CHAPTER 7: OPPORTUNISTIC SIGHTING INFORMATION AND ANCILLARY FISHERIES DATA

7.1 Introduction

Dolphin sighting information is often generated from a variety of other sources such as recreational fishers and the general public. As my surveys were resource intensive there long-term application for "monitoring" purposes is severely restricted. Hence, it was considered useful to explore other sