometre. In another study area this restriction may not apply. The unbalanced design of sampling effort across depths resulted from logistical constraints but might be avoided elsewhere. The greatest contribution of this survey approach to this study of dolphin habitat usage was its successful stratification of sampling effort, in terms of the chosen habitat variables. As such, it provides an objective assessment of dolphins' "apparent" usage of preferred areas and also particular sites within a local area.

In retrospect, I would pursue a transect survey to monitor habitat usage and utilise sightings made in transit between randomly sampled transects, to gain complete photographic sighting records to obtain abundance estimates of dolphins in the study area (see Chapter 6). I would reduce the number of depth classes but increase effort to create a statistically more powerful orthogonal survey design.

Furthermore, I would design a sighting data form which allowed any biases in effort to be assessed, specifically for use by any commercial operators of dolphin watch tours in the study area. This would replace data from the S&E Survey, providing "opportunistic" sighting information as supporting evidence for transect survey data (see Chapter 7).

#### **4.4.4 Summary**

There appear to be a number of common trends across the S&E and Transect Survey data sets. These consistently relate to habitat variables (e.g. the focus of sightings in shallow waters and over the rarer substrata of rocky areas and seagrass) and group composition variables (e.g. mean sighting sizes and trends in the occurrence of calves). Hence, these data strongly suggest that dolphins in the study area exhibit patterns of preferred habitat usage over time. The reasons for such patterns are not readily apparent. The results from both the S&E and Transect Surveys indicate that association patterns in terms of environmental variables are generally limited and patchy. Shane (1990a) concluded for bottlenose dolphins at

Sanibel Island that "...a complex array of temporal, environmental and social factors is associated with the activity patterns...[and] that behavior is dictated by a complicated web of interacting elements, and no single factor is very useful in explaining it...".

**TABLE 4.6: Summary Table of Results from analyses of Line Transect Survey Effort data**

**In the Table below:** na = indicates analysis not applicable to data set; S indicates a statistically significant result (at alpha = 0.05) with the trend indicated in the LH margin; and NS indicates a non-significant result. Line reference number is indicated by column l.

l		Route (n=195)	Survey (n=58)	Field Hours (n=353)	Tidal State (n=164)	Distance Searched (km) (n=2,908)	Year per annual effort
i	Year	na	NS	na	na	na	na
ii	Season/ more in autumn	na	S	na	na	na	
iii	Quadrant	NS	na	na	na	na	na
iv	Time of Day/ greater at midday vs am & pm	na	na	S	na	na	na
v	Tidal State	na	na	na	NS	na	na
vi	Depth/ greater in ≤10m vs deeper	na	na	na	na	S	na
vii	Total Number Dolphins (n=1068)	na	na	na	na	na	NS
viii	Total Number Calves (n=59)	na	na	na	na	na	NS

**TABLE 4.7: Summary Tables of Results from analyses of Line Transect Sighting (TS) data**

In all tables below: **na** = indicates analysis not applicable to data set; **ee** = derivation estimated elsewhere; **du** = data unavailable; **assoc** means a statistically significant association was indicated (at  $\alpha = 0.05$  and where expected values from contingency tests were equal to or greater than one, see Section 2.4) but no positive or negative trend was apparent, this typically relates to categorical variables and the area of strongest association is indicated in the appropriate column (see relevant Results & Discussion sections, for details); **S** indicates a statistically significant result (at  $\alpha = 0.05$ ) with the greatest area of difference indicated in the respective Table, in the LH margin; **S but H** indicates a significant result but data is heteroscedastic; and **NS** indicates a non-significant result or a significant result (at  $\alpha = 0.05$  but where expected values from contingency tests were less than one, indicated by  $\blacklozenge$ , see Section 2.4). Unless otherwise stated (i.e. as a result of missing data or requirements of analyses) sample sizes for “sighting event” analyses are  $n=26$ ; “pod” analyses are  $n=35$  and “survey” analyses are  $n=58$ . Quad. refers to arbitrarily chosen quadrants of the Bay and SS Temp. refers to sea surface temperature. Sighting and pod size classes, i.e. small (1-5), medium (6-14) and large (15+) are indicated by sm, med, and lge; unless “2 Classes” are indicated, i.e. small (1-10) or large (11+). Line reference number is indicated by column **l**

**4.7a: Analyses of Line Transect Sampling Effort**

	Year	Quad. of Bay	Time of Day	Tidal State	SS Temp	Depth per area	Substrata per area & $\leq 10m$
<b>Transects (<math>n=264</math>) more in 1991 than 1992; greater at midday vs am &amp; pm; warmest in autumn then summer, &amp; cooler in both winter &amp; spring; greater in waters <math>\leq 10m</math> vs deeper; greater over seagrass &amp; rock both throughout the Bay &amp; in waters <math>\leq 10 m</math> in depth only</b>	<b>S</b>	<b>NS</b>	<b>S</b>	<b>NS</b>	<b>S</b>	<b>S</b>	<b>S</b>

**Table 4.7b:** Analyses of Group Composition

I		Mean Total Number	Sighting Size Classes	Number of Pods	Mean Pod Number	Pod Size Classes
i	Pres/Abs Calves	NS	NS	NS	NS	ee
ii	Number of Pods	na	assoc/ single pods in sm, med & lge classes; multiple pods only med & lge	na	na	na
iii	Number of Calves per Pod	na	na	na	na	NS/ 2 Classes

**Table 4.7c:** ANOVA results for Depth and Substratum across all Transects

I		6 Depths over Sand (n=162)	2 Depths over 3 Substrata (n=174)
i	Sighting Event	S but H	S but H
ii	Total Number of Dolphins	NS	NS
iii	Total Number of Calves	NS	S but H
iv	Total Number of Pods	S but H	NS

**Table 4.7d: Other Analyses of Depth**

<b>I</b>		<b>Depth wrt three areas of the Bay</b>	<b>Transect Depth Classes (4m &amp; 8m only)</b>	<b>Shallow (<math>\leq 11.5\text{m}</math>) / Deep (<math>&gt; 11.5\text{m}</math>) (NB no sightings were made at <math>&gt; 11.5\text{m}</math>)</b>	<b>Mean Sighting Depth (NB only Transect depth recorded)</b>
<b>i</b>	<b>Sighting Event / greater in <math>\leq 10\text{m}</math></b>	<b>S</b>	<b>ee</b>	<b>na</b>	<b>na</b>
<b>ii</b>	<b>Mean Total Number</b>	<b>na</b>	<b>ee</b>	<b>du</b>	<b>du</b>
<b>iii</b>	<b>Sighting Size Classes</b>	<b>na</b>	<b>NS</b>	<b>du</b>	<b>du</b>
<b>iv</b>	<b>Number of Pods</b>	<b>na</b>	<b>ee</b>	<b>du</b>	<b>du</b>
<b>v</b>	<b>Mean Pod Number</b>	<b>na</b>	<b>NS</b>	<b>du</b>	<b>du</b>
<b>vi</b>	<b>Pod Size Classes</b>	<b>na</b>	<b>assoc/ sm pods at 8m; med pods at 4m &amp; lge either</b>	<b>du</b>	<b>du</b>
<b>vii</b>	<b>Pres/Abs Calves</b>	<b>na</b>	<b>NS</b>	<b>du</b>	<b>du</b>
<b>viii</b>	<b>Pres/Abs Calves per Pod</b>	<b>na</b>	<b>NS</b>	<b>du</b>	<b>du</b>

**Table 4.7e:** Other Analyses of Substrata

<b>I</b>		<b>Substrata wrt area of each in Bay</b>	<b>Transect Substrata</b>	<b>Substrata <math>\leq 10</math> m (NB all sightings were made at 4m &amp; 8m)</b>
<b>i</b>	<b>Sighting Event / greater over rarer substrata</b>	<b>S</b>	ee	NS (wrt area of each)
<b>ii</b>	<b>Mean Total Number</b>	na	ee	ee
<b>iii</b>	<b>Sighting Size Classes</b>	na	NS	ee
<b>iv</b>	<b>Number of Pods</b>	na	ee	ee
<b>v</b>	<b>Mean Pod Number</b>	na	NS	ee
<b>vi</b>	<b>Pod Size Classes</b>	na	NS	ee
<b>vii</b>	<b>Pres/Abs Calves</b>	na	NS	ee
<b>viii</b>	<b>Pres/Abs Calves per Pod</b>	na	NS	ee
<b>ix</b>	<b>Mean Sighting Depth (NB only Transect depth recorded)</b>	na	du	du
<b>x</b>	<b>2 Transect Depth Classes</b>	na	ee	ee

**Table 4.7f:** ANOVA results for Depth and Substratum at Transect Sites.

<b>I</b>		<b>6 Depths over Sand (n=30)</b>	<b>2 Depths over 3 Substrata (n=29)</b>
<b>i</b>	<b>Summed Total Number / increasing with depth over rock; decreasing number with increasing depth over other two substrata</b>	NS	S
<b>ii</b>	<b>Summed Number of Calves / more calves over rock at 8m than any other depth/substratum combination</b>	NS	S
<b>iii</b>	<b>Summed Number of Pods</b>	NS	NS
<b>iv</b>	<b>Maximum Number per Sighting</b>	NS	NS
<b>v</b>	<b>Sighting Success</b>	S but H	S but H
<b>vi</b>	<b>Sighting Frequency</b>	S but H	NS

**Table 4.7g:** Analyses of Environmental Variables

**Table 4.7g(1)**

<b>I</b>		<b>Quadrant wrt the area of each</b>	<b>Half of Bay (Nth &amp; Sth)</b>	<b>Season</b>	<b>BF (all sightings made under good conditions, BF 0-3)</b>
<b>i</b>	<b>Sighting Event / greater in the NW</b>	<b>S</b>	<b>ee</b>	<b>NS</b>	<b>na</b>
<b>ii</b>	<b>Mean Total Number</b>	<b>na</b>	<b>NS</b>	<b>NS</b>	<b>na</b>
<b>iii</b>	<b>Sighting Size Classes</b>	<b>na</b>	<b>NS</b>	<b>NS/ 2 Classes</b>	<b>na</b>
<b>iv</b>	<b>Number of Pods</b>	<b>na</b>	<b>NS</b>	<b>NS</b>	<b>na</b>
<b>v</b>	<b>Mean Pod Number</b>	<b>na</b>	<b>NS</b>	<b>NS</b>	<b>na</b>
<b>vi</b>	<b>Pod Size Classes</b>	<b>na</b>	<b>NS</b>	<b>NS/ 2 Classes</b>	<b>na</b>
<b>vii</b>	<b>Pres/Abs Calves</b>	<b>na</b>	<b>NS</b>	<b>NS</b>	<b>na</b>

**Table 4.7g:** Analyses of Environmental Variables (contd)

**Table 4.7g(2)**

<b>I</b>		<b>Tidal State</b>	<b>Time of Day</b>	<b>Wind Dirn.</b>	<b>SS Temp.</b>
<b>i</b>	<b>Sighting Event / greater in the middle of the day</b>	NS	S	na	na
<b>ii</b>	<b>Mean Total Number</b>	NS	NS	NS	NS
<b>iii</b>	<b>Sighting Size Classes</b>	<b>assoc/ 2 Classes: sm at low; lge at high &amp; ebb; &amp; at flood mainly sm</b>	NS/ 2 Classes	NS/ 2 Classes	NS/ 2 Classes
<b>iv</b>	<b>Number of Pods</b>	<b>assoc/ single at low; multiple at ebb &amp; flood; &amp; at high single</b>	NS	NS	<b>assoc/ single pods in warmer waters; multiple pods in cooler</b>
<b>v</b>	<b>Mean Pod Number / greatest at high; smallest at flood tide</b>	S	NS	NS	du
<b>vi</b>	<b>Pod Size Classes</b>	<b>assoc/ 2 Classes: sm at ebb &amp; flood; lge at low &amp; high</b>	NS/ 2 Classes	NS/ 2 Classes	du
<b>vii</b>	<b>Pres/Abs Calves</b>	NS	NS	NS	NS
<b>viii</b>	<b>Sighting Event per Season / warmest in summer then autumn; cooler in winter &amp; spring</b>	na	na	na	S

**Table 4.7h: Abundance Patterns**

<b>I</b>		<b>Quadrant per area</b>	<b>Season per survey effort</b>	<b>Year per annual effort</b>	<b>Substrata ≤ 10m per area</b>
<b>i</b>	<b>Total Number (<i>n</i>=289) / greatest in the NW &amp; autumn; more over rock</b>	<b>S</b>	<b>S</b>	<b>NS</b>	<b>S (<i>n</i>=230)</b>
<b>ii</b>	<b>Calves (<i>n</i>=14) / more in 1991</b>	<b>na</b>	<b>na</b>	<b>S</b>	<b>na</b>

**Table 4.7i: Density Estimates**

<b>Estimated Dolphin density (no. per sq. km)</b>					
<b>I      Quadrant</b>		<b>SW</b>	<b>NW</b>	<b>NE</b>	<b>SE</b>
<b>i</b>	<b>Mean no./survey/area at depths ≤ 10m</b>	<b>0.35</b>	<b>0.16</b>	<b>0.05</b>	<b>0.06</b>
<b>Substratum</b>		<b>Sand</b>	<b>Seagrass</b>	<b>Rock</b>	
<b>ii</b>	<b>Mean no./sighting event/area at depths ≤ 10m</b>	<b>0.7</b>	<b>1.1</b>	<b>4.35</b>	

**TABLE 4.8: Summary Tables of Results from analyses of Non-Transect Sightings at Transect Sites (NTTS).**

In all tables below: **na** = indicates analysis not applicable to data set; **ee** = derivation estimated elsewhere; **du** = data unavailable; **assoc** means a statistically significant association was indicated (at  $\alpha = 0.05$  and where expected values from contingency tests were equal to or greater than one, see Section 2.4) but no positive or negative trend was apparent, this typically relates to categorical variables and the area of strongest association is indicated in the appropriate column (see relevant Results & Discussion sections, for details); **S** indicates a statistically significant result (at  $\alpha = 0.05$ ) with the greatest area of difference indicated in the respective Table, in the LH margin; **S but H** indicates a significant result but data is heteroscedastic; and **NS** indicates a non-significant result. Unless otherwise stated (i.e. as a result of missing data or requirements of analyses) sample sizes for “sighting event” analyses are  $n=23$ ; “pod” analyses are  $n=36$  and “survey” analyses are  $n=58$ . SS Temp. refers to Sea Surface Temperature. Sighting and pod size classes, i.e. small (1-5), medium (6-14) and large (15+) are indicated by sm, med, and lge; unless “2 Classes” are indicated, i.e. small (1-10) or large (11+). Line reference number is indicated by column **I**

**Table 4.8a: Analyses of Group Composition**

<b>I</b>		<b>Mean Total Number</b>	<b>2 Sighting Size Classes</b>	<b>Number of Pods</b>	<b>Mean Pod Number</b>	<b>2 Pod Size Classes</b>
<b>i</b>	<b>Pres/Abs Calves</b>	NS	NS	NS	NS	ee
<b>ii</b>	<b>Number of Pods</b>	na	NS	na	na	na
<b>iii</b>	<b>Number of Calves per Pod</b>	na	na	na	na	NS

**Table 4.8b: Analyses of Depth**

<b>I</b>		<b>Depth wrt three areas of the Bay</b>	<b>3 ‘Transect’ Depth Classes (4m, 8m &amp; 15m)</b>	<b>Shallow (≤11.5m)/ Deep (&gt;11.5m) (NB only 2 sightings were made at &gt;11.5m)</b>	<b>Mean Sighting Depth (NB only Transect depth used for analyses)</b>
<b>i</b>	<b>Sighting Event/ greatest in the area of the Bay ≤10m</b>	S	na	na	na
<b>ii</b>	<b>Mean Total Number</b>	na	NS	na	na
<b>iii</b>	<b>Sighting Size Classes</b>	na	NS/ 2 Classes	na	na
<b>iv</b>	<b>Number of Pods</b>	na	NS	na	na
<b>v</b>	<b>Mean Pod Number</b>	na	NS	na	na
<b>vi</b>	<b>Pod Size Classes</b>	na	NS/ 2 Classes	na	na
<b>vii</b>	<b>Pres/Abs Calves</b>	na	NS	na	na
<b>viii</b>	<b>Pres/Abs Calves per Pod</b>	na	NS	na	na

**Table 4.8c:** Analyses of Substrata

I		Substrata wrt area of each in Bay	Transect Substrata	Substrata $\leq 10\text{m}$
i	<b>Sighting Event/ more over rarer substrata</b>	S	ee	S (wrt area of each, $n=20$ )
ii	<b>Mean Total Number</b>	na	NS	NS
iii	<b>Sighting Size Classes</b>	na	NS/ 2 Classes	NS/ 2 Classes
iv	<b>Number of Pods</b>	na	NS	NS
v	<b>Mean Pod Number / largest over rock, then seagrass &amp; smallest over sand (<math>n=30</math>)</b>	na	NS	S
vi	<b>Pod Size Classes</b>	na	NS/ 2 Classes	<b>assoc/ 2 Classes: sm only over sand; both sm &amp; lge over rock &amp; seagrass</b>
vii	<b>Pres/Abs Calves</b>	na	NS	NS
viii	<b>Pres/Abs Calves per Pod</b>	na	NS	NS
ix	<b>Mean Sighting Depth (NB only Transect depth used for analyses)</b>	na	na	na
x	<b>3 Transect Depths</b>	na	NS	na
xi	<b>2 Transect Depths</b>	na	na	NS

**Table 4.8d:** Analyses of Environmental Variable

**Table 4.8d(1)**

<b>I</b>		<b>Quadrant wrt the area of each</b>	<b>Half of Bay (Nth &amp; Sth)</b>	<b>Season</b>	<b>BF (all sightings made under good conditions BF 0-3)</b>
<b>i</b>	<b>Sighting Event</b>	NS	ee	NS	na
<b>ii</b>	<b>Mean Total Number</b>	na	NS	NS	na
<b>iii</b>	<b>Sighting Size Classes</b>	na	NS/ 2 Classes	NS/ 2 Classes	na
<b>iv</b>	<b>Number of Pods</b>	na	NS	NS	na
<b>v</b>	<b>Mean Pod Number</b>	na	NS	NS	na
<b>vi</b>	<b>Pod Size Classes</b>	na	NS/ 2 Classes	NS/ 2 Classes	na
<b>vii</b>	<b>Pres/Abs Calves</b>	na	NS	NS	na

**Table 4.8d:** Analyses of Environmental Variables (contd)

**Table 4.8d(2)**

<b>I</b>		<b>Tidal State</b>	<b>Time of Day</b>	<b>Wind Direction</b>	<b>SS Temp.</b>
<b>i</b>	<b>Sighting Event</b>	NS	NS	na	ee
<b>ii</b>	<b>Mean Total Number</b>	NS	NS	NS	NS
<b>iii</b>	<b>Sighting Size Classes</b>	<b>assoc/2 Classes: sm at ebb &amp; flood; lge at low &amp; high</b>	NS/ 2 Classes	NS/ 2 Classes	NS/ 2 Classes
<b>iv</b>	<b>Number of Pods</b>	NS	NS/ 2 Classes	NS	NS/ 2 Classes
<b>v</b>	<b>Mean Pod Number / greatest with winds from the west; smallest with winds from the south</b>	NS	NS	S	du
<b>vi</b>	<b>Pod Size Classes</b>	<b>assoc/2 Classes: sm at ebb &amp; low; lge at high &amp; low; at flood mainly sm</b>	NS/ 2 Classes	<b>assoc/ 2 Classes: mainly sm under Nth &amp; Sth winds; lge under west winds</b>	du
<b>vii</b>	<b>Pres/Abs Calves</b>	<b>assoc/ present all tidal states, peaks at low &amp; ebb</b>	NS/ 2 Classes	NS	NS
<b>viii</b>	<b>Sighting Event per Season</b>	na	na	na	S but H

**Table 4.8e:** Abundance Patterns

	Quadrant per area	Season per survey effort	Substrata $\leq 10\text{m}$ per area
<b>Total Number (<math>n=361</math>) greatest in the NW &amp; autumn; more over seagrass and rock</b>	S	S	S ( $n=240$ )

**TABLE 4.9: Summary Tables of Results from analyses of all Non-Transect Sightings (NTS) from the Transect Survey.**

In all tables below: **na** = indicates analysis not applicable to data set; **ee** = derivation estimated elsewhere; **du** = data unavailable; **+ve** indicates a positive association; **assoc** means a statistically significant association was indicated (at  $\alpha = 0.05$  and where expected values from contingency tests were equal to or greater than one, see Section 2.4) but no positive or negative trend was apparent, this typically relates to categorical variables and the area of strongest association is indicated in the appropriate column (see relevant Results & Discussion sections, for details); **S** indicates a statistically significant result (at  $\alpha = 0.05$ ) with the greatest area of difference indicated in the respective Table, in the LH margin; **S but H** indicates a significant result but data is heteroscedastic; and **NS** indicates a non-significant result. Unless otherwise stated (i.e. as a result of missing data or requirements of analyses) sample sizes for “sighting event” analyses are  $n=54$ ; “pod” analyses are  $n=89$  and “survey” analyses are  $n=58$ . SS Temp. refers to Sea Surface Temperature. Sighting and pod size classes, i.e. small (1-5), medium (6-14) and large (15+) are indicated by **sm**, **med**, and **lge**; unless “2 Classes” are indicated, i.e. small (1-10) or large (11+). Line reference number is indicated by column **I**

**Table 4.9a: Analyses of Group Composition**

<b>I</b>		<b>Mean Total Number</b>	<b>Sighting Size Classes</b>	<b>Number of Pods</b>	<b>Mean Pod Number</b>	<b>Pod Size Classes</b>
<b>i</b>	<b>Pres/Abs Calves / present in larger sightings</b>	<b>S</b>	<b>assoc/ 2 Classes: present mainly in lge groups</b>	<b>NS</b>	<b>NS</b>	<b>assoc/2 Classes: present mainly in sm pods</b>
<b>ii</b>	<b>Number of Pods</b>	<b>na</b>	<b>+ve/ more pods in larger groups</b>	<b>na</b>	<b>na</b>	<b>na</b>
<b>iii</b>	<b>Number of Calves per Pod</b>	<b>na</b>	<b>na</b>	<b>na</b>	<b>na</b>	<b>NS/ 2 Classes:</b>

**Table 4.9b:** Analyses of Depth

<b>I</b>		<b>Survey Effort in ≤10m &amp; &gt;10m</b>	<b>Depth wrt three areas of Bay</b>	<b>Shallow (≤11.5m)/Deep (&gt;11.5m)</b>	<b>Mean Sighting Depth</b>
<b>i</b>	<b>Sighting Event/ greatest in area of the Bay ≤10m</b>	S	S	ee	na
<b>ii</b>	<b>Mean Total Number</b>	na	na	NS	na
<b>iii</b>	<b>Sighting Size Classes</b>	na	na	NS	na
<b>iv</b>	<b>Number of Pods</b>	na	na	NS	na
<b>v</b>	<b>Mean Pod Number</b>	na	na	NS	na
<b>vi</b>	<b>Pod Size Classes</b>	na	na	NS	na
<b>vii</b>	<b>Pres/Abs Calves</b>	na	na	NS	NS
<b>viii</b>	<b>Pres/Abs Calves per Pod</b>	na	na	NS	du

**Table 4.9c:** Analyses of Substrata

I		Substrata wrt area of each in Bay	Substrata	Substrata ≤10m
i	Sighting Event / greater over rarer substrata	S	ee	S (n=45)
ii	Mean Total Number	na	NS	NS
iii	Sighting Size Class	na	NS	NS
iv	Number of Pods	na	NS	NS
v	Mean Pod Number		NS	NS (n=70)
vi	Pod Size Classes	na	NS	assoc/ 2 Classes: lge pods mainly over seagrass; sm pods mainly over sand & seagrass; over rock mainly sm
vii	Pres/Abs Calves	na	NS	NS
viii	Pres/Abs Calves per Pod	na	NS	NS
ix	Mean Sighting Depth/ deeper over sand, then rock & seagrass	na	S	na

**Table 4.9d:** Analyses of Environmental Variables

**Table 4.9d(1)**

<b>I</b>		<b>Quadrant wrt area of each</b>	<b>Half of Bay (Nth &amp; Sth)</b>	<b>Season</b>	<b>BF (94% of sightings in good conditions BF 0-3)</b>
<b>i</b>	<b>Sighting Event / greater in NW</b>	<b>S</b>	<b>ee</b>	<b>NS</b>	<b>na</b>
<b>ii</b>	<b>Mean Total Number</b>	<b>na</b>	<b>NS</b>		<b>na</b>
<b>iii</b>	<b>Sighting Size Classes</b>	<b>na</b>	<b>NS/ 2 Classes</b>	<b>NS</b>	<b>na</b>
<b>iv</b>	<b>Number of Pods</b>	<b>na</b>	<b>NS</b>	<b>assoc/ single &amp; multiple pods mainly in autumn</b>	<b>na</b>
<b>v</b>	<b>Mean Pod Number</b>	<b>na</b>	<b>NS</b>	<b>NS</b>	<b>na</b>
<b>vi</b>	<b>Pod Size Classes</b>	<b>na</b>	<b>NS/ 2 Classes</b>	<b>NS/ 2 Classes</b>	<b>na</b>
<b>vii</b>	<b>Pres/Abs Calves</b>	<b>na</b>	<b>NS</b>	<b>NS</b>	<b>na</b>

**Table 4.9d: Analyses of Environmental Variables (contd)**

**Table 4.9d(2)**

I		Tidal State	Time of Day	Wind Dirn.	SS Temp.
i	Sighting Event	NS	NS	na	na
ii	Mean Total Number	NS	NS	NS ( <i>n</i> =49)	NS
iii	Sighting Size Classes	NS/ 2 Classes	NS/ 2 Classes	NS/ 2 Classes	NS/ 2 Classes
iv	Number of Pods	NS	NS	NS	NS
v	Mean Pod Number	S but H	NS	NS ( <i>n</i> =74)	du
vi	Pod Size Classes	assoc/ 2 Classes: sm pods mainly ebb & low; lge pods even across all but least at ebb	NS/ 2 Classes	NS/ 2 Classes	du
vii	Pres/Abs Calves	NS	NS	NS	NS
viii	Sighting Event per Season / higher in summer & autumn; and lower in winter & spring	na	na	NS	S

**Table 4.9e: Analyses of Spatial Pattern**

<b>I</b>		<b>Sighting Spatial Pattern</b>	<b>Pod Spatial Pattern</b>
<b>i</b>	<b>Sighting event</b>	na	na
<b>ii</b>	<b>Mean Total Number</b>	NS	na
<b>iii</b>	<b>Sighting Size Classes</b>	<b>assoc/ all sizes mainly clumped with peak for lge class; but both spread &amp; mixed patterns evenly across all sizes</b>	na
<b>iv</b>	<b>Number of Pods</b>	NS	na
<b>v</b>	<b>Mean Pod Number</b>	na	NS
<b>vi</b>	<b>Pod Size Classes</b>	na	NS/ 2 Classes
<b>vii</b>	<b>Pres/Abs Calves</b>	NS	na
<b>viii</b>	<b>Pres/Abs Calves per Pod</b>	na	NS
<b>ix</b>	<b>Mean Sighting Depth</b>	NS	na
<b>x</b>	<b>Shallow/Deep</b>	NS	NS
<b>xi</b>	<b>Substrata</b>	NS	NS
<b>xii</b>	<b>Quadrant</b>	NS	NS
<b>xiii</b>	<b>Season</b>	NS	NS
<b>xiv</b>	<b>SS Temp</b>	NS	NS
<b>xv</b>	<b>BF</b>	na	na
<b>xvi</b>	<b>Tidal State</b>	NS	NS
<b>xvii</b>	<b>Time of Day</b>	<b>assoc/ both clumped &amp; dispersed patterns across am, midday &amp; pm but both mainly at midday</b>	NS
<b>xviii</b>	<b>Wind Direction</b>	NS ( <i>n</i> =49)	NS ( <i>n</i> =74)

**Table 4.9f: Analyses of Behavioural Variables**

**Table 4.9f(1)**

I		Sighting Behaviour (n=53)	Pod Behaviour (n=88)	Dolphin's Direction of Travel
i	Sighting Spatial Pattern	NS	na	na
ii	Pod Spatial Pattern	na	NS	na
iii	Sighting Event	na	na	na
iv	Mean Total Number	NS	na	na
v	Sighting Size	na	na	na
vi	Number of Pods	na	na	na
vii	Mean Pod Number	na	NS	na
viii	Pod Size Classes	na	NS/ 2 Classes	na
ix	Pres/Abs Calves per pod	na	NS	na
x	Mean Sighting Depth	NS	na	na
xi	Shallow/Deep	na	NS	na
xii	Substrata	na	assoc/travel & social/feed across all substrata but mainly over sand; milling only over seagrass & rock & mainly over seagrass	na
xiii	Half of Bay (Nth & Sth)	na	assoc/ the greatest frequency of all behaviours were in the north; social/feed fairly evenly across both	na
xiv	Season	na	NS	na
xv	BF	na	na	na

**Table 4.9f:** Analyses of Behavioural Variables (contd)

**Table 4.9f(2)**

<b>I</b>		<b>Sighting Behaviour (<i>n</i>=53)</b>	<b>Pod Behaviour (<i>n</i>=88)</b>	<b>Dolphin's Direction of Travel</b>
<b>i</b>	<b>Tidal State</b>	na	NS	NS
<b>ii</b>	<b>Time of Day</b>	na	NS ( <i>n</i> =82)	<b>assoc (<i>n</i>=49)/ heading north &amp; west=am; north &amp; south=midday; nil &amp; east direction even across both</b>
<b>iii</b>	<b>SS Temperature</b>	na	NS	na
<b>iv</b>	<b>Wind Direction</b>	na	NS	NS ( <i>n</i> =49)

Table 4.9g: Abundance Patterns

I		Quadrant per area	Season per survey effort	Year per annual effort	Substrata ≤ 10m per area
i	Total Number (n=779) greatest in the NW & autumn; more over seagrass & rock	S	S	NS	S (n=639)
ii	Calves (n=45) greatest in the NW & autumn; more over seagrass & rock	S	S	NS	S (n=37)

Table 4.9h: Density Estimates

Estimated Dolphin density (no. per sq. km)					
I		Quadrant			
		SW	NW	NE	SE
i	Mean no./survey/area at depths ≤ 10 m	0.48	0.59	0.34	0.38
		Season			
		AUT	SPR	SUM	WIN
ii	Mean no./survey for whole of Bay	0.14	0.05	0.21	0.06
		Substratum			
		Sand	Seagrass	Rock	
iii	Mean no./sighting event/area at depths ≤ 10 m	0.8	1.8	3.7	
		Substratum			
		Sand	Seagrass	Rock	
iv	Mean no. of calves/sighting event/area at depths ≤ 10 m	0.02	0.09	0.06	

## CHAPTER 5: REGIONAL SURVEY

### 5.1 Introduction

Because a considerable amount of data had been collected on the animals which regularly utilise the Bay it was considered important to investigate if, and with what frequency, this species uses the open-ocean, inshore environment adjacent to Jervis Bay. Prior to these surveys only anecdotal information on sightings of dolphins along the coast north and south of Jervis Bay was available. Hence a simultaneous boat survey of the coastline immediately north and south, and inside the Bay, was conducted to allow some comparison of usage. It was considered such a strategy may also enable the detection of the extent of some individuals' home ranges beyond the Bay. The Regional Survey used the same survey approach and data collection procedures as for the Search and Encounter (S&E) Survey. This involved searches of shallow waters approximately 400 m from shore which recorded opportunistic sightings of bottlenose dolphins. As the three Regional Surveys were slightly different the results from each will be presented separately.

### 5.2 Materials and Methods

During the Regional Survey three vessels searched simultaneously. Four different boats were used over the three survey periods. The university boat and its associated equipment (see Section 2.2) was used to search the Bay. The circuit inside the Bay commenced and ended at HMAS Creswell (35°07'04" S; 150°42'03" E). A privately owned 5.2 m fibreglass vessel fitted with twin 60hp engines was used on the northern leg for the first two surveys and a Sitex echosounder recorded the log, speed, surface temperature and depth. On the third survey a NSW Fisheries boat was used, also with an echosounder. For the southern leg, the (then) Australian National Parks and Wildlife Service (ANPWS) supplied a 7.2 m aluminium Marlin Broadbill, fitted with twin 140hp outboard engines. A speedometer was used to record speed and calculate the log. A thermometer (used to standardise the other vessels' echosounder-mounted thermometers) recorded

surface water temperature. The depth was estimated using the captain's local knowledge and hydrographic Chart Aus 193 (R.A.N., 1986). All vessels carried cameras fitted with zoom lenses to photograph dolphins for individual identification (see Section 2.2).

On the third Regional Survey only, a NSW National Parks and Wildlife Service (NPWS) Squirrel AS-350 helicopter was used to search the total study area on two of the three days. The pilot and myself searched 90° port and starboard. A third person was responsible for photographing sightings, using an Olympus OM-3 and Zuiko 135 mm f2.8 lens and Ilford 400ASA film. All photographs taken from the helicopter were printed (20 x 25 cm) and assessed using a 8x loupe eyepiece as well as using the video procedure described in Chapter 6.

### 5.3 Survey Design

The timing of a pilot survey, from the 20<sup>th</sup> to the 22<sup>nd</sup> of March 1992, was determined primarily by logistical constraints. Three vessels searched for bottlenose dolphins, within Jervis Bay, north to Crookhaven Lighthouse and south to the entrance of Swan Lake (see Fig. 2.4). The boats departed at approximately 0630 on each day and travelled at speeds between 15-25 km per hour, approximately 400 m from shore. All searches were undertaken between 0645 and 1430. Four of the six volunteer observers on the three boats had previous training, by myself, in sighting and data collection procedures. The other two were staff of wildlife agencies.

The shoreline of the Bay is approximately 47.5 km and the approximate length of return trips on the northern and southern routes were 74 km and 67 km, respectively. The average total distance covered per survey (i.e. over each three day period) was approximately 649 km and the average total distance searched per day of both open coastal and embayment water was approximately 216.3 km. The total distance travelled, and the search duration for each route varied between the three days of a Survey and between Surveys. This variation was primarily due to

whether or not animals were seen, and the variable sea and weather conditions. This pilot survey indicated that it might be possible to collect meaningful data using this approach, hence two more of these Regional Surveys took place in late November 1992 and early April 1993. The third survey was timed to provide a comparison with the March pilot survey.

The type of data collected and the procedures for data handling were the same as for the S&E Survey (see Section 3.2). Observer effort on the Regional Surveys, however, varied from the S&E Survey (see Section 2.3) in the number of volunteers used and hence the allocation of tasks.

In terms of investigating the distribution of sightings across habitats, one of the three substratum categories, seagrass was only known inside the Bay. Hence, only sand and rocky areas were available for comparison across all three routes. Also a new habitat category, deep water (>20 m) over rock, was identified along the steep rocky cliff-line characteristic of the coastal routes, but this habitat was not available on the Bay route.

However, due to the small number of sightings along the coastal routes, the usual habitat, environmental and behavioural data were not available for statistical analyses. Hence, only a summary of habitat and prevailing environmental conditions for sightings on the Regional Surveys are provided in the Results section. Because the sighting rate for each Survey in the Bay was also low, only the total number of sightings made over all three Regional Surveys were chosen for further investigation.

## **5.4 Results**

This Result Section presents findings from the three Regional Surveys separately, i.e. March 1992 (Section 5.4.1); November 1993 (Section 5.4.2) and April 1993 (Section 5.4.3). The results of analyses on all sightings made within Jervis Bay on all three Regional Surveys is then presented (Section 5.4.4).

Appendix 5 contains the detailed statistical analyses of all data presented in this Chapter (TABLES A5.1 - A5.9). The results from statistical analyses of the combined sightings made within Jervis Bay, on all three Regional Surveys (Section 5.4.4) are presented in Summary Tables at the end of the Chapter (see Tables 5.13a-h). A line reference using roman numerals is included to assist referral to these Tables (e.g. Table 5.13a-*liii*).

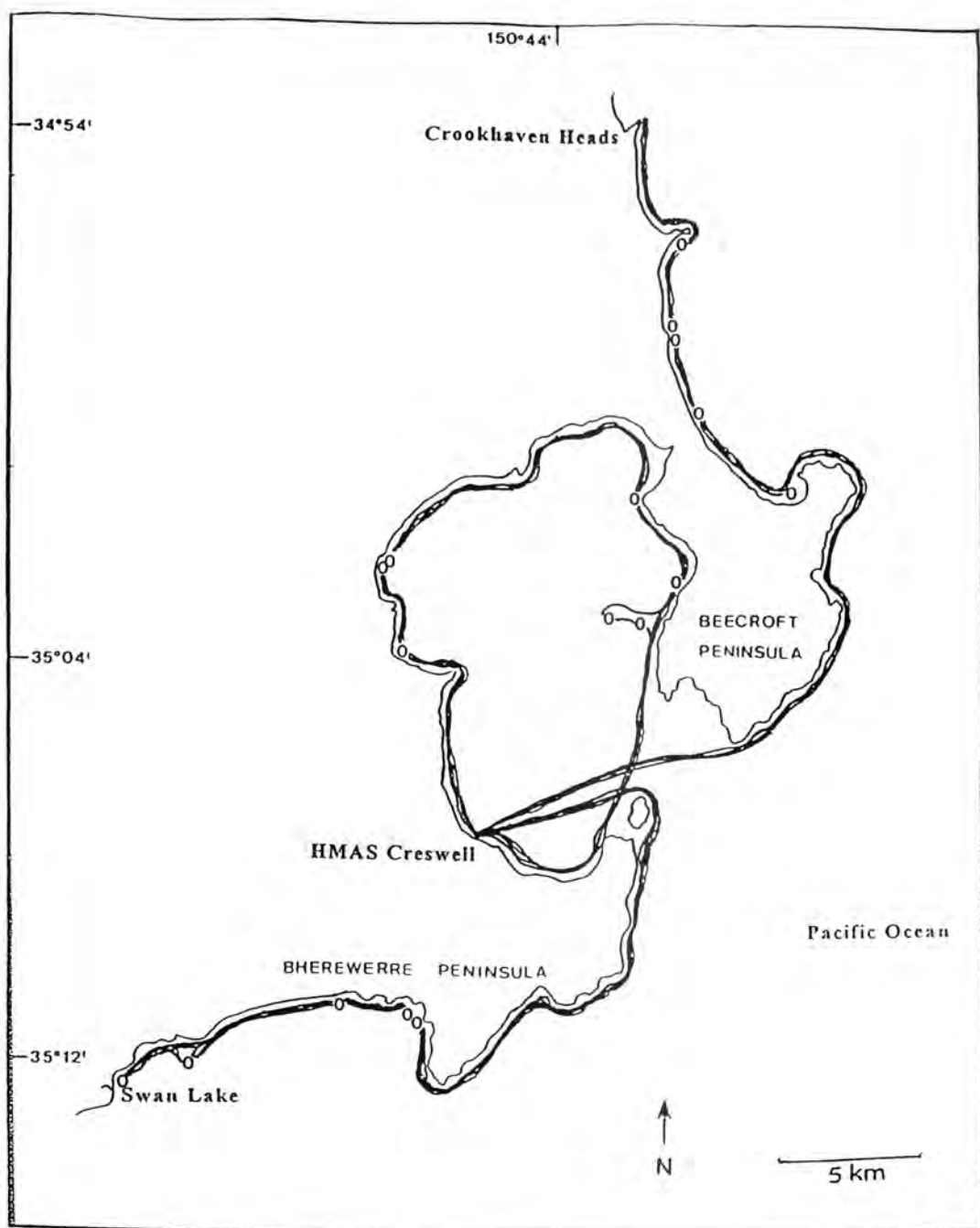
#### **5.4.1 March 1992 Survey**

##### **5.4.1.1 Survey Effort and Sightings**

A map of the survey routes for the March 1992 Survey and the location of sightings is provided in Figure 5.1. The total distance travelled searching for dolphins over the three days in the Bay, on the northern and southern legs were 176.5, 318.0 and 191.2 km, respectively. These results are included in Table 5.1 which combines data on the total distance travelled searching for dolphins from all three Regional Surveys. The total time spent searching over the three day survey was 47 hours and 11 minutes. Thirty-six percent of the search time was spent in the Bay, 37% on the northern leg and 27% on the southern leg which probably reflects differences in route lengths and average boat speeds. These results are included in Table 5.2 which combines data on the total time spent searching for dolphins, from all three Regional Surveys.

Animals were sighted on all three days in the Bay, on two days on the northern leg and on all three days on the southern leg. These results are included in Table 5.3 which combines data on the number of successful survey days from all three Regional Surveys.

During this Survey there were seven sightings in the Bay, and five on each of the northern and southern legs. These results are included in Table 5.4 which combines data on the number of sighting events from all three Regional Surveys.



**Figure 5.1: Map of March 1992 Regional Survey routes and the location of sightings indicated by a circle.**

**TABLE 5.1: The total distance (km) travelled searching for dolphins for the three days of each of the three Regional Surveys on the designated routes.**

Total Distance Travelled (km)					
Survey	Route	Bay	North	South	Total
MAR 1992		176.5	318	191.2	685.7
NOV 1992		184.4	280	207.4	671.8
APR 1993		275.2	165	149	589.2
Total		636.1	763	547.6	1946.7

**TABLE 5.2: The total time spent searching for dolphins for the three Regional Surveys on the designated routes.**

Total Time Searching (hr:min)					
Survey	Route	Bay	North	South	Total
MAR 1992		17:10	17:16	12:45	47:11
NOV 1992		17:10	17:52	13:49	48:51
APR 1993		22:58	10:55	11:07	45:00
Total		57:18	46:03	37:41	141:02

**TABLE 5.3: The total number of successful survey days (i.e. where sightings were recorded) out of three days each Regional Survey on each of the designated routes, (i.e. a total of nine survey days). Zero indicates no sightings, i.e. unsuccessful survey days.**

Survey	Successful Survey Days				
	Route	Bay	North	South	Total
MAR 92		3	2	3	8
NOV 92		3	0	0	3
APR 93		3	1	0	4
Total		9	3	3	

**TABLE 5.4: The total number of sighting events for the three Regional Surveys on the designated routes.**

Survey	Total Number of Sighting Events				
	Route	Bay	North	South	Total
MAR 1992		7	5	5	17
NOV 1992		4	0	0	4
APR 1993		11	1	0	12
Total		22	6	5	33

The contact rates (i.e. the actual time spent observing animals divided by the total time spent searching) for the Bay, and northern and southern legs were approximately 22%, 11% and 14%, respectively. It is not known whether the low rate of contact of the coastal legs versus the Bay was influenced by sub-optimal weather conditions (see Section 5.4.1.4) or reflects the actual abundance of *Tursiops* in the study area. The total time spent observing the animals was seven hours and 23 minutes, that is only 16% of the time spent on the water in March was spent with animals. These results are included in Table 5.5 which combines data on the total time spent observing dolphins from all three Regional Surveys. The mean observation period per sighting on the March Survey in the Bay was 32 minutes approximately and only 23 and 21 minutes for the northern and southern legs. The estimated total number of individuals sighted on the March Survey was 136. These results are included in Table 5.6 which combines data on the total number of dolphins sighted from all three Regional Surveys

#### **5.4.1.2 Group Composition**

Of the 136 dolphins sighted in March five were identified as calves. The maximum number of calves sighted with any single pod was two. The average daily number of animals sighted in the Bay and on the northern and southern legs were, respectively, 14, 14.3 and 17. The mean sighting size across all three legs was 8.0 (S.E. 1.0). A total of 20 pods were reported in March ranging in size from two to 15 animals with a mean size of 6.8 (S.E. 0.8 ). ANOVA indicated no significant difference in mean sighting or pod sizes across the three legs of the March Survey. Please note, as these are the only two statistical analyses performed for the separate data sets from each of the Regional Surveys these two results are not presented in a Summary Tables (see Appendix 5, TABLE A5.1).

**TABLE 5.5: The total time spent observing dolphins for the three Regional Surveys on the designated routes.**

Survey	Total Time Observing (hr:min)				
	Route	Bay	North	South	Total
MAR 1992		3:44	1:55	1:44	7:23
NOV 1992		4:43	0	0	4:43
APR 1993		9:05	0:30	0	9:35
Total		17:32	2:25	1:44	21:41

**TABLE 5.6: The total number of dolphins sighted on each of the three Regional Surveys on the designated routes.**

Survey	Total Number of Animals				
	Route	Bay	North	South	Total
MAR 1992		42	43	51	136
NOV 1992		67	0	0	67
APR 1993		127	5	0	132
Total		236	48	51	335

#### **5.4.1.3 Distribution of sightings across Habitats**

##### **a) Depth**

When sighting depths in the Bay were divided into the depth classes used in the Transect Survey five of the seven sightings were made at 11.5 m or less and the remaining two at 17.5 m or less. On the coastal routes, all sightings on the northern leg were made in shallow waters at 11.5 m or less as they were also on the southern leg, except one sighting made at 24 m. These results are included in Table 5.7 which combines data on sighting depths from all three Regional Surveys.

##### **b) Substratum**

In the Bay all sightings were recorded over sand, except for one over seagrass. On both the northern and southern legs sightings were mainly over sand, with two and one, respectively, over rock. These results are included in Table 5.8 which combines these data on sighting substratum from all three Regional Surveys.

#### **5.4.1.4 Environmental Variables**

In March six of the seven sightings from the Bay were recorded in the northern half of the Bay, with four in the NE, two in the NW, and the other one from the SW quadrant.

Weather conditions during the pilot survey in March were not optimal. Cloud cover varied from 5-100% over the three days and Beaufort wind force conditions ranged from 2-4. The swell waves on the second day peaked at 5-6 m, which severely restricted sightings on approximately half of the northern leg and virtually all of the southern leg. The average sea surface temperatures over the three days for the Bay, northern and southern legs were 20°C, 21.6°C and 21.5°C, respectively.

**TABLE 5.7: Distribution of all sighting events across the depth classes, used in the Transect Survey, on the designated routes for all three Regional Surveys.**

Total Number of Sighting Events					
Depth (m)	Route	Bay	North	South	Total
0 - 6.0		11	3	1	15
6.0 - 11.5		7	3	3	13
11.5 - 17.5		2	0	0	2
17.5 - 22.5		0	0	0	0
22.5 - 27.5		2	0	1	3
27.5 - 40.0		0	0	0	0
Total		22	6	5	33

**TABLE 5.8: Distribution of all sighting events across substrata, on the designated routes for all three Regional Surveys.**

Total Number of Sighting Events					
Substratum	Route	Bay	North	South	Total
Sand		13	3	4	20
Seagrass		6	0	0	6
Rock		3	3	1	7
Total		22	6	5	33

Fourteen of the 17 sightings were recorded in the morning category with the remainder in the midday category. The March Survey extended over two tidal states with four sightings at flood tide and the majority of sightings recorded at high tide. Five of the nine wind direction categories were recorded at the time of an initial sighting, with 47% recorded under winds from the southeast, and 23% from the northeast, both of which are onshore winds and the remainder being from the south, southwest and west.

#### **5.4.2 November 1992 Survey**

##### **5.4.2.1 Survey Effort and Sightings**

A map of the survey routes for the November 1992 Survey and the location of sightings is provided in Figure 5.2. The total distance travelled searching for dolphins over the three days in the Bay was 184.4 km (see Table 5.1). The total time spent searching over the three day Survey was 48 hours and 51 minutes. Thirty-five percent of the search time was spent in the Bay, 37% on the northern leg and 28% on the southern leg which was similar to the March Survey effort (see Table 5.2).

On this Survey *Tursiops* were only sighted in the Bay. A total of four encounters were recorded with animals sighted on all three days (see Tables 5.3 & 5.4). Animals were observed within the Bay for slightly longer than on the previous Survey, i.e. 27% of the time on the water was spent observing bottlenose dolphins (see Table 5.5). The average observation period per encounter was one hour and 11 minutes. These results probably reflect the improved weather conditions on this Survey. Because no sightings were made on either coastal legs the overall contact rate for the November Survey was low, i.e. 10%. These results suggest that the actual abundance of *Tursiops* is less along the coast compared with the Bay. At the four sightings in the Bay the estimated total number of dolphins was 67 (see Table 5.6).

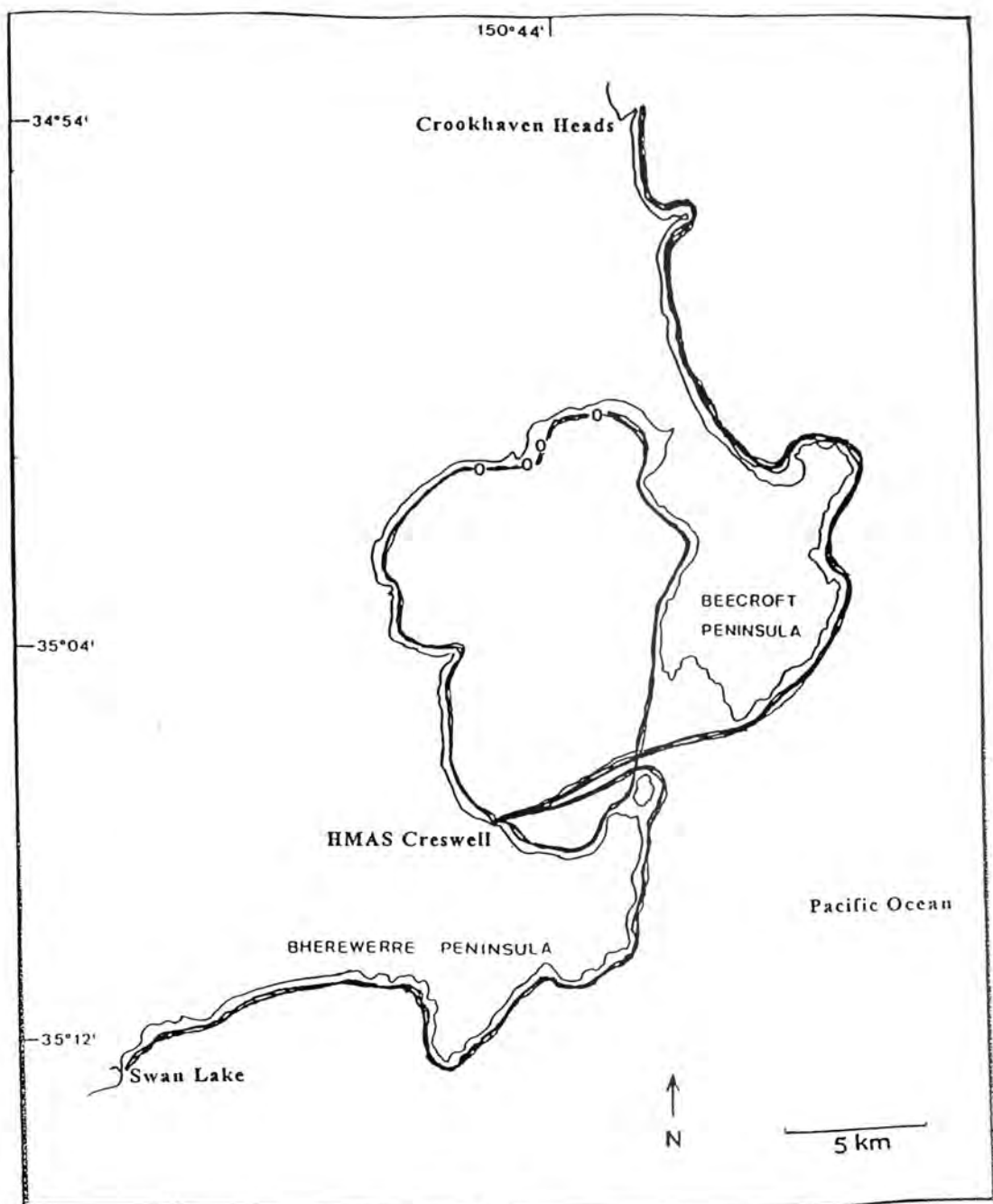


Figure 5.2: Map of November 1992 Regional Survey routes and the location of sightings indicated by a circle.

#### **5.4.2.2 Group Composition**

The mean sighting size was 16.7 (S.E. 5.8). The nine pods recorded varied in size from two to 20 animals with a mean size of 7.4 (S.E. 1.8 ). As sightings were only recorded in the Bay on this Survey no comparisons can be made of group composition variables across the different Survey routes (as for the March Survey). Of the 67 individuals counted, eight were identified as calves. The maximum number of calves sighted with any single pod was again three and a maximum number of four calves on one Survey day was recorded. The average daily number of animals sighted in the Bay was approximately 22.

#### **5.4.2.3 Distribution of sightings across Habitats**

##### **a) Depth**

All four sightings in the Bay were made at depths of 6 m or less (see Table 5.7).

##### **b) Substratum**

Three sightings were made over seagrass and one over rock (see Table 5.8).

#### **5.4.2.4 Environmental Variables**

The four sightings recorded were in the NW (3) and NE (1) quadrants of the Bay. The weather conditions were markedly better than on the previous survey (i.e. cloud cover ranged from 0-100%; BF was 0-2 and maximum swell was 2 m), so weather seems unlikely to have influenced the nil sighting outcome on the two coastal legs. The average sea surface temperatures over the three days for the Bay, northern and southern legs were 18°C, 16.7°C and 17.5°C, respectively. All four sightings were made in the morning time of day category with three at flood tide and one at high tide. Three sightings were recorded with winds from the southwest and one from the south.

### 5.4.3 April 1993 Survey

#### 5.4.3.1 Survey Effort and Sightings

A map of the survey routes on the April 1993 Survey and the location of sightings are provided in Figure 5.3. On the first day sea conditions were not optimal and the northern leg was cancelled so an extra partial search of the Bay was carried out. Consequently the search effort on the April Survey between days and legs cannot be directly compared with the other two Regional Surveys. Accordingly the total distances travelled searching for dolphins were: in the Bay, 275.2 km; and on the northern and southern routes, 165 km and 149 km, respectively (see Table 5.1). The total time spent searching from boats over the three days was 45 hours. Fifty-one percent of the search time was spent in the Bay, 24% on the northern leg and almost 25% on the southern leg (see Table 5.2).

*Tursiops* were sighted on all three days in the Bay, only on one day on the northern leg and no sightings were made on the southern route, as for the November Survey (see Table 5.3). On this Regional Survey therefore, no sightings were recorded on the southern leg, only one sighting was made on the northern route and 11 sightings were made in the Bay (see Table 5.4). The contact rates for the Bay, northern and southern legs were approximately 43%, 5% and nil, respectively. The total time spent observing the animals was nine hours and 35 minutes, that is 21% of the time spent on the water in April was spent with animals (see Table 5.5). This was the highest overall contact rate for all three Regional Surveys and appears to reflect the relatively greater search effort in the Bay. On the April survey in the Bay, the mean observation period was 49 minutes and for the single sighting on the northern leg the duration of the observation was 30 minutes. From the 12 sightings, an estimated total number of 132 animals was recorded (see Table 5.6).

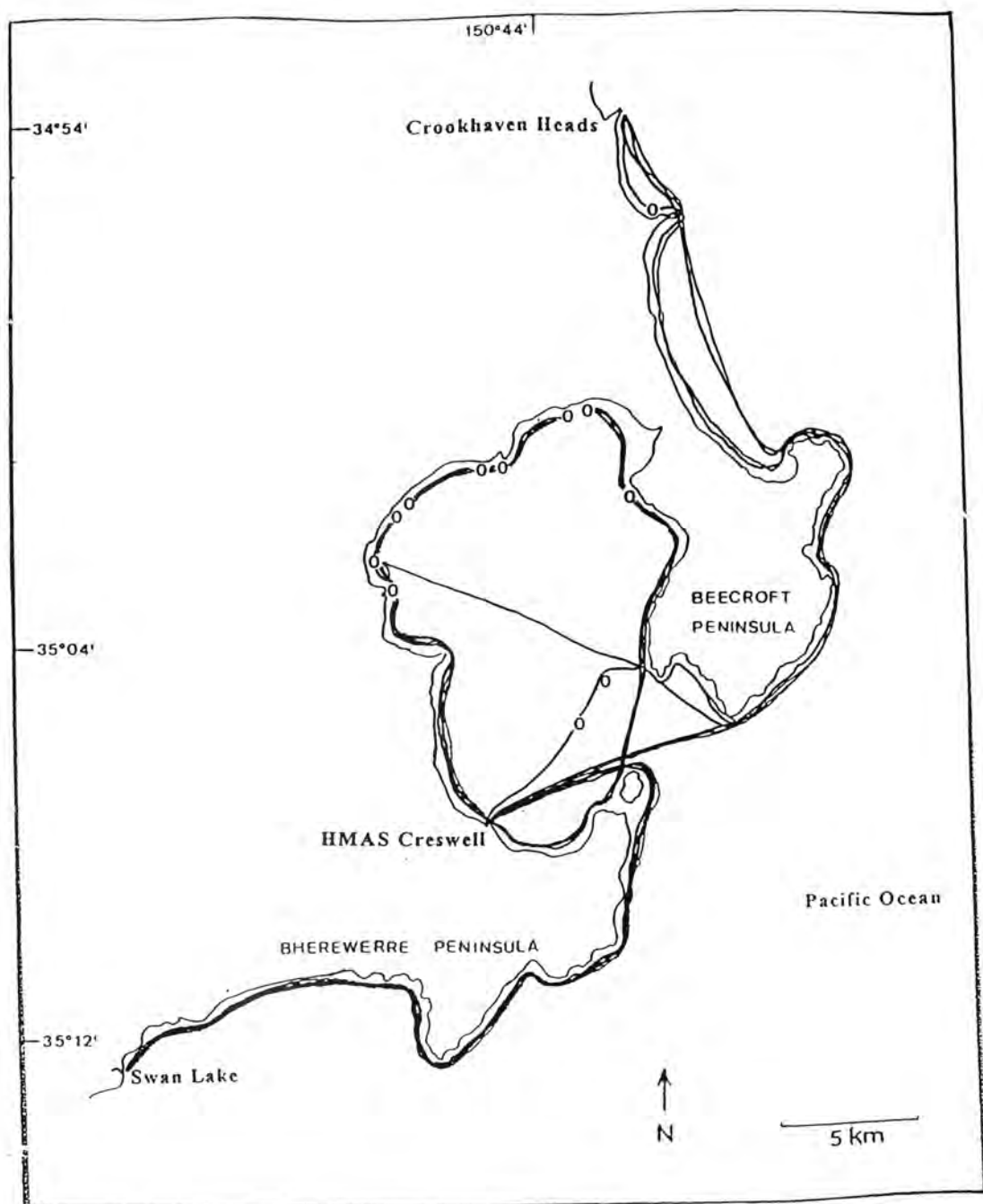


Figure 5.3: Map of April 1993 Regional Survey routes and the location of sightings indicated by a circle.

#### **5.4.3.2 Group Composition**

The mean sighting size across the two legs where sightings were made, i.e. the Bay and the northern leg, was 11.0 (S.E. 1.9). The 19 pods recorded varied in size from two to 15 animals with a mean size of 6.9 (S.E. 0.7). Because only one sighting was recorded outside the Bay on this Survey, no comparisons could be made of group composition variables across the different Survey routes (as for the March Survey). The total number of calves recorded was eight. On only one occasion in the Bay were two calves recorded at a single sighting event with each calf in separate pods. All other sightings of calves were singular. The one sighting made on the northern leg, however, involved a single pod of five animals including two calves. Over the three day survey period the average daily number of animals sighted in the Bay was 42.

#### **5.4.3.3 Distributions of sightings across Habitats**

##### **a) Depth**

The northern sighting was in shallow water (3.7 m). Only two of the 11 sightings in the Bay were made in deep water at 23.4 and 25.0 metres, with the remainder at 11.5 m or less (see Table 5.7).

##### **b) Substratum**

The northern sighting was over rock. In the Bay seven sightings were made over sand, with two over seagrass and two over rock (see Table 5.8).

#### **5.4.3.4 Environmental Variables**

In April the 11 sightings recorded from the Bay were mainly in the northern half with six in the NW, three in the NE and two from the SE quadrants. While cloud cover varied from 0-100% over the three days the weather was mainly clear, other than early on the second day when it was overcast. However on the first day winds averaged 16 knots from the south, a Beaufort sea state (BF) of 4. By the second

day the southerly had eased to an average of 4 knots (BF 2) in the morning and the winds swung round to the NE in the afternoon and dropped further. On the final day winds remained from the north but increased slightly to 7 knots (BF 3). The average sea surface temperatures over the three days for the Bay, northern and southern legs were 20°C, 20.6°C and 20.2°C, respectively. This Survey extended across the morning and midday time of day categories as well as into the afternoon (i.e. 1400-1800) on the Bay leg, on the second of the three days. Dolphins were recorded from all three categories with five sightings made in both the morning and midday, and two in the afternoon. This Survey extended across four tidal states. The two deep-water sightings near the entrance of the Bay were the only ones to occur in the late afternoon and on flood tides. Most (6) were recorded at low tide, with three at ebb tide and one at high.

#### **5.4.4 Sightings within Jervis Bay only from all three Regional Surveys**

##### **5.4.4.1 Sampling Effort**

On all nine Regional Survey days animals were sighted in the Bay (see Table 5.3). A total of 22 sightings were recorded and chi-square goodness of-fit test indicated no significant difference among the numbers of sighting events per survey on the basis of effort, in terms of survey days (Table 5.13a-li). However, two of these sightings were recorded by the vessel unable to search the northern route due to bad sea conditions, on the April Survey. Not unexpectedly, the chi-square goodness-of-fit test still indicated no significant difference between the number of sighting events per survey on the basis of effort per survey days using sightings made from the vessel allocated the Bay leg only, i.e. the designated route (Table 5.13a-li).

For analyses of effort only sightings made from the vessel allocated the Bay leg were used ( $n=20$ ). An estimated 16 hours 57 minutes were spent observing dolphins from the Bay vessel, out of the total 52 hours and 47 minutes spent searching in the Bay on all three Surveys. Hence, the contact rate was

approximately 32%. The duration of each encounter varied between three minutes and two hours thirty-seven minutes, the mean observation time was 51 minutes. The distances travelled per sighting while observing animals also varied greatly, from 150 m to 7.6 km, with an average of 1.8 km.

On all three Surveys the vessel allocated to search the Bay completed a circuit, hence survey effort was distributed equally across all quadrants of the Bay (Table 5.13a-*lii*). Six of the nine survey days were conducted in autumn and three in spring (Table 5.13-*liii*). Sampling effort ( $n= 52.8$  hours) was not distributed equally across the three time of day categories which the Regional Survey in the Bay covered. Only one hour and 45 minutes occurred after 1400, hence this category was omitted and the morning and midday categories (i.e. morning=0600-1000 and midday=1000-1400) were considered. Sampling effort in hours ( $n=51.03$ ) was equally distributed across these two time of day categories (Table 5.13a-*liv*).

Sampling effort was equally distributed across the four tidal states (i.e.  $n=27$ , based on three hourly intervals) for Bay surveys (Table 5.13a-*lv*). Survey effort was not distributed evenly throughout the Bay with respect to depth, as Figures 5.1-5.3 suggest. The distribution of sampling effort across depth was focused on nearshore waters (i.e.  $\leq 10$  m in depth) as for the S&E Survey. However, effort in terms of distance travelled in nearshore versus deeper waters is unable to be estimated due to incomplete records by volunteers of the route taken.

Because of the small data set, all sightings in the Bay ( $n=22$ ) have been used in analyses below. All group composition variables for Regional Survey data from within the Bay were analysed as for the S&E Survey (Chapter 3) and Non-Transect Sightings (NTS) made on the Transect Survey (Chapter 4). However, for the remaining variables (i.e. habitat, environmental, spatial pattern and behaviour) only analyses for which similar or significant results were found for both the S&E and NTS data sets were considered (see Summary Tables 3.8 & 4.10). This approach was adopted because of the relatively small size of the Regional Survey data set.

#### 5.4.4.2 Group Composition

At the 22 sighting events within the Bay, a total of 236 individuals were recorded (see Tables 5.4 & 5.6), clustered into 36 pods, i.e. 14 sightings involved multiple numbers of pods. The minimum number of animals per sighting event was two and the maximum 32. The mean sighting size in the Bay across all Surveys was 10.7 (S.E. 1.68). ANOVA indicated no significant difference in the mean sighting size across the three Surveys (Table 5.13b-li). The mean pod size across all Surveys was 6.6 (S.E. 0.6) and ANOVA indicated no significant difference in the means (Table 5.13b-li).

On the 12 occasions where calves were observed, a total of 19 individual calves were recorded. The maximum number of calves sighted, at any one sighting event and on a single survey day was four in each instance. Calves represented 8% of observed animals in the Bay. The majority of calf sightings were of single calves in a single pod ( $n=11$  occasions) and on four occasions there were two calves in a single pod. ANOVA indicated no significant difference in the mean number of calves sighted in the Bay across the three Surveys (Table 5.13b-li).

As no differences were found across Surveys in the Bay for sighting size, pod size and the number of calves it was considered valid to combine all sightings in the Bay and analyse group composition as for the S&E (see Section 3.2.4) and NTS data sets (see Section 4.3.4.2).

A *t*-test indicated that the mean number of animals recorded at each sighting was larger when calves were present (Table 5.13b-lii). However, when sightings were divided into size classes (i.e. small  $\leq 10$  dolphins and larger  $>11$ ) there was no association between the presence or absence of calves (Table 5.13b-lii).

There was a positive association between sighting size and the number of pods recorded at each sighting event, with the number of pods increasing with

increasing sighting size class (Table 5.13b-liii). In this data set all small sightings consisted of single pods and all large sightings involved multiple pods. No association was found between the number of pods recorded at each sighting event and the presence or absence of calves (Table 5.13b-lii).

A *t*-test indicated no significant difference in mean pod size when calves were present or absent (Table 5.13b-lii). However, an association was indicated between the presence or absence of calves when pods were divided into size classes (i.e. small  $\leq 10$  dolphins and larger  $>11$ ) with calves only present when pods were small (Table 5.13b-lii). No association was indicated between pod size classes (as above) and the number of calves per pod (Table 5.13b-liv). This result is not considered further as some expected values in this contingency table were less than one.

#### **5.4.4.3 Distribution of sightings across Habitats**

##### **a) Depth**

ANOVA indicated no significant difference in the mean sighting depth across the three Surveys (Table 5.13c-li). The mean sighting depth for all Surveys was 8.8 m (S.E. 1.3 m) and the minimum and maximum, 3.0 m and 25.0 m, respectively. There was however, a significant difference in the distribution of all sightings made in the Bay for all three Regional Surveys when the Bay was divided into three depth categories (see Table 3.3). The majority (68%) of all sightings were recorded in a depth of 10 m or less (Table 5.13c-lii).

##### **b) Substratum**

An association was indicated between sighting substratum and the three different Surveys; however, some expected values in this contingency table were less than one, so this result is not considered further (Table 5.13d-li). There was a significant difference in the distribution of sightings over the three substrata in the Bay when the area of each was considered (see Table 2.1), for all three Regional Surveys (Table 5.13d-lii). Although less than expected, the majority of sightings

(59%) were recorded over sand. However, more sightings than expected were recorded over the rarer substrata of seagrass and rocky areas. ANOVA indicated no significant difference in the mean sighting depths over the three substrata (Table 5.13d-liii).

When the area of the three different substrata is derived for waters  $\leq 10$  m (see Table 3.4), the pattern of the distribution of sightings across substrata varied between the S&E and NTS data sets. However, as the majority of all sightings were recorded in a depth of  $\leq 10$  m, for completeness, the distribution of sightings across habitats within this depth zone only was considered. As for the S&E Survey no significant difference was found in the distribution of these sightings corrected on the basis of these areas (Table 5.13d-lii).

#### 5.4.4.4 Environmental Variables

A significant difference was indicated in the distribution of sightings ( $n=20$ ) across the quadrants of the Bay, when the area of each was considered (see Table 3.1a, Table 5.13e-li). Eighty-five percent of sightings were recorded in the northern half of the Bay and 50% were in the NW quadrant. The two sightings made by the 'northern' vessel were also in the north of the Bay. However, no association was indicated between the presence or absence of calves across the north or south of the Bay (Table 5.13e-liii). Although on 11 of the 12 occasions when calves were recorded these sightings occurred in the northern half of the Bay.

There was no significant difference in the distribution of sighting events made from the Bay vessel ( $n=20$ ) across tidal states (Table 5.13e-li). There was also no association between tidal state and the group composition variable, size of pod (Table 5.13e-lii).

A *t*-test indicated no significant difference between the mean sea surface temperatures recorded at sighting events across the two seasons when surveys were conducted (Table 5.13e-liv).

#### **5.4.4.5 Spatial Pattern**

Of the seven descriptive categories for the spatial arrangement of dolphins with respect to each other, four were recorded for sighting events and only three for pods (Table 5.9). It was necessary to combine categories for the purpose of analysis which resulted in two categories (i.e. clumped and dispersed) (see Section 3.2.5).

Of the 21 sightings where spatial pattern was recorded, the whole group was mainly in single or multiple clumped groups (81%). As expected, the spatial arrangement recorded for 35 pods was also primarily clumped (86%) (Table 5.9).

The only variable which was associated with the spatial arrangement of groups for both the S&E Survey and NTS was sighting size, i.e. the total number of dolphins per sighting event. Hence only this variable was analysed and no association was found (Table 5.13f).

#### **5.4.4.6 Behavioural Variables**

Of the nine descriptive categories for behaviour (see Section 3.2.6), a total of six were recorded (Table 5.10). When these categories were combined into four main activities, the proportions of their occurrence were similar to both the S&E and NTS data sets. For the 35 pods where behaviour was recorded, most were travelling (67%), almost 17% were socialising, 11% were milling and only 5% were recorded as feeding. Because no associations were found between the activity of each pod and environmental variables, for both the S&E and NTS data sets, no analyses were pursued for this data set (see Section 4.4.2).

**TABLE 5.9: Frequency of spatial patterns for sighting events,  $n=21$ , and pods,  $n=35$ , sighted within the Bay, for all three Regional Surveys. Where na indicates not applicable and nil indicates the spatial pattern was not recorded.**

	Clumped	Spread	Core Group + others spread	Multiple clumped pods	Linear	Abreast	Circle
Sighting	9	1	3	8	nil	nil	nil
Pod	30	2	3	na	nil	nil	nil

**TABLE 5.10: Frequency of overall behavioural activities recorded per pod,  $n=35$ , sighted within the Bay, for all three Regional Surveys. Where nil indicates the behaviour was not recorded.**

	Slow Travel	Mod. Travel	Fast Travel	Mill	Rest	Social	Feed	Feed/ Travel	Social/ Travel
Pod	14	10	nil	4	nil	1	nil	2	4

#### 5.4.4.7 Abundance and Density Estimates

##### a) Abundance

It is not applicable to investigate abundance in terms of monthly, seasonal or annual dolphin and calf sightings (as for the S&E and NTS data sets) as only three surveys were conducted, two of which were in the same year and two in the same season. However, the total number of dolphins and calves sighted across quadrants and the three substrata in  $\leq 10$  m of water is reported as for the S&E and NTS data sets.

The total number of dolphins sighted in the Bay ( $n=236$ ) varied significantly across the different quadrants of the Bay when these were adjusted for the area of each (see Table 3.1a). That is, 91% of animals recorded were in the northern half of the

Bay (Table 5.13g-li). The highest number sighted were in the NW (55%), the next highest in the NE (36%). The total number of calves sighted ( $n=19$ ) varied significantly across the different quadrants of the Bay when these were adjusted for the area of each with 95% of calves recorded in the northern half of the Bay and 53% in the NW (Table 5.13g-lii).

The total number of animals sighted over sand, seagrass and rock were 118, 105 and 13. Even when sightings at depths beyond 10 m were excluded, most animals were over seagrass (103), then sand (73) and least over rock (13). When the areas of each substratum in these waters were considered (see Table 3.4) more dolphins than expected were seen over seagrass and less than expected over both rock and sand (Table 5.13g-li). The total number of calves sighted over sand, seagrass and rock were 7, 11 and 1. Even when sightings with calves at depths beyond 10 m were excluded, most calves remained over seagrass (11), then sand (3) and least over rock (1). When the areas of each substratum in these waters were considered the same pattern as for total abundance was found (Table 5.13g-lii).

## **b) Density**

The density estimates which showed a similar pattern for both the S&E and NTS data sets were: the density of dolphins throughout the Bay, and the density of dolphins and calves over the three substrata in waters  $\leq 10$  m in depth (see Section 4.4.2). Hence, these analyses were investigated for all sightings made on the Regional Surveys. All density estimates are based on small sample sizes and should be regarded with caution. Furthermore the unknown level of resightings within and between field days would further reduce these estimates.

The mean density estimate for the whole study area (117.2 sq km) based on the total number of animals sighted in the Bay ( $n=236$ ) during the Regional Surveys ( $n=9$ ) was 0.22 dolphins/sq. km.

Estimated dolphin density varied across the different substrata located in  $\leq 10$  m of water of the Bay on the Regional Surveys (Table 5.13h-li). The highest density occurred over seagrass with 1.2 *Tursiops*/sq. km and then rocky complex areas and sand with 0.7 & 0.35 *Tursiops*/sq. km, respectively. Estimated calf density also varied across the different substrata located in  $\leq 10$  m of water of the Bay on the Regional Surveys (Table 5.13h-lii). The highest density occurred over seagrass with 0.20 calves/sq. km, followed by rocky complex areas then sand with 0.10 & 0.03 calves/sq. km, respectively.

## **5.5 Helicopter Survey**

### **5.5.1 Survey Design**

A concurrent aerial search by helicopter, following the same routes as the boats for the whole study area, was conducted on two of the three days on the final Regional Survey in April 1993. The aims of these snapshot aerial surveys were to assess: (a) vessel-based sighting reliability; (b) accuracy of counts and calf recordings; and (c) the possible extended range of the coastal groups.

The helicopter was flown while searching at an average speed of 55-60 knots (101 - 111 km/h, approximately 1.0 NM/minute), at an altitude of 500 ft (150 m) and approximately 500 m offshore. When a sighting was made on this survey, the helicopter descended to a minimum altitude of 150 ft (45 m) and was able to remain stationary while data were recorded and photographs taken, and then returned to the search path. On the first day of the aerial survey, two surveys of the whole study area were completed, the first from 0900-1130; the second from 1530-1730. The first was conducted concurrently with boat searches and the route flown followed the southern leg first, then the Bay, the northern leg and the Bay again. The second survey took place when no survey vessels were on the water and the route flown was the southern leg, then the northern leg and finally the Bay.

On the second day the first survey followed the same procedures and route as the first survey on the previous day, searching from 0830-1100. Two other searches of the Bay only were then conducted from 1145-1230 and 1245-1315.

It was initially considered extending the helicopter survey further north and south of the boat survey routes, to investigate if the low counts on these routes were due to these legs representing only part of the range of dolphins using the coast. However, logistical restrictions limited the aerial survey to the boat search paths.

## **5.5.2 Results**

### **5.5.2.1 Survey Effort and Sightings**

A map of the helicopter survey routes in April 1993 and the location of sightings made from the helicopter are provided in Figure 5.4. A total of seven hours were spent conducting the three searches of the whole Survey route. Also a further one hour and 15 minutes were spent searching the Bay only.

On the three aerial surveys which searched all three routes, only four sightings were made, two on each morning flight (Table 5.11). Three were in the Bay, one

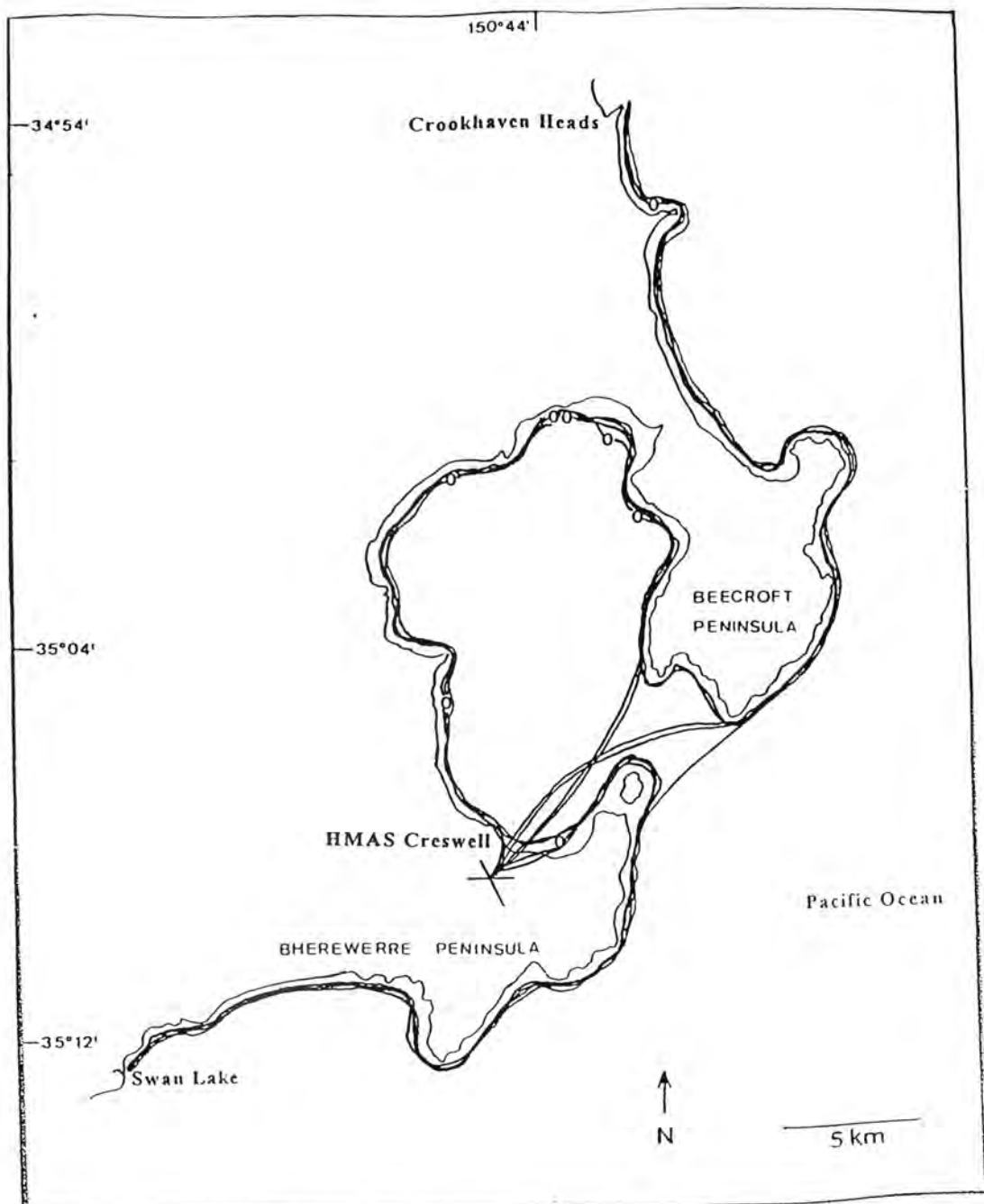


Figure 5.4: Map of April 1993 Regional Helicopter Survey routes and the location of sightings is indicated by a circle.

**TABLE 5.11: The total number of sighting events for the two day aerial survey on the designated routes. NoS indicates no survey was conducted over these areas.**

Survey	Total Number of Sighting Events			
	Route	Bay	North	South
<b>2.4.93</b>				
AM		2	0	0
PM		0	0	0
<b>3.4.93</b>				
AM		1	1	0
1st Bay only		1	NoS	NoS
2nd Bay only		1	NoS	NoS

on the northern leg and none on the southern leg. On the two short searches of the Bay, only a single sighting was recorded on each flight and it is believed these were the same group of animals as seen on the morning search.

#### **5.5.2.2 Boat-based sighting reliability**

Only one of the four sightings was first seen by the helicopter, the other three were first observed from vessels. That is, the aerial search only reported one extra sighting over the length of the Survey route for the five hours that both vessels and helicopter were searching. No definitive comments can be made from “snapshot” surveys such as these but unless sightings were also missed by the helicopter, these findings suggest that few sightings are being missed along the boat search paths.

#### **5.5.2.3 Accuracy of counts and calf recordings**

For the first sighting made in the Bay, I made a visual estimation from the air of 25 animals. The count recorded from the vessel was 20. Fifteen photographs were taken of this sighting from the helicopter. The maximum number recorded from a single photograph was nine animals at or within approximately one metre of the surface (Table 5.12). No calves were seen from the helicopter nor were any able to be identified from the photographs. It should be noted that all counts are regarded as a minimum estimation.

At the time of the observation from the air the group was recorded as having a clumped spatial arrangement with no calves reported. From the vessel, this sighting commenced only five minutes prior to the helicopter’s arrival and reported two clumped pods consisting of a pod of eight animals including two calves and another of 12 animals with one calf. The photographs from this sighting were indicative of all the photographic material from the helicopter, that is the numbers of animals were difficult to assess. Effectively only animals surfacing or within approximately one metre of the surface could be counted confidently due to a lack of visibility beneath the water surface. This distance was based on the

**TABLE 5.12: The number of animals recorded using three different approaches (i.e. visual estimation from the boat or helicopter, and estimates based on aerial photographs) for all six sighting events. NoP indicates no photographs were taken from the helicopter and NoB indicates no boat was present.**

Date	Estimated Number of Dolphins		
	Boat - Visual	Helicopter - Visual	Aerial Photographs
2.4.93	20	25	9
	17	12	7
3.4.93	5	6	3
	5	6	NoP
	7	5	NoP
	NoB	3	2

visibility of an individual, i.e. for an animal with only its melon clear of the surface as it rises to breath, the dorsal fin beneath the surface would just be visible but its tail flukes would not. Likewise, the dorsal fin of an arched diving animal would be clear of the water with its tail flukes visible just beneath the surface, but often even the white of the tip of the rostrum would not be visible. Hence, any animal swimming at a depth greater than one metre would not be seen or, at best, be marked by a shadow and so could not be included with any confidence in a count. Detection of submerged animals can occur as a result of sighting cues not requiring resolution through the water such as surface disturbance and wake; however, these were also not used for counts. At the time of observation these animals were in 5 m of water over sand which should have provided optimal background contrast conditions. However, contrast conditions were not markedly different across all three substratum types.

It was reported from the vessel that animals displayed avoidance behaviours when the helicopter was overhead. At 180 ft (55 m) the down draught from the helicopter made visible patterns on the water and behaviour appeared to alter when the helicopter descended to an altitude of 150 ft (45 m). Subsequently when observing animals the helicopter remained at an average altitude of 250 ft (76 m) only descending to 150 ft for photographs.

The second sighting made on this survey was reported by a different vessel which apparently continued to follow the same group of animals after the first vessel continued on their search route (see Section 5.4.3.1). From the helicopter, on its return leg approximately one hour after the first sighting, the total number of animals visually estimated was 12 in one clumped group. The second vessel reported three pods, consisting of seven, five and five dolphins including a single calf. Of the 16 photographs from this sighting, the maximum number from a single frame was seven animals, in a single group (see Table 5.12). No calves were able to be identified from aerial photographs. These animals were reported to be in 6.4 m of water traversing sand and seagrass.

On the second day the first and only sighting was made from the helicopter which was not reported from a vessel. This sighting, in the Bay, was of three animals, spread apart. It was estimated these animals were in 6 m of water traversing seagrass. From the six photographs of this sighting, only two animals were recorded on a single frame (see Table 5.12). Again as the helicopter hovered overhead, the animals increased their apparent dive time and speed, and clumped together. Aerial behaviour was recorded also, including numerous leaps with the whole body clearing the water, and this was well documented in the photographs. No calves were reported.

The second sighting event of the day was on the northern leg, where it was estimated six animals were at the time of observation in 6 m over a rocky reef. No calves were recorded. The search vessel had been with the animals for 25 minutes prior to the helicopter's arrival. The animals had been milling and idling in the same area for this period and it was only with the arrival of the helicopter that they increased speed and commenced directional travel. While the helicopter was present, the sighting was reported as five animals, consisting of three adults and two smaller animals. From the ten photographs taken only three animals were indicated in a single frame (see Table 5.12). This sighting represented the most northerly sighting made on the Regional Survey.

On the two short surveys of the Bay only, both sightings made from the helicopter were observed from the research boat also but unfortunately no photographs were taken from the helicopter on these flights. A total of six animals was visually estimated from the helicopter, including one calf. The record from the boat was of five animals with one calf. The animals were recorded as being at an average depth of 5.8 m over sand at the time observations were made from the helicopter. These animals had been observed for one and a half hours prior to the helicopter's arrival and displayed a definite change in direction of travel and behaviour while the helicopter was overhead. Occasional tail slaps and brief bow-wave riding were the only deviations from milling and idling prior to the helicopter's arrival. When the helicopter was present, repeated lateral and forward leaps by individuals as well as

in unison with three and four animals commenced. After the helicopter left these surface behaviours continued for at least another ten minutes, after which the observation boat ceased to follow the animals.

On the second of the Bay-only searches, the single sighting from the helicopter was estimated to include a total of five dolphins, with no calves sighted. The record from the boat was of seven animals including one calf. At the time of the helicopter's presence, the animals were reported to be in 12 m of water over sand. These animals had only been observed for a few minutes prior to the helicopter's arrival; however, leaping was again recorded when the helicopter arrived. Also at this time the group split into two, and travelled in different directions. There is a possibility that all or part of this group was the same as recorded on the earlier flight. After the helicopter left, leaping was reported at every five minute scan sample for the next 25 minutes; from then on, the frequency of this activity decreased.

The estimated total number of animals recorded per sighting from the helicopter and boat, using either visual estimation or photographs are summarised in Table 5.12. The greatest difference between visual estimations made from the helicopter and a boat, of the number of animals at any one sighting event, was five animals. In these two incidents the boat both under and over-estimated the helicopter counts by 25% & 42%, respectively. Counts from the aerial photographs were fewer than estimates derived from the other two approaches. However, a one-factor ANOVA found no significant difference in the mean estimates of the number of dolphins sighted across the three different approaches (see Appendix 5, TABLE A5.9).

## 5.6 Discussion

Few definitive statements can be made on the basis of only three surveys. However the aim of this Survey was to collect baseline data on the presence of *Tursiops truncatus* outside Jervis Bay and this was achieved. As for both the S&E and

Transect Surveys, the level of resightings within and between survey days is unknown.

During the Regional Survey *Tursiops* was sighted in the Bay on all nine days but only on four days along the adjacent coast. This relatively higher level of use of the Bay by *Tursiops* suggests the Bay's importance, in the larger geographical context, to the local bottlenose dolphin "population". The repeated finding of animals in the Bay on these Surveys which were conducted eight and four months apart, reflects the results from the more intensive Search and Encounter (S&E) and Transect Surveys which had sighting rates in the Bay of 77.5% and 62%, respectively. Furthermore the mean number of individuals sighted per day, over these nine days, in the Bay was 26 but along the open coast was only 11. These results also suggest the greater relative importance of the Bay.

The fact that animals were sighted simultaneously on all routes on two days in March, establishes that animals reported along the coast are not necessarily the dolphins from Jervis Bay and *vice versa*. Also, the consistent sightings and larger numbers of *Tursiops* in the Bay strongly challenge the commonly held local view that the animals seen in Jervis Bay are only "visiting" or "passing through". Indeed the rarer sightings and smaller groups seen along the coast possibly better reflect such a usage pattern.

While seasonal analysis of this data set is obviously not appropriate, it is interesting to note that the highest total numbers of animals recorded was in April 1993 but March 1992 was lower than November 1992. That is, no seasonal trends in abundance are apparent from this data set. Whether this is related to the small number of surveys, interannual variation or that the pattern of use of the Bay has no consistent seasonal trends, is unknown.

Of the 21 calves sighted on the Regional Survey, 19 were recorded in the Bay. The largest total number of calves sighted was on the November Survey, in contrast to the S&E and NTS data sets which reported the lowest calf sightings and abundance

levels in spring. CSIRO (1994) indicated that for most of the year, the East Australian Current keeps water offshore warmer than in the Bay, except at the peak of summer, when Bay waters may become warmer than offshore. The mean temperatures recorded on the Regional Survey reflect this pattern, except in November when the Bay was warmer than coastal waters. Hence warmer temperatures inside the Bay are unlikely to explain the higher number of calves in the Bay versus along the coast in March and April, but may have influenced the relatively higher number recorded in November.

The lack of sightings on both coastal routes in November probably suggests that these legs do not cover the whole ranges of the groups sighted previously. Whether these animals range further either inshore along the coast or offshore from the surveyed areas is unknown. Also, these results may suggest some seasonal influence on their movements or interannual variability but these cannot be ascertained definitely from such a small number of surveys.

As indicated the number of sightings along the coast was small and did not allow for much statistical analysis. Interestingly the habitat characteristics of these sightings were similar to embayment sightings from these Regional Surveys and mirror earlier findings from the S&E and Transect Surveys. That is, ten of the 11 coastal sightings were in waters 11.5 m or less. Seven of these coastal sightings were over, or immediately adjacent to, rocky outcrops, with the remaining three over sand. The single deep water sighting was over sand and adjacent to the mouth of an estuary.

The helicopter surveys suggest that the reliability of small boats as observational platforms using the described survey effort and operational procedures, in this study area, is very good. That is, if the animals are present along the search path, mostly they will be sighted. Leatherwood and Show (1980) conducted aerial surveys using a Cessna 172 aircraft to estimate the size of three *Tursiops* populations, and refine data collection and data analysis techniques. They operated their aerial survey at 167 km/hr (90 kn) as they considered 80 kn to be the safest

speed at which "...sustained low level flights (<1000 ft) involving frequent orbiting could be justified...". Obviously the reduced operational speed of the helicopter used in this Survey (i.e. 55-60 kn) increased the possibility of detection by increasing sighting time (i.e. with regard to sighting distance and aircraft speed). Leatherwood and Show (1980) investigated the effect of four altitudes, on the numbers of *Tursiops* sightings and estimation of herd size. These authors found flights at 750 ft (228 m) resulted in higher numbers of sightings and estimates of total population but that the extremely low significance of altitude implies "...herd size estimation is almost totally unaffected by the altitude from which the estimate is obtained, between 500 and 1,250 ft (380 m)...". Like Leatherwood and Show (1980), my surveys were conducted at 500 ft.

The degree to which avoidance behaviour impacts on sighting rates from the helicopter needs to be considered. Cockcroft *et al.* (1992) noted that, while dolphin responses to approaching vessels has been considered, no data exist for making inferences about dolphin group awareness of, and reaction to, overflying aircraft. This Survey strongly suggests a range of responses to low flying and stationary helicopters, some of which are likely to impact on group size estimations from such aircraft.

In terms of the accuracy of counts, it is difficult to make direct comparisons between the different methods. Statistically there was no significant difference in the estimates of the total number of dolphins per sighting, visually made from the helicopter or boat, or from aerial photographs. However, improved aerial estimates are likely to occur if a camera with motor drive is used in order to capture all animals on successive frames over their staggered surfacing interval (Hammond *et al.*, 1990).

Incongruously, the Bay is renowned for its water clarity yet counts were affected by the lack of visual penetration beyond approximately one metre below the water surface. It was also difficult to discern calves even when their presence was recorded from the boats. This may be due to the proximity of calves to their

mothers' bodies and variable surface conditions which may obscure calf surfacing cues.

Small boat surveys appear to be particularly useful for calf sightings and the collection of detailed habitat, environmental and behavioural data. An important factor is the ability to observe animals closely for extended periods. As Shane (1990a) noted, most of the dolphins in her study area appeared to become "...habituated to my boat (i.e. recognised it and were not visibly disturbed by it) within 6 months...". However, as noted in Chapter 4 (see Section 4.4.3) a dual approach using small boat surveys and photographic identification of individuals as well as regular aerial surveys is advocated to estimate population abundance and density.

Finally, the combined sighting data for all three Regional Surveys in the Bay, repeated a number of the trends identified in the S&E and NTS data sets. These are summarised below:

#### **Group Composition**

- \* both the mean sighting size (11) and pod size (7), fall within the most common mean group size range (2-15) reported by Wells *et al.*, (1990);
- \* the smaller the total number of animals recorded per sighting, the more likely it is to be a single pod while large sightings are more likely to consist of multiple pods;
- \* the majority of calf sightings were of a single calf per pod (58%);
- \* the maximum number of calves sighted at any one sighting event and on a single survey day were both four; and
- \* the total number of calves observed represented 8% of all dolphins observed.

### **Habitat Variables**

- \* the majority of sightings (68%) were recorded in waters  $\leq 10$  m which cover approximately 24% of the Bay; and
- \* significantly more sightings (41%) were recorded over the rarer substrata of rocky complex areas and seagrass which only cover approximately 10% of the area of the Bay.

### **Environmental Variables**

- \* 86% of sightings were made in the northern half of the Bay and of these 50% of all sightings were in the NW quadrant; and
- \* 83% of calf sightings were made in the northern half of the Bay.

### **Abundance Patterns**

- \* the majority of animals sighted were in the northern half of the Bay (91%) and these were mainly in the NW quadrant (55%);
- \* animals were more abundant over seagrass (54%), then sand (39%) and least over rock (7%) in waters  $\leq 10$  m in depth;
- \* significantly more dolphins were sighted over seagrass in waters  $\leq 10$  m, when the area of each substratum was considered;
- \* 95% of calves recorded were in the northern half of the Bay with 53% in the NW;
- \* calves were most abundant over seagrass (73%), then sand (20%) and least over rock (7%) in waters  $\leq 10$  m; and
- \* significantly more calves were sighted over seagrass in waters  $\leq 10$  m, when the area of each substratum was considered.

### **Density Estimates**

- \* the density of dolphins in the Bay (0.22 dolphins/sq. km) was relatively low (Shane *et al.*, 1986); and
- \* the highest density of calves in  $\leq 10$  m of water occurred over seagrass, then over rocky complex areas and least over sand.

### **Behaviour**

- \* approximately 68% of the pods recorded were travelling, socialising and milling, fairly equally recorded around 13% of the time each and the remaining pods (6%) were reported feeding.

**TABLE 5.13: Summary Tables of Results from analyses of sightings within Jervis Bay from all three Regional Surveys.**

**In all tables below:** **na** = indicates analysis not applicable to data set; **nam** = no analysis made due to the relatively small size of this data set; **ee** = derivation estimated elsewhere; **du** = data unavailable; **+ve** indicates a positive association; **assoc** means a statistically significant association was indicated (at alpha = 0.05 and where expected values from contingency tests were equal to or greater than one, see Section 2.4) but no positive or negative trend was apparent, this typically relates to categorical variables and the area of strongest association is indicated in the appropriate column (see relevant Result & Discussion Sections, for details); **S** indicates a statistically significant result (at alpha = 0.05) with the greatest area of difference indicated in the respective Table, in the LH margin; and **NS** indicates a non-significant result. Unless otherwise indicated (i.e. as a result of missing data or requirements of analyses) sample sizes for “sighting event” analyses are *n*=22, except for “effort” analyses where *n*=20 (i.e. only sightings made from the vessel allocated the Bay route were used); “pod” analyses are *n*=36 and “survey” analyses are *n*=9. SS Temp. refers to Sea Surface Temperature. Sighting and pod size classes, i.e. small (1-10) or large (11+) are indicated by sm and lge. Line reference number is indicated by column **I**

**Table 5.13a: Analyses of Survey Effort**

<b>I</b>		<b>Across 3 Regional Surveys</b>	<b>Route</b>	<b>Survey Days</b>	<b>Field Hours (<i>n</i>=51.03)</b>	<b>Tidal State (<i>n</i>=27)</b>	<b>Distance Searched (km) (<i>n</i>=1946.7)</b>
<b>i</b>	<b>Sighting Events per 9 survey days</b>	NS	NS	na	na	na	na
<b>ii</b>	<b>Quadrant</b>	na	nam	na	na	na	na
<b>iii</b>	<b>Season</b>	na	na	nam	na	na	na
<b>iv</b>	<b>Time of Day</b>	na	na	na	NS/ am & midday only	na	na
<b>v</b>	<b>Tidal State</b>	na	na	na	na	NS	na
<b>vi</b>	<b>Depth</b>	na	na	na	na	na	du

Table 5.13b: Analyses of Group Composition

I		Mean Sighting Number	Sighting Size Classes	Number of Pods	Mean Pod Number	Pod Size Classes	Mean Calf Number
i	Across 3 Regional Surveys ( <i>n</i> =3)	NS	na	na	NS	na	NS
ii	Pres/Abs Calves present in larger sightings	S	NS	NS	NS	assoc/ only present in sm pods	na
iii	Number of Pods	na	+ve / more pods in larger groups	na	na	na	na
iv	Number of Calves per Pod	na	na	na	na	NS	na

Table 5.13c: Analyses of Depth

I		Depth wrt three areas of Bay	Mean Sighting Depth
i	Across Regional Surveys	na	NS
ii	Sighting Event / greatest in area of the Bay ≤10m	S	nam

Table 5.13d: Analyses of Substrata

I		Substrata wrt area of each in Bay	Substrata	Substrata ≤10m
i	Across Regional Surveys	na	NS	na
ii	Sighting Event / greater over rarer substrata	S	ee	NS (n=15)
iii	Mean Sighting Depth	na	NS	na

5.13e: Analyses of Environmental Variables

I		Quadrant wrt area of each	Half of Bay (Nth & Sth)	Season	Tidal State
i	Sighting Event / greater in the NW	S	nam	nam	NS
ii	Pod Size Classes	nam	nam	nam	NS
iii	Pres/Abs Calves	nam	NS	nam	nam
iv	SS Temperature	na	na	NS	na

Table 5.13f: Analyses of Spatial Pattern

I	Sighting Spatial Pattern	Pod Spatial Pattern
Sighting Size	NS	na

**Table 5.13g: Abundance Patterns**

I		Quadrant per area	Substrata $\leq 10\text{m}$ per area
i	Total Number ( $n=236$ ) / greatest in the NW; more over seagrass	S	S ( $n=189$ )
ii	Calves ( $n=19$ ) / greatest in the NW; more over seagrass	S	S ( $n=15$ )

**Table 5.13h: Density Estimates**

Estimated Dolphin density (no. per sq. km)				
I	Substratum	Sand	Seagrass	Rock
i	Mean no./sighting event/area at depths $\leq 10\text{m}$	0.35	1.2	0.7
ii	Mean no. of calves/sighting event/area at depths $\leq 10\text{m}$	0.03	0.20	0.10

## CHAPTER 6: INDIVIDUAL IDENTIFICATION

### 6.1 Introduction

The use of natural scarring and shape of the dorsal fins of dolphins for the identification of individuals has been well documented (Hammond *et al.*, 1990; Scott *et al.*, 1990b). These data can suggest such individuals' minimum range, residence status in the study area, demographics or social structure and allow population size estimation (Würsig & Würsig, 1977; Wells *et al.*, 1980; Shane, 1987; Connor *et al.*, 1992; Williams *et al.*, 1993).

Individual identification, however, was not the primary aim of this research. Photographs were taken on the Search and Encounter (S&E), Line Transect and Regional Surveys, after all other data had been collected. Hence photographic sampling can only be regarded as opportunistic. The objective of this component of the research was to estimate the minimum number of dolphins using the Bay, and consider any identified individual's residency status and movement pattern where possible. Home range estimates and association patterns of identified individuals were also investigated.

### 6.2 Methods and Materials

Surveys on which photographs were taken span three years (i.e. April 1990-93). At no single sighting event were all the animals present systematically photographed; but as many individuals as possible were photographed. The accessibility of individuals appeared to vary primarily with their behavioural activity which affected the duration surface time and the time they would tolerate close proximity of the boat before displaying avoidance behaviour (see Appendix 2). Also individuals on specific occasions, such as females with young calves, appeared to actively avoid the boat. Hence there is for this data set no "complete sighting group", where (by convention Würsig & Würsig, 1977; Shane, 1987; Hansen, 1983; Ballance, 1990) all members of a group are photographed and every

identifiable individual is represented by a minimum of four identifiable photographs.

I took approximately 2000 photographs using the equipment described in Sections 2.2 and 5.2. The minimum number of photographs taken at a single sighting event was one and the maximum 88. The number of photographs taken per sighting event was recorded in the field and the negatives later developed and filed by date and sighting event. These were transferred to video using a Trinicon Sony Video camera fitted with a zoom lens ( $0.8 \rightarrow \infty$ ), connected to Sony Beta and Akai VHS G10 video recorders. This resulted in images magnified up to 70x. These negatives included from one to as many as eight individuals, of which all, some or none were usable for identification purposes, i.e. were of a quality which allowed identification of individuals (Würsig & Harris, 1990).

Using the video to make an initial screening of all 2000 negatives, 248 were chosen for printing, using a Rodagon enlarger 1:2.8 with a  $f=50$  mm Rodenstock lens, which resulted in maximum magnifications of 20x. Sixty-two percent of these 248 negatives were of a quality which allowed identification of individuals.

A total of 76 individuals (non-calves) were identified from this procedure, based on fin shape and the shape, number and placement of notches in the dorsal fin (for examples of photographs and markings, see Mandelc & Fairweather, 1995). These 76 dolphins were represented in only 324 out of the total 2,000 frames (16%). Using this catalogue of individuals, the video was viewed again and all sightings of each individual per sighting event were recorded as well as any other identifiable individuals in the same frame. From this, matrices were derived for a) each individual present at any one sighting event and their location and b) the presence or absence of other individuals already represented in the catalogue at any one sighting event. The first matrix allowed movement and occurrence patterns of the identified individuals to be considered. The second matrix suggested possible patterns of association between identified individuals.

## 6.3 Results

Appendix 6 includes the five statistical analyses of data presented in this Chapter (TABLES A6.1 - A6.4). The results are presented in a Summary Table located at the end of the Chapter (see Table 6.10). A line reference using roman numerals is included to assist referral (e.g. Table 6.10-*lii*).

### 6.3.1 Photographic Effort

Photographic effort within Jervis Bay involved photographs taken on 55 out of a total of 104 survey days (53%) and at 75 out of the total of 151 sighting events (50%). However, on only 51 of the 55 photographic surveys were photographs taken that were usable, i.e. photographs of a quality which allowed identification of individuals. Hence, from the 75 sighting events where photographs were taken only 65 (87%) resulted in usable photographs. A total of 69 individually identified dolphins were recorded in the Bay. There were also occasional resightings of individuals within survey days inside the Bay, at different sighting events. These results are included in Table 6.1 which also summarises a number of other factors.

Outside the Bay dolphins were photographed at 10 of the 11 sighting events recorded (1992-93). Only four of these sighting events (40%) resulted in photographs of a quality which allowed the identification of seven individuals.

There were multiple sighting events on 12 survey days (23% of survey days), 11 days with two sighting events and one day with four sighting events photographed. Annual photographic survey effort was only analysed for surveys inside the Bay between 1990 and 1992, due to the limited number of surveys conducted outside the Bay ( $n=9$ ) and in 1993 ( $n=3$ ). Chi-square analysis indicated the annual survey effort, in the Bay, in terms of usable photographic survey days was equally distributed (Table 6.10-*li*). There was also no difference in the distribution of sighting events which allowed individuals to be identified, when this effort was considered (Table 6.10-*lii*). However, the total number of sightings within the Bay

**TABLE 6.1: Summary table of the annual total number of: photographic survey days within Jervis Bay where ‘usable’ photographs were taken; ‘usable’ photographic sighting events (% of usable sighting events where photographs were taken); dolphins recorded on ‘usable’ photographic survey days; sightings of 69 individuals in the Bay per sighting event; identified individuals recorded; and sighting events where resightings of individuals occurred on the same day.**

	Year				
	1990	1991	1992	1993	Total
<b>Total Number</b>					
Usable Survey Days	9	19	21	2	<b>51</b>
Usable Sighting Events (%)	11 (44)	23 (96)	26 (84)	5 (83)	<b>65</b>
Dolphins recorded	125	380	429	37	<b>971</b>
Sightings of identified individuals	53	70	161	25	<b>309</b>
Identified individuals	35	36	48	19	<b>138</b>
Sighting events on the same day where resightings of individuals occurred	1	1	5	3	<b>10</b>

of 69 identifiable dolphins were not equally distributed annually (Table 6.10-iii). While sightings increased each year, in terms of survey effort, the number of sightings were as expected in the first year but lower in 1991 and greater than expected in 1992.

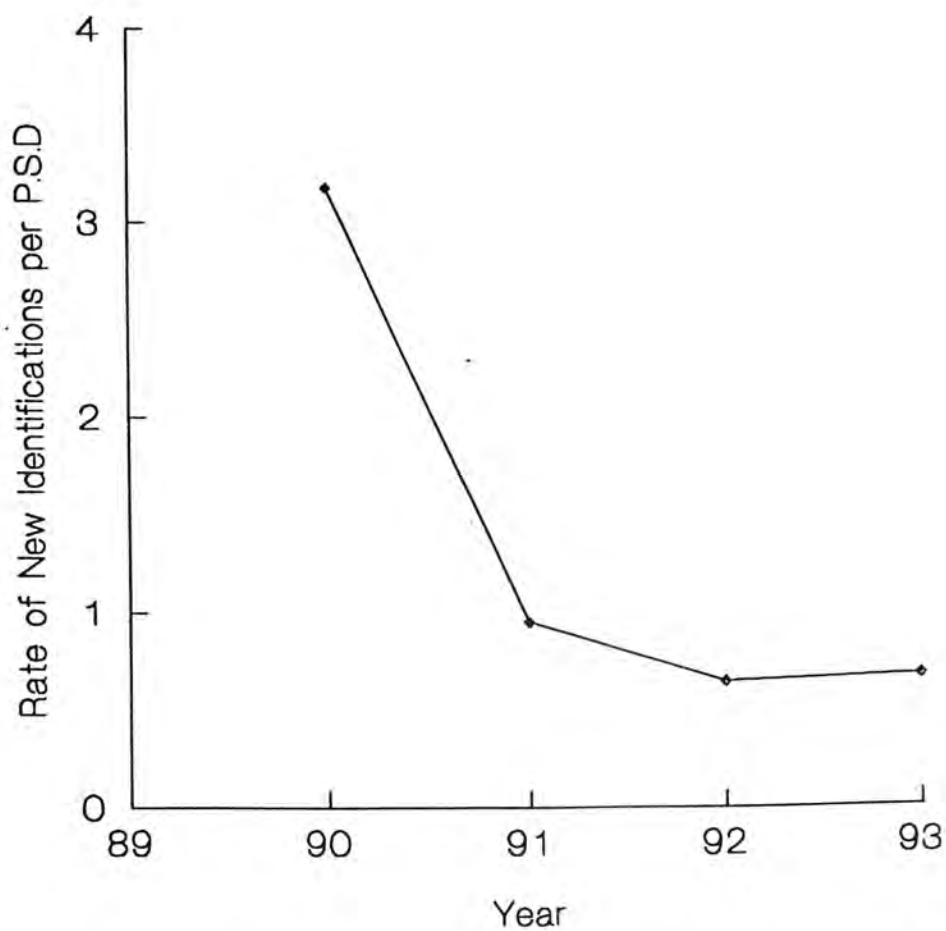
### 6.3.2 New Identifications

Of the total number of 76 individuals identified, 64 were recorded in the Bay only and seven along the coast only. Five probable resightings of animals from the Bay were made along the coast. These five resightings were all made in 1992 and each individual was recorded at only one sighting event. They are referred to as probable resightings because although multiple photographs were taken of these individuals, all were at a distance (it would seem as a result of the volunteer's relative inexperience).

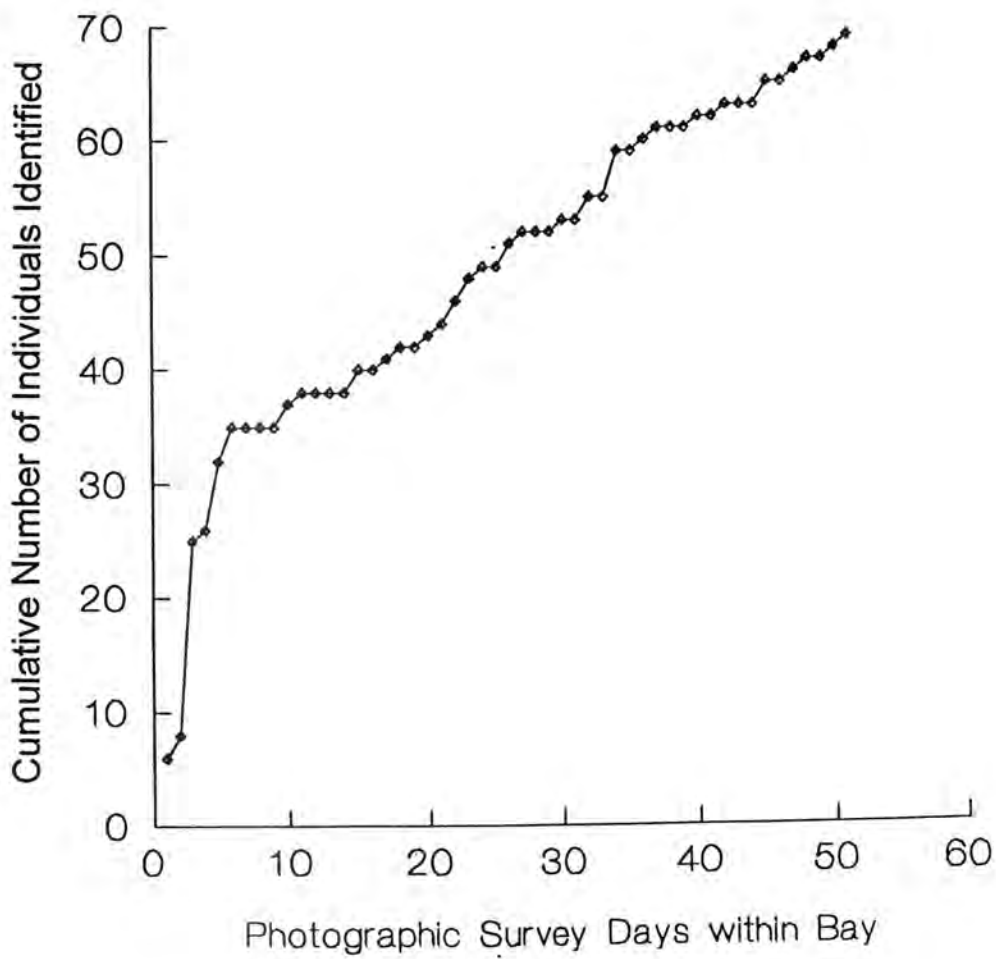
Six of the seven animals only known from outside the Bay were only seen at one sighting event, with one other animal seen twice on the March 1993 Regional Survey (i.e. 20.3.92 & 21.3.92). These animals are not considered in any of the following analyses (i.e. analyses involve only the 69 dolphins recorded from inside Jervis Bay).

The number of new identifications in the Bay decreased annually from 1990 to 1993 (i.e. 35, 18, 14 and two, respectively). The annual discovery rate (i.e. the number of new identifications per survey day/the number of photographic survey days) decreased from 1990 to 1992 with a very slight increase in 1993. However, this latter rate was derived from only three survey days. The greatest rate of discovery was by far in the first year and a flattening out of this curve is apparent (Fig. 6.1).

A cumulative discovery curve (i.e. the number of individuals identified per survey day) shows that 51% of identifications were made on the first six survey days (Fig. 6.2). The remaining 34 individuals were recorded over the subsequent 45 days, at a



**Figure 6.1: Rate of discovery of new sightings annually from 1990-1993 where the rate of identification is equivalent to the number of new identifications per photographic survey day per year, i.e. new ID/P.S.D/yr.**



**Figure 6.2: Discovery curve for the 69 individually identified dolphins in Jervis Bay.**

fairly constant rate of three new identifications every four survey days that photographs were taken. No leveling off of this discovery curve was apparent which suggests more new identifications would occur with any extra effort. Thus, the 69 individuals identified represent a bare minimum estimate of the number of animals using the Bay.

### **6.3.3 Seasonality of occurrence of Identified Individuals within Jervis Bay**

As only two surveys with usable photographs were conducted in 1993 (Table 6.2), these data were excluded from the following analyses. Survey effort was not equally distributed across seasons in 1990-92 (Table 6.10-li) with significantly more surveys conducted in autumn and fewer in all other seasons. The number of sightings of 67 identified dolphins at different sighting events during each season, over the three years from April 1990-92 showed a marked peak in autumn 1992, with lesser peaks in summer 1992 and winter 1991& 1990 (Table 6.3). When the expected number of identified dolphins sighted across seasons was adjusted for the differences in survey effort, there remained a significant difference in their seasonal distribution (Table 6.10-lii). The greatest number of identified dolphins were sighted in autumn in the Bay, although this was less than expected on the basis of survey effort. However, the second highest number of identified dolphins were sighted in winter and this was significantly more than expected on the basis of survey effort.

### **6.3.4 Resightings within Jervis Bay**

Of the 69 individuals recorded from the Bay, 19 (28%) were sighted once in the Bay while 50 (72%) were resighted two or more times. The number of days on which an individual dolphin was sighted varied from one to 15 (Fig. 6.3). There were approximately 26%, 39% and 7% of individual dolphins sighted on two to three, four to nine and more than nine (i.e. 9-15) days, respectively.

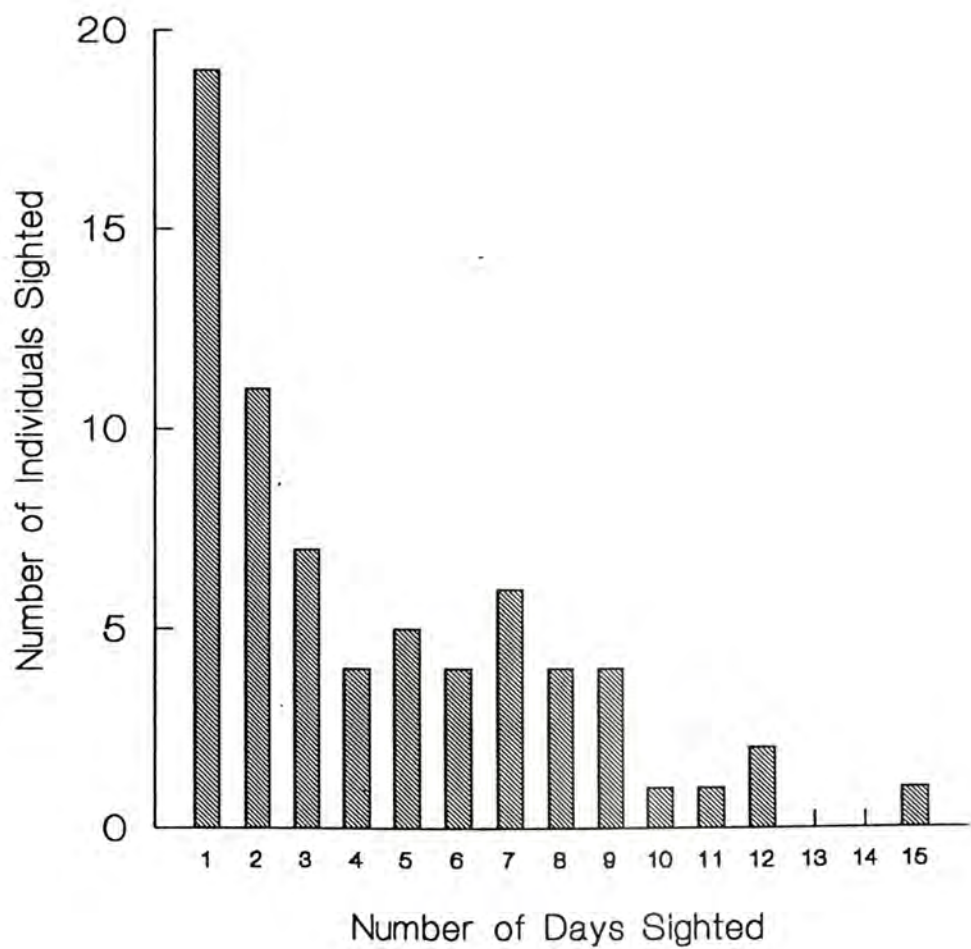
As a dolphin identified later in the survey period cannot be resighted as often as

**TABLE 6.2: Distribution across seasons per year of the total number of photographic surveys on which usable photographs were taken, where zero indicates no usable surveys were conducted.**

Year	Season				Total
	AUT	WIN	SPR	SUM	
1990	1	2	2	4	9
1991	8	6	5	0	19
1992	12	1	2	6	21
1993	2	0	0	0	2
Total	23	9	9	10	51

**TABLE 6.3: The total number of sightings of 67 identified dolphins across seasons, in the Bay between 1990-92, where zero indicates no usable photographic surveys were conducted.**

Year	Season				Total
	AUT	WIN	SPR	SUM	
1990	6	26	9	12	53
1991	24	30	16	0	70
1992	86	17	19	39	161
Total	116	73	44	51	284

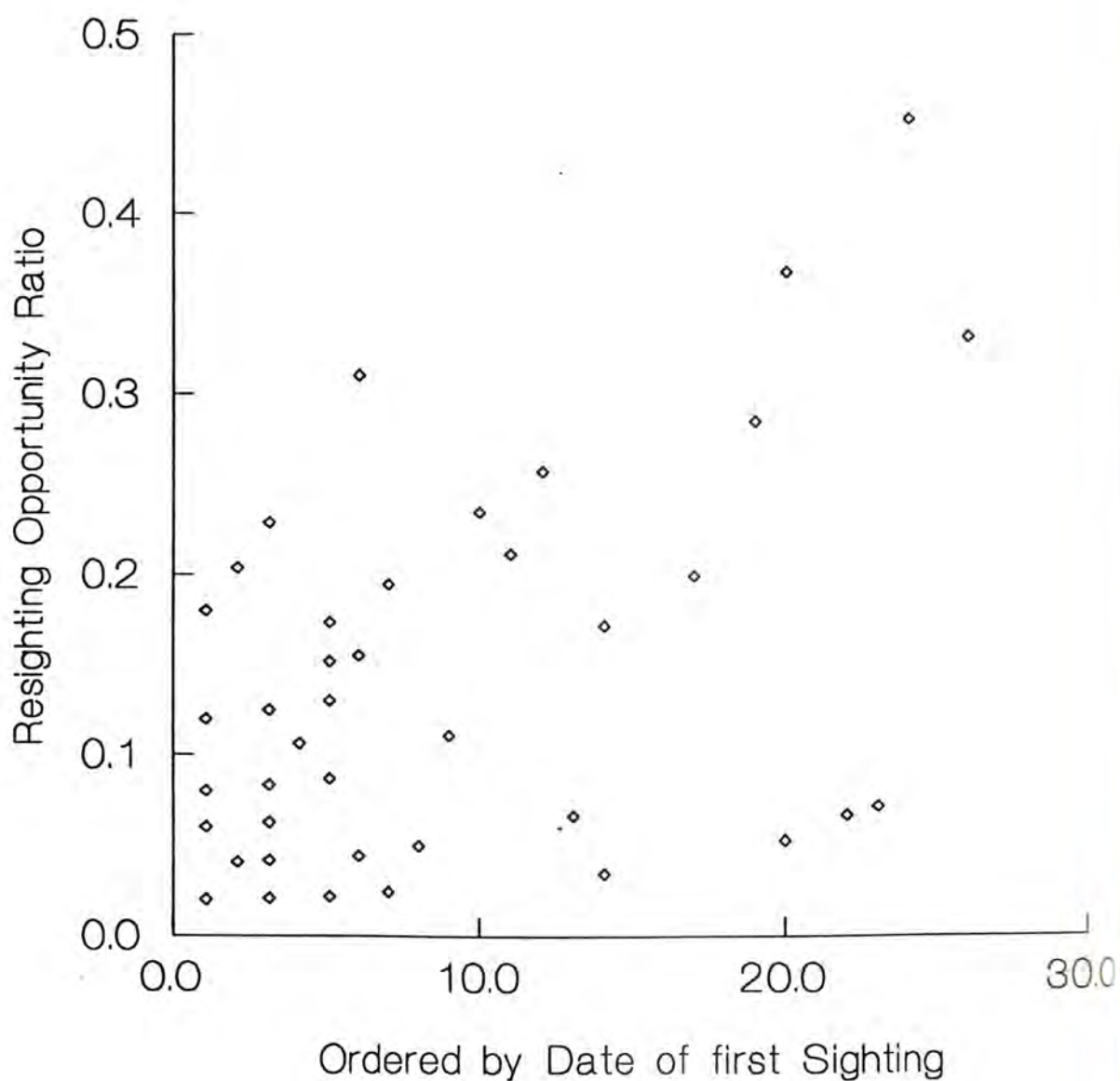


**Figure 6.3: The number of days 69 individually identified dolphins were sighted in Jervis Bay.**

one identified earlier, it is important to consider the above results in conjunction with, the “opportunity” for resighting, i.e. the number of days after initial identification that photographic surveys were conducted. Hence, I divided the number of resightings by the days upon which resightings were possible. This “resighting opportunity ratio” (ROR) for the 50 individuals sighted on more than one day within the Bay ranges between 0.02 and 0.454. Individual #62 which had the minimum ROR was sighted on the first survey and once again in 1990 but not thereafter. Individual #8 had the highest ROR and was first identified in the middle of 1992 (i.e. late in the survey period) and resighted on five of the remaining 11 survey days. Ten individuals sighted for the first time on the same day had the same ROR as another individual on that day. Figure 6.4 plots the RORs by date of the first sighting of individuals,  $n=40$ .

Hence when the opportunity for resightings is considered, nine individuals had ratios  $\geq 0.227$ , i.e. were resighted relatively consistently after their initial identification. Four of these individuals were first sighted in 1992, that is in the latter half of the survey when 45% of ‘usable’ photographic surveys were conducted. The remaining (82%) individuals displayed either sparse resightings over the survey period or a low total number of resightings. This overview of the data gives no indication of the duration of stay of these individuals in the Bay nor their frequency of movement into and out of the Bay. On the 12 days when multiple sighting events ( $n=26$ ) were photographed, the same individuals were resighted at 10 sighting events (38%). Hence, while only a small number of individuals and resightings of these individuals occurred, this indicates some individuals, and possibly groups, were resighted on the same day during this study (see Table 6.1).

In 1990, 35 individuals were identified in the Bay. In 1991, a total of 36 individuals were positively identified, 18 of which were resightings from 1990, i.e. 51% of previously identified animals were resighted. In 1992, a total of 48 individuals were positively identified, 34 of which were resightings from at least one of the two years previous, i.e. 64% of identified animals were resighted. On



**Figure 6.4:** The “resighting opportunity ratio” (ROR) for identified dolphins sorted chronologically (i.e. by date of first sighting). Where ROR is equivalent to the number of resightings subsequent to initial identification of an individual per the number of survey days remaining ( $n=40$ ).

three days in April 1993, a total of 19 individuals were positively identified, 17 of which were resightings from at least one of the previous three years, i.e. 25% of identified animals were resighted even with very limited effort. Table 6.4 indicates the number and year individual dolphins were first identified and resighted.

Five individuals were photographed in all four years of the photographic survey. Another 18 were photographed in three years of the survey. That is, approximately 33% of the 69 individuals identified, at least used the Bay annually over a three year period between 1990 and 1993. Table 6.5 indicates the number of identified individuals sighted on more than one occasion in the Bay ( $n=50$ ), across the years they were resighted.

### **6.3.5 "Residency Status" of Identified Individuals within Jervis Bay**

Ballance (1990) described the residency status of known individuals in her study area by: the number of resightings of identified individuals; the time between the first sighting and last resighting of each dolphin; and the average number of days between adjacent sightings for an individual. Data for the first of these three parameters has been presented above as well as the ROR, the latter two are described below.

The surveys on which photographs were taken during this study spanned a period of 1,073 days. The time interval between the first and last sighting of any one dolphin (i.e. for individuals sighted on more than one occasion on separate days,  $n=50$ ) ranged from 30 to 1,073 days with the average time between first and last sighting of approximately 551 days (S.D. 294), i.e. 18 months (Fig. 6.5). There is little that can be deduced from this information directly, but the frequency distribution of the number of days between the first and last sightings of individuals, in classes of 30 days, indicates a mode between 630 and 660 days which contrasts with a lesser mode at 30 to 60 days (Fig. 6.6). As previously indicated annual photographic survey effort in the Bay from 1990-93 was evenly distributed (see Table 6.2). There is also no apparent trend in the number of

**TABLE 6.4: The number and year individual dolphins were first identified and the year they were first resighted. Where - indicates no resightings possible.**

	Year first Identified				Total
	1990	1991	1992	1993	
Sighted once only	4	6	7	2	19
Year of first Resighting					
1990	4	-	-	-	4
1991	18	2	-	-	20
1992	9	10	3	-	22
1993	0	0	4	-	4
Total number of new identifications	35	18	14	2	69

**TABLE 6.5: The number of identified individuals resighted across the years of the Survey (i.e. individuals sighted on more than one occasion in the Bay,  $n=50$ ). Where - indicates no resightings possible.**

	Year(s) of Resightings								Total
	1990	1991	1992	1993	91 & 92	92 & 93	91 & 93	91, 92 & 93	
Within year only	4	2	3	0	-	-	-	-	9
Year first identified									
1990	-	2	8	0	10	1	1	5	27
1991	-	-	4	0	-	6	-	-	10
1992	-	-	-	4	-	-	-	-	4
Total	4	4	15	4	10	7	1	5	50

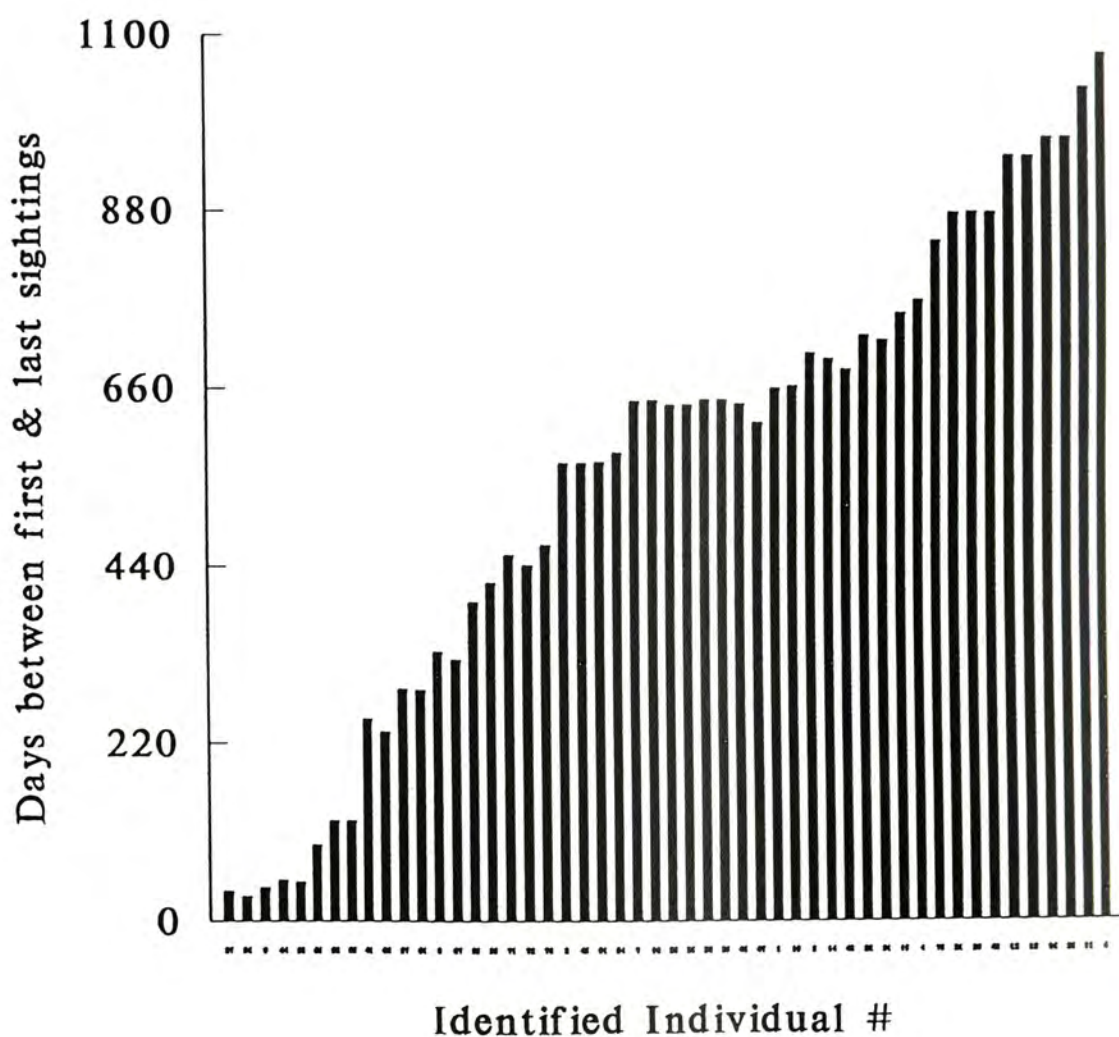
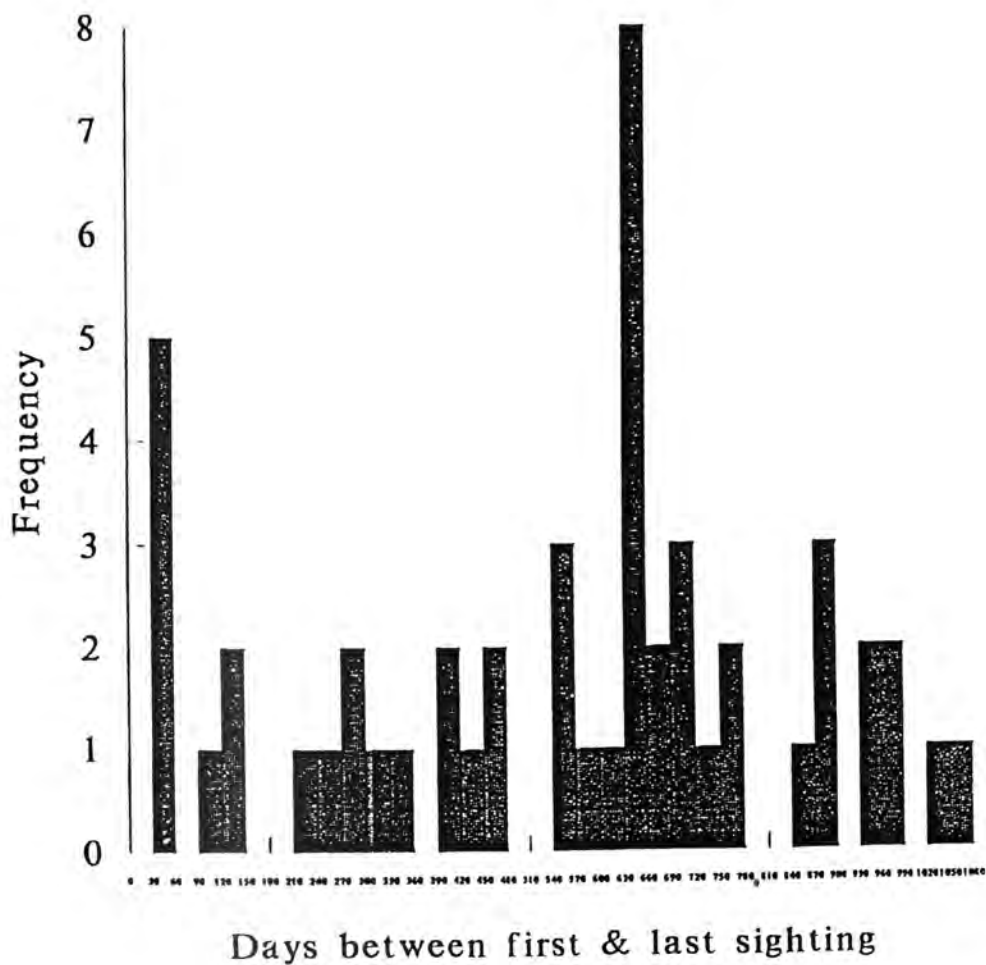


Figure 6.5: The number of days between the first and last sightings of the 50 individuals sighted on more than one occasion, on separate days in the Bay.



**Figure 6.6: The frequency distribution of the number of days between the first and last sightings, in classes of 30 days, of 50 identified dolphins resighted at least once in the Bay.**

surveys per month or between months over the total 32 month period, other than a peak in May 1992 (Fig. 6.7). However, to reduce any bias associated with the reduced opportunity for resightings of individuals identified late in the survey period, individuals first sighted on the first half of the photographic surveys only were also considered (Fig. 6.8). These data also indicate a mode between 630 and 660 days. Hence, the data suggest individuals display different temporal patterns of use of the Bay which may reflect differences in the duration of stay or frequency of movement in and out of the Bay. The mode between 630-660 days suggests some individuals (16%) did spend relatively long periods in the Bay or at least moved in and out of the Bay fairly frequently over the three years most photographs were taken. While no mode between 30 to 60 days was evident when the opportunity for resighting was considered (see Fig 6.8), it is apparent some individuals spent a relatively shorter period of time in the Bay or if they did not remain for these periods may have moved in and out of the Bay fairly intensively over one to two months, during this study.

The average number of days between sightings for each identified dolphin was determined by dividing the time between first and last sightings of an individual by the total number of sightings of each individual and ranged between 10 and 319 days with a mean of 107 days (S.D. 67.3), i.e. three to four months (Fig 6.9). The frequency distribution of this data when divided into 30 day classes indicated a peak at two to three months. That is, 54% of individuals were resighted on multiple occasions within three month periods (Fig 6.10). The average number of days between sightings for another 24% was four to five months and for the remaining 22%, six to 11 months. These trends are not reflected in monthly photographic survey effort (see Fig 6.7).

Because of the sparseness of photographic survey effort, it was considered useful to investigate the distribution of sightings of identified individuals on consecutive surveys, even though the time span between such ranged between one and 179

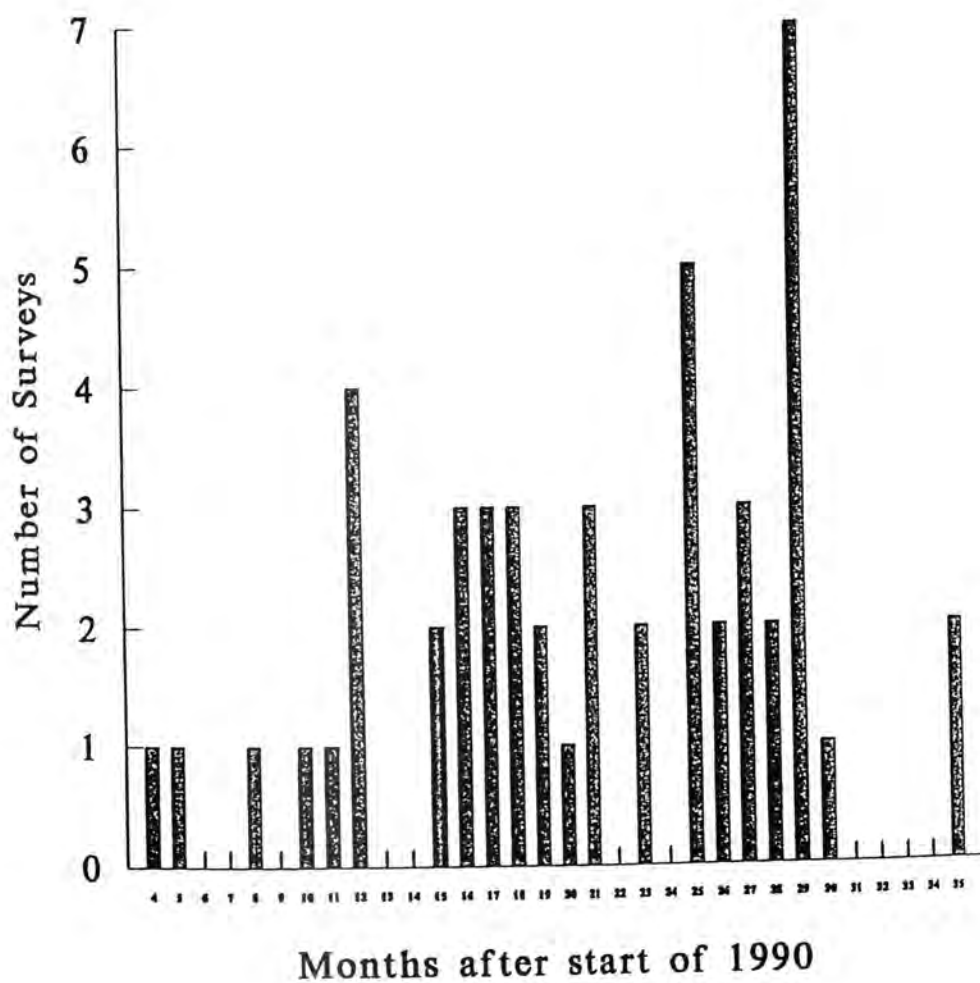


Figure 6.7: The number of usable photographic surveys per month conducted within Jervis Bay across a 32 month period commencing in April, 1990 until November 1992.

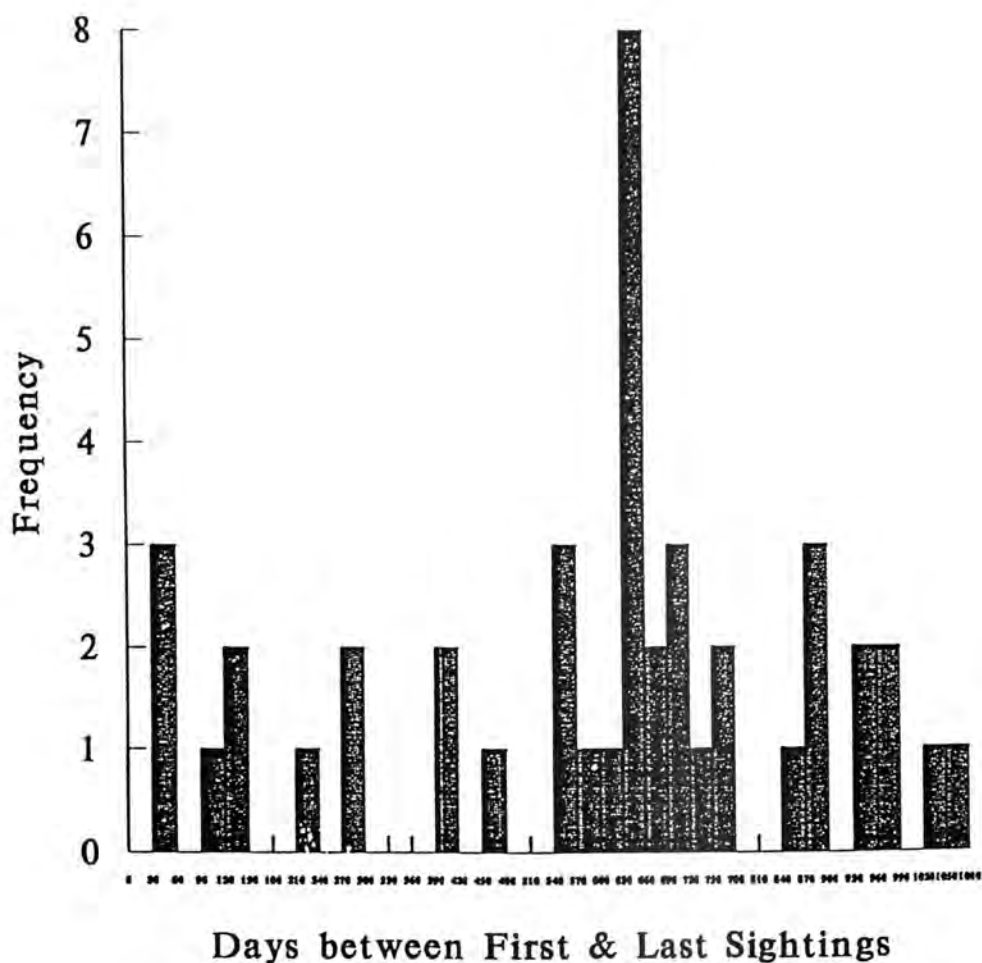


Figure 6.8: The frequency distribution of the number of days between the first and last sightings, in classes of 30 days, of 43 identified dolphins first sighted on the first half of photographic surveys in the Bay.

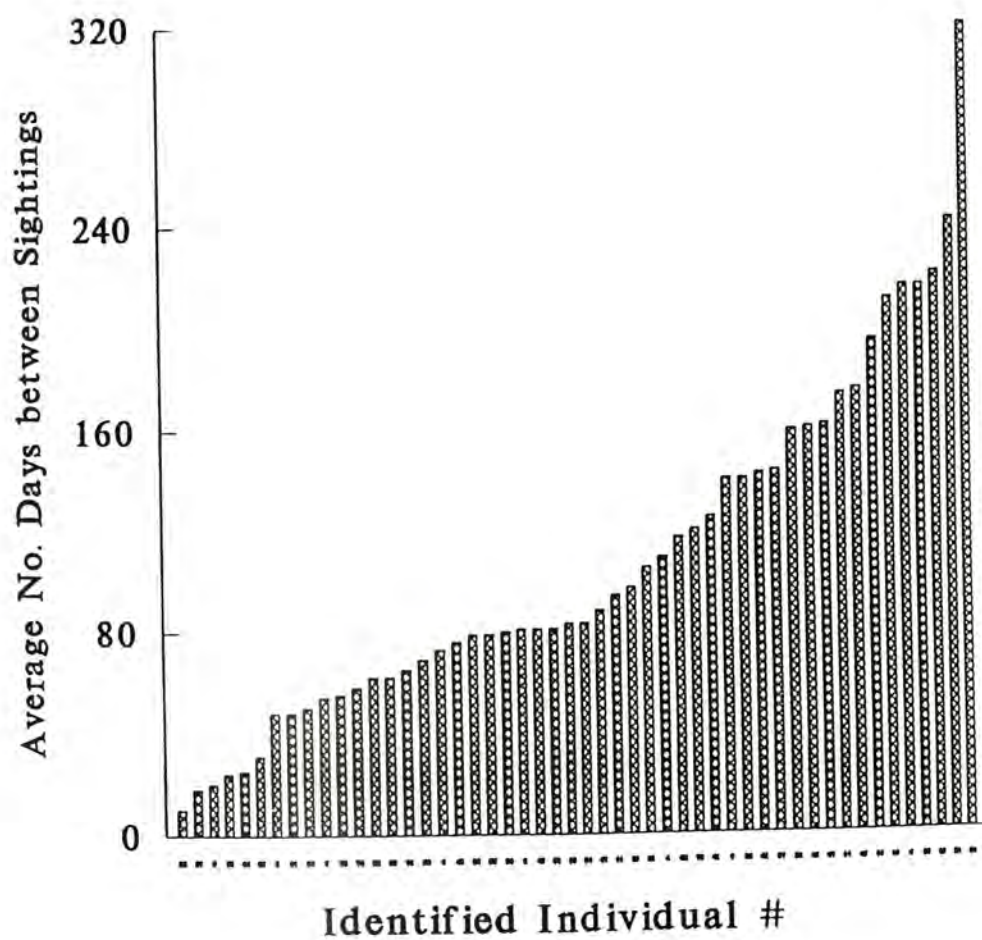
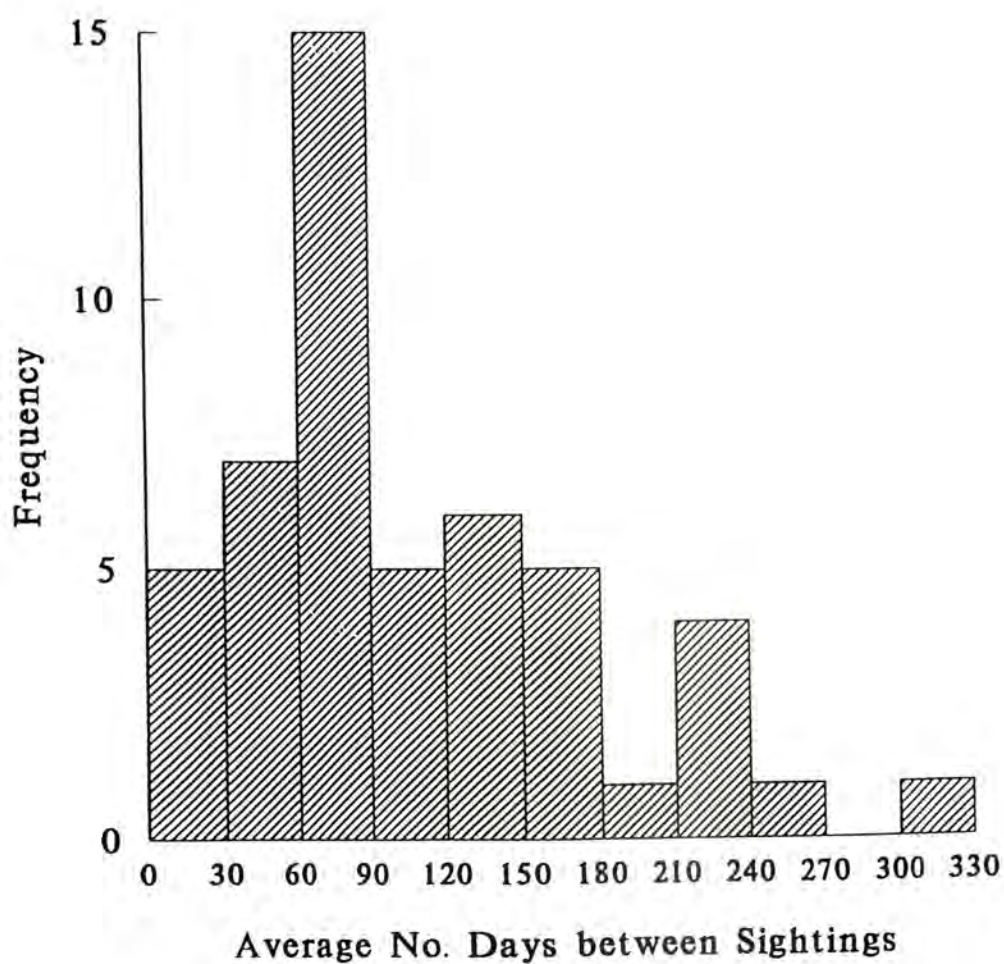


Figure 6.9: The average number of days between sightings, i.e. where time between first and last sightings was divided by the total number of sightings of each individual ( $n=50$ ).



**Figure 6.10:** The frequency distribution of the average number of days between sightings in classes of 30 days, of 50 identified dolphins in the Bay.

days. Twenty-five (50%) individuals were recorded on consecutive photographic surveys. The minimum and maximum number of successive consecutive surveys for which any one dolphin was sighted ranged between two and four. The number of days between the first and last sightings on these consecutive surveys for individuals ranged between one and 180, with a mean of 31 days (lower than 107 days reported above for all surveys) and a median of 4-5 days (see Table 6.6). Three individuals were seen on two consecutive surveys on more than one occasion (ID#7, 70 and 72) and these surveys ranged between one and 10 days apart. A further six individuals were seen at more than two consecutive surveys, i.e. on either three or four consecutive surveys (ID#2, 10, 11, 12, 28 and 31). The maximum time between the first and last sightings of an individual across these consecutive surveys was 180 days for ID#28, sighted on the last day of the main sampling period and then on the next Regional Survey six months later. This individual was the exception, however, with the maximum time between the first and last sightings being 88 days for the five other individuals across these consecutive surveys. That is, when individuals ( $n=8$ ) were sighted on two or more consecutive surveys or on two consecutive surveys on more than one occasion, these surveys tended to be close together (i.e. the mean number of days between consecutive surveys for these individuals was five to six days). Hence the above data are limited in their use for highlighting an individual's possible residency status in the Bay for periods beyond five or six days.

Ultimately, because of the sparseness of the photographic surveys, it is impossible to establish if and when animals left the Bay between sightings and for how long. Effectively, an individual's residency status is only relative to other identified individuals' residency status in this study, based on comparisons between a number of parameters. The parameters investigated in this study included: the frequency of sightings; opportunity for sightings; the number of days between first and last sightings; the average number of days between sightings; the number of years sighted; the number of consecutive surveys on which an individual was sighted and the average number of days between consecutive survey sightings. Table 6.6 tabulates these results for the 50 dolphins sighted more than once in the

**TABLE 6.6: Summary of aspects of an individual's 'residency status' in Jervis Bay (excluding all individuals only sighted once). ROR is an abbreviation for 'resighting opportunity ratio' and - denotes not possible.**

Residency Status	Dolphin ID NO	Number of Sightings on different days	ROR	Number of Days between 1st & last Sighting	Average number of days between Sightings	Year(s) Sighted	Number of Consecutive Surveys Sighted (year)	Average number of days between consecutive Sightings
High	31	15	0.311	717	48	90-91-92	3 (1992)	12
	7	9	0.258	643	54	91-92-93	2 (1991)	10
							2 (1992)	2
	8	6	0.454	333	48	92 & 93	2 (1992)	179
	28	12	0.229	968	69	90-91-92	2 (1992)	1
						& 93	3 (1992)	180
	48	9	0.235	681	76	91-92-93	2 (1992)	1
	71	7	0.286	454	65	90-92-93	0	0
	72	8	0.386	441	55	91-92-93	2 (1992)	4
							2 (1992)	1
							2 (1992)	1
	10	12	0.229	644	50	90-91-92	3 (1990-91)	88
	11	11	0.204	1030	94	90-91-92	3 (1992)	5
						& 93	2 (1992)	1
	1	8	0.212	658	73	91-92-93	2 (1993)	1

TABLE 6.6 contd.

Residency Status	Dolphin ID NO	Number of Sightings on different days	ROR	Number of Days between 1st & last Sighting	Average number of days between Sightings	Year(s) Sighted	Number of Consecutive Surveys Sighted (year)	Average number of days between consecutive Sightings
Medium	12	10	0.18	946	79	90 & 92	4 (1992) 2 (1992)	17 1
	29	9	0.174	876	97	90-91-92 & 93	2 (1991)	19
	21	8	0.152	875	109	90-91-92 & 93	2 (1992)	2
	47	6	0.172	616	88	91 & 92	2 (1992)	8
	70	8	0.156	466	58	91-92-93	2 (1991) 2 (1992)	1 1
	15	9	0.195	750	83	91-92-93	2 (1992)	1
	4	7	0.12	766	109	90-91-92	2 (1990)	43
	30	7	0.125	644	80	90 & 92	2 (1992)	1
	51	7	0.13	569	81	90-91-92	2 (1990)	32
	2	7	0.125	568	81	90-91-92	3 (1992)	42
	73	7	0.125	840	120	90-91-92	0	0

TABLE 6.6 contd.

Residency Status	Dolphin ID NO	Number of Sightings on different days	ROR	Number of Days between 1st & last Sighting	Average number of days between Sightings	Year(s) Sighted	Number of Consecutive Surveys Sighted (year)	Average number of days between consecutive Sightings
Low	67	3	0.334	323	161	90-91-92	0	0
	3	5	0.111	701	140	91-92-93	2 (1992-93)	126
	53	5	0.111	395	79	91 & 92	0	0
	54	6	0.106	580	83	90-91-92	0	0
	33	3	0.05	419	140	91 & 92	0	0
	57	2	0.021	287	143	90 & 91	0	0
	6	5	0.08	1073	215	90-92-93	2 (1992)	5
	9	2	0.053	41	20	92	0	0
	13	4	0.06	945	236	90-91-92	0	0
	14	4	0.06	694	173	90 & 92	0	0
	16	5	0.083	968	194	90-91-93	0	0
	19	3	0.042	661	220	90 & 92	0	0
	20	2	0.021	638	319	90 & 92	0	0
	22	3	0.041	723	241	90-91-92	0	0
	26	4	0.062	638	159	90 & 92	2 (1990)	112
	27	2	0.022	37	18	92	0	0
	33	3	0.05	419	140	91 & 92	0	0
	39	3	0.042	644	215	90 & 92	0	0

TABLE 6.6 contd.

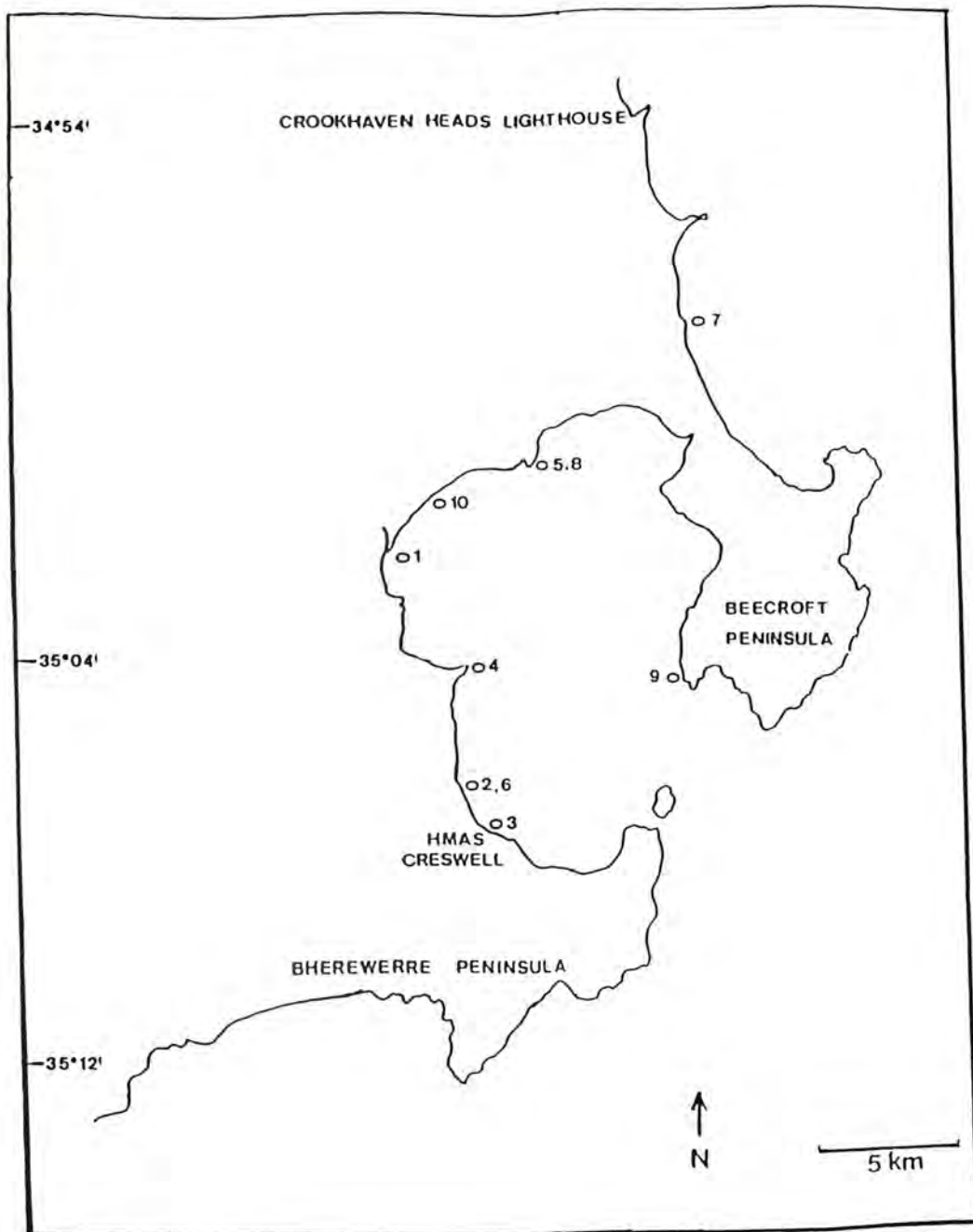
Residency Status	Dolphin ID NO	Number of Sightings on different days	ROR	Number of Days between 1st & last Sighting	Average number of days between Sightings	Year(s) Sighted	Number of Consecutive Surveys Sighted (year)	Average number of days between consecutive Sightings
Low contd.								
	41	2	0.071	250	125	92	0	0
	43	5	0.087	875	175	90-91-92-93	0	0
	44	2	0.067	50	25	92	0	0
	46	4	0.062	639	160	90 & 92	2 (1992)	1
	52	2	0.021	124	62	90	0	0
	56	3	0.067	30	10	91	2 (1991)	2
	58	2	0.024	48	24	91	0	0
	61	2	0.034	285	142	91 & 92	0	0
	62	2	0.02	234	117	90	0	0
	63	2	0.021	124	62	90	0	0
	65	3	0.045	94	31	90 & 91	2 (1990-91)	87

Bay. On the basis of these data individuals are allocated a high, medium or low residency status. Twenty percent of these dolphins have a relatively high residency status involving typically: a high ROR, between six and 15 sightings occurring relatively frequently (i.e a lower mean number of days between sightings) over an extended period, and over at least two years. A further 22% were allocated a medium residency status, i.e typically a lower ROR, between six and 10 sightings occurring less regularly (i.e. greater mean number of days between sightings) over an extended period, and over at least two years. The remaining individuals (58%) were considered to have a relatively lower residency status, i.e typically a low ROR, between 2 and 6 sightings but infrequently (i.e higher mean number of days between sightings) over a relatively short period, and sightings ranging from within one year to four years. The importance of considering all these variables in determining the residency status of an individual, and not just one or two, are discussed in Section 6.4.2.

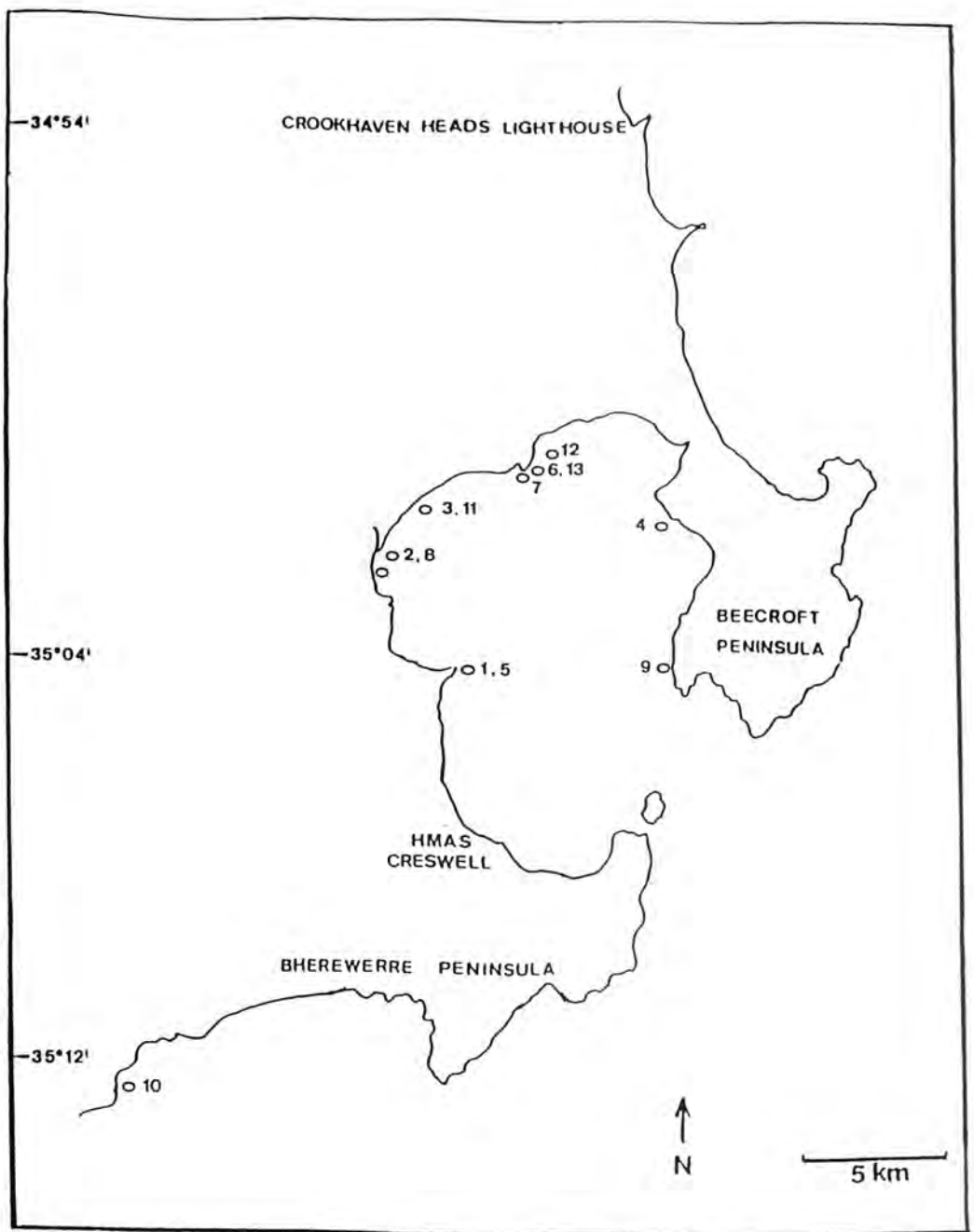
### **6.3.6 Movement patterns of Identified Individuals**

All of the identified individuals in this study are regarded as members of the same population, i.e. "...dolphins that inhabit the study area at any time during the year, ...are considered to constitute a breeding unit but not necessarily represent the entire breeding stock..." after Shane (1987). This hypothesis is supported by the probable resighting of five animals recorded from inside the Bay along the open coast to the north or south. However none of these five individuals nor the seven dolphins only recorded outside the Bay were seen along both the north and south coasts.

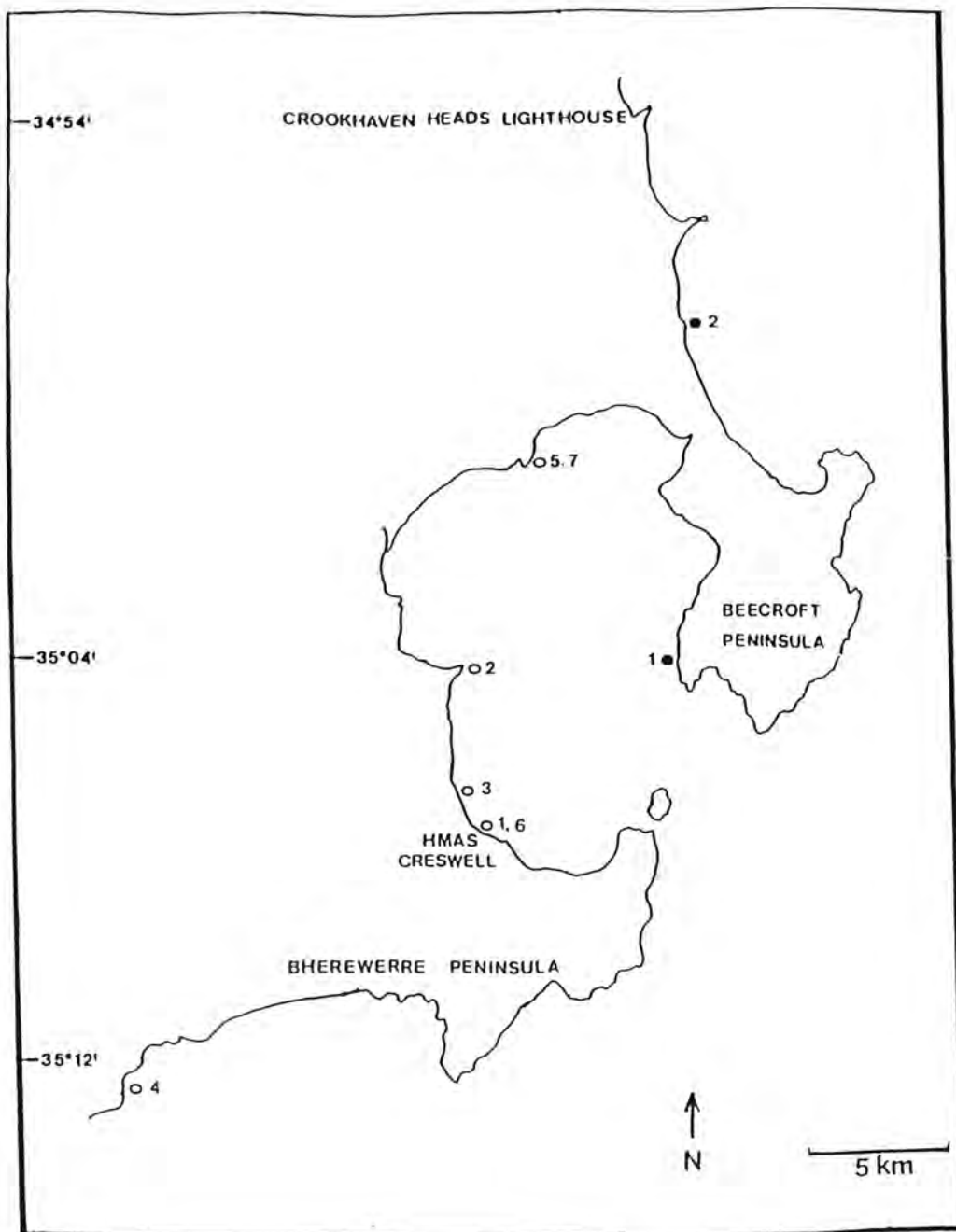
Maps of the regional study area which identify the location of all sightings involving five identified dolphins which were resighted at least once outside the Bay, are presented in Figures 6.11-6.14. One of the five animals that were probable resights outside the Bay was first seen very near the entrance and then 100 days later outside the Bay (ID#18). The other four dolphins (ID#1, 10, 47 and 73) were



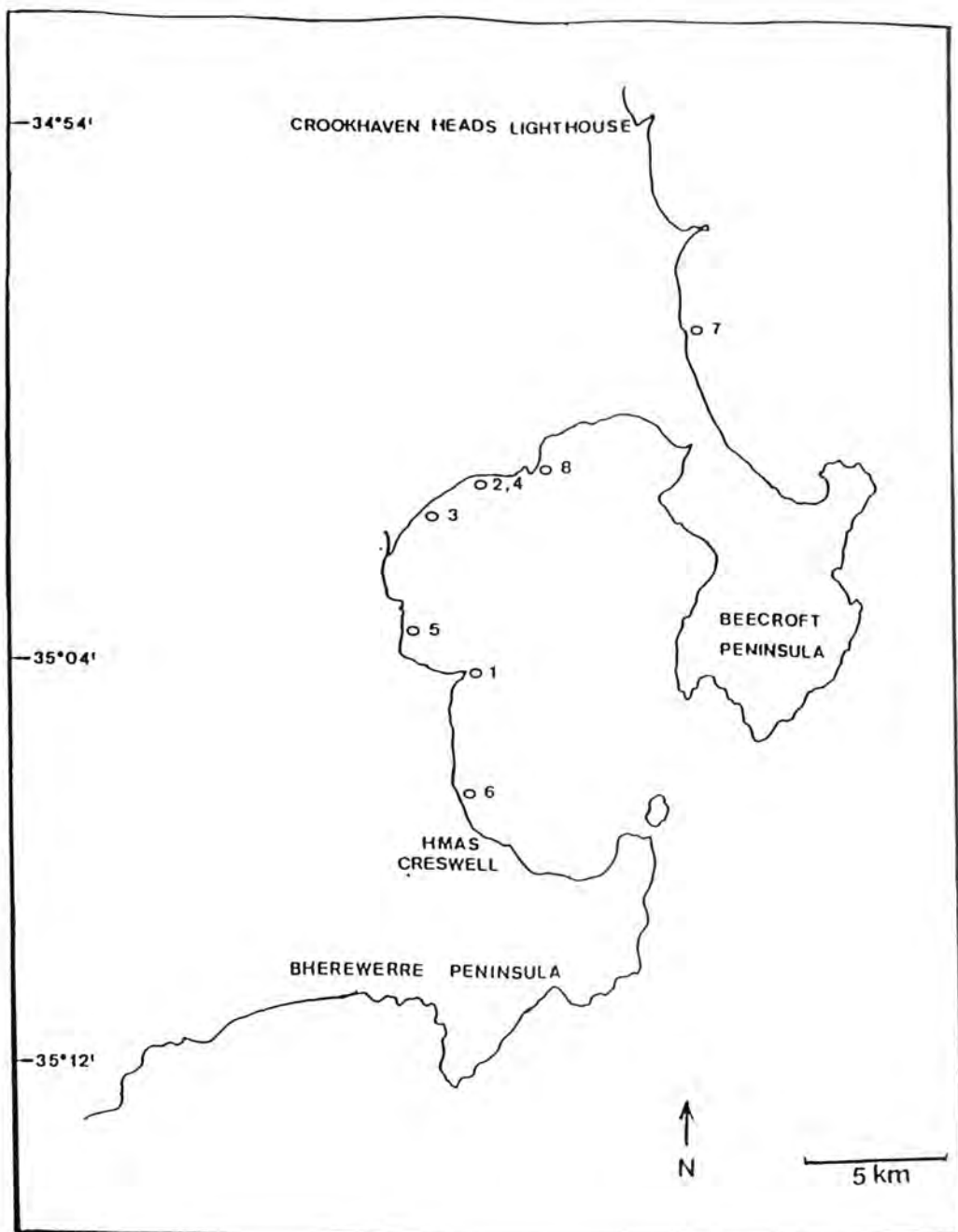
**Figure 6.11: Map of regional study area, indicating the location of sightings of identified individual #1 and probable resighting outside the Bay, from 1991-1993. The location of sightings are indicated by a circle which are numbered in sighting sequence.**



**Figure 6.12: Map of regional study area, indicating the location of sightings of identified individual #10 and probable resighting outside the Bay, from 1990-1992. The location of sightings are indicated by a circle which are numbered in sighting sequence.**



**Figure 6.13: Map of regional study area, indicating the locations of sightings of identified individuals #18 (1992 only) and #47 and probable resightings outside the Bay, from 1991-1992. The location of sightings of #18 are indicated by a solid circle which are numbered in sighting sequence. The location of sightings of #47 are indicated by an open circle which are numbered in sighting sequence.**



**Figure 6.14: Map of regional study area, indicating the location of sightings of identified individual #73 and probable resighting outside the Bay, from 1990-1992. The location of sightings are indicated by a circle which are numbered in sighting sequence.**

approximately one every nine days. None of these individuals were seen on the last seen in the Bay at multiple sighting events, on more than one survey day and over multiple years. The number of days between the last sighting in the Bay and the resighting outside for these four dolphins ranged between 20 and 58 days.

Photographic survey effort for the 79 days immediately prior to the Regional Survey in March 1992, when these sightings were made outside the Bay, averaged survey in the Bay, four days prior to the last Regional Survey nor on the three Bay legs of that Regional Survey. The number of days between sightings outside and the resighting in the Bay, ranged between 54 and 387 days. Survey effort following the March Regional Survey mirrored that prior to the Regional Survey. My standard surveys recommenced 18 days after the Regional Survey with an average of one survey conducted a week for the next 69 days. The differences in duration between these two intervals (i.e. prior to the sighting outside the Bay, and the resighting in the Bay) may approximate the real pattern of movement in and out of the Bay for these four individuals. Furthermore, these data suggest, as described in Section 6.3.5, that the duration of time spent in and out of the Bay is highly variable between individuals. In this instance, three animals (ID#10, 47 and 73) were resighted in the Bay within three months but ID#1 was not photographed again for over a year.

Only two females (#12 & #15) with calves, assumed to be the mother because of the small size and proximity of the calf, were able to be identified from photographs. ID#12 was first photographed on 27.4.90 and again on the 10.8.90 without a calf. She was not resighted until the 22.3.92 when she was accompanied by a small calf. She and the calf were then resighted on 7 separate sighting events over the next 71 days. The next survey did not take place until 179 days later when this animal was resighted with her calf. The last series of surveys commenced 126 days later in April, 1993 when the animal was not seen. I suggest this animal left the Bay in late 1990 and, while she may have frequented the Bay briefly (i.e. less than 10 day periods) during 1991, did not stay in the Bay for longer until 1992. Although it is always possible she was in the Bay but not sighted. When resighted in 1992 the size of her calf suggested she may have returned soon after calving or

indeed to give birth. This animal proceeded to remain in the Bay for the remainder of 1992, at least.

The second identifiable mother #15 was first photographed on the 16.3.91 with a calf approximately 1.3 m in length and estimated to be approximately one year old. They were recorded together on 3 out of the 8 subsequent sightings over the following 14 months. On the five occasions she and the calf were not photographed together, the calf may have been: beside her but not captured on film; a short distance from the mother but effectively in the same area as her; or being "baby-sat" elsewhere (Shane, 1987). This female was then not seen for almost a year when she was sighted on the 4.4.93 without her calf. There were a further four separate sightings of adults with calves which could not be identified, two in summer and one each in autumn and winter.

While there is no strong seasonal pattern suggested by photographs of mother and calves in the Bay (other than the return of the individual #12) there is some suggestion of habitat preference. Both sightings of #12 without a calf in 1990 were in the southern half of the Bay. In the three month period following her resighting with a calf, eight out of nine sightings were in the northern half of the Bay and five of these were in an area of only approximately 4 sq. km. The exception was the second sighting on one day in the SW of the Bay, which indicates she ranged throughout the Bay, possibly on a daily basis. The area where she appeared to spend more time was over a seagrass meadow and an adjacent rock platform (i.e. Hare Bay & Callala Pt), both the largest in the Bay. The last sighting of this mother and calf sometime later was again in the identified area.

On three out of the four occasions #15 was sighted with a calf, it was in the same area described for #12. Between these photographs with her calf, there were five other sightings of this adult, one of which was in the area previously described and the other four along the north and southwestern shorelines. When she was resighted almost a year later without her calf she was in the NW quadrant. Four sightings were made of unidentified females with calves, two in Hare Bay and the

others at Plantation Pt and Scottish Rocks in the SE. See Figure 2.2 for the location of all sites referred to in this Section. Hence, all four sightings were over seagrass or rocky outcrops adjacent to patches of seagrass. See Figure 2.3 for a map of the three main substrata throughout the Bay.

Of the 19 animals for which only one sighting was made, 53% were recorded at either Plantation (8) or Callala (2) Points. The remainder were all at separate sites around the periphery of the whole Bay (i.e. spread across all arbitrary quadrants of the Bay, see Section 3.2.1). Four of these animals were sighted in 1990 and not photographed again (although I have a record of one of these individuals from 1988, before this study formally began). Another six animals were recorded in 1991, seven in 1992 and two in 1993.

For the remaining 50 individuals sighted in the Bay on more than one occasion, their movement patterns are as follows. For the 11 animals photographed on only two occasions, none were rephotographed at the same site. Six individuals were sighted at Plantation Point on one of these sighting events (55%) while the remainder of sites were only represented once or twice. In terms of the distribution of sightings around the whole Bay, two individuals were resighted in the same quadrant (NW) and one in the NE. All other sightings were spread across different quadrants. Eight of these individuals were recorded in the same year (three in 1990; one in 1991; and four in 1992), while two were recorded in 1991 & 92, one in 1990 & 91 and one in 1990 & 92.

For the seven individuals that were photographed on three occasions, none were resighted at the same site, and only one individual was sighted in a single quadrant (NW) only and this was in two separate years. One individual was sighted in only one year but in two different quadrants. The remaining five individuals were sighted across at least two years and two quadrants.

Of the four individuals identified from photographs on four occasions, none were recorded at the same site and one dolphin was seen in all four quadrants (ID#13).

However, four of the five individuals sighted on five occasions were seen 2 or 3 times at the same site with one individual also seen in all four quadrants (ID#43). Of the remaining 23 animals sighted on 6 to 15 occasions, 21 were sighted at least twice at the same site and 10 were resighted at multiple sites. Ten individuals, sighted on 7 to 15 occasions, were seen in all four quadrants. Generally, increased sightings of an individual meant greater repetition at particular sites as well as a wider distribution around the Bay. However, estimated home range data suggest that after nine sightings, for this data set, the size of an individual's home range in the Bay is not likely to increase significantly (see Section 6.3.7).

Animals were photographed at 24 sites around the Bay. Of the 309 photographed sightings of the 69 identified individuals in the Bay the highest number of sightings were made at Plantation (48) and Callala (44) Points, representing almost 30% of all sightings (Table 6.8). The next most utilised sites were Huskisson Reef (28), Callala Bay (26), Red Point (23) and the middle of Callala Beach (22), representing a further 32% of all sighting incidences. In summary, 62% of sightings of identified individuals were recorded at only six of the 24 known sites (25%) where dolphins were sighted in the Bay.

Figure 2.2 indicates the lines of latitude and longitude which delineate the quadrants of the Bay used throughout this thesis. On the basis of these arbitrary divisions 74% of sightings of individuals were located off the western shore and 67% of sightings of identified individuals were in the northern half of the Bay.

### **6.3.7 Provisional “home range” estimates of 14 Identified Individuals within Jervis Bay**

The opportunistic nature of the photographic effort in this study and the resulting sparseness of sightings between 1990 and 1993, makes it necessary to view “home range” estimates derived from this study with caution. That is, the area covered by these temporally sparse sightings cannot be assumed to represent the area over which an animal “...normally travels during its routine activities...” (Burt, 1943).

**TABLE 6.8: The number of times identified dolphins were sighted at 24 specific sites in the Bay (see Map in Fig. 2.2).**

Quadrant	Site	Primary Substratum	1990	1991	1992	1993	Total
NW	Huskisson Reef	Rocky	4	14	10	0	28
	Nth Callala Beach	Sand	8	4	0	0	12
	Callala Point	Rocky	7	4	29	4	44
	Callala Bay	Seagrass	2	0	24	0	26
	Tapalla Point	Rocky	0	0	6	0	6
	Sth Callala Point	Rocky	0	2	0	0	2
	Collingwood Beach	Sand	0	1	1	0	2
	Mussel Raft	Sand	0	0	1	0	1
	Moona Moona Point	Rocky	0	0	0	1	1
	Middle Callala Beach	Sand	0	6	3	13	22
NE	Green Point	Rocky	1	8	0	0	9
	Cabbage Tree Point	Rocky	0	3	0	1	4
	Red Point	Seagrass	0	1	22	0	23
	Sth Long Beach	Seagrass	0	1	0	0	1
	Hare Bay	Seagrass	0	1	11	0	12
	Honeymoon Bay	Rocky	0	0	7	0	7
	Gutway	Rocky	2	0	0	0	2
	Groper Coast	Rocky	0	0	5	0	5
SW	Plantation Point	Rocky	23	12	13	0	48
	Hyams Beach	Sand	0	1	0	0	1
	Creswell Breakwall	Rocky	0	8	11	0	19
	Hyams Point	Rocky	0	4	13	0	17
SE	Scottish Rocks	Rocky	6	0	5	0	11
	Dart Point	Rocky	0	0	0	6	6
	<b>Total</b>		<b>53</b>	<b>70</b>	<b>161</b>	<b>25</b>	<b>309</b>

For example, as previously noted, there is no way of knowing if, when and with what frequency animals left the Bay between photographically recorded sightings nor for how long. Sighting data suggest some individuals appear to stay in the Bay for periods ranging between days to months (see Section 6.3.5). Consequently the whole Bay or part of it may include temporary home ranges for some individuals but this is not necessarily represented in the photographic record. Accordingly these data are presented as provisional estimates of individual's home ranges in a section of the study area, i.e. within the Bay. These estimated areas are therefore assumed to represent only a part of an individuals' entire range which may, or may not, include some or all of an individuals temporary or permanent home range. Wells *et al.* (1980) determined home range size "...by measuring the area enclosed by a polygon that included all sightings of an individual, excluding land masses...". Wells *et al.* (1980) found that after approximately 15 sightings of an individual at Sarasota, Florida, the home range was no longer found to increase in area and consequently only used dolphins seen at least 15 times in calculations of home range size. Home ranges were determined for dolphins seen on fewer than 15 sightings but these were referred to as "provisional" ranges (Wells, 1986). Shane (1987) used three animals, which were sighted more than 15 times (i.e.  $n=16, 18, 19$ ), to determine the percentage of the maximum known size that was represented by each sighting. Using the mean of these percentages, Shane (1987) estimated the maximum known size of the home ranges of 17 other individuals sighted fewer than 15 times. These 17 other individuals had sighting frequencies ranging from  $n=6$  to  $n=13$ .

The maximum number of occasions an individual was photographically recorded within Jervis Bay was 15 followed by 14 and 13 times for two other individuals. Hence a similar approach to that used by Shane (1987) to derive home ranges, was used to estimate the range within the Bay of individuals sighted on less than 15 occasions. To derive an area for each successive sighting, Shane (1987) "...calculated home range size by measuring the approximate area for all sectors in which an individual dolphin was sighted...[and] included sectors in which [she] did not actually see the individual but that it had to travel through in order to reach the

**TABLE 6.10: Summary Table of Results for annual photographic survey effort and the seasonality of sightings of 69 identified dolphins within Jervis Bay**

**In the Table below:** na = indicates analysis not applicable to data set; S indicates a statistically significant result (at alpha = 0.05) with the greatest area of difference indicated in the LH margin; and NS indicates a non-significant result. Line reference number is indicated by column I

I		Years 1990-92	Seasons 1990-92
i	Sampling Effort of usable photographic surveys (n=49) / more in autumn	NS	S
ii	Usable Sighting Events (n=60)	NS	na
iii	Total Sightings of 69 individual dolphins (n=284) / more in 1992 & more in autumn	S	S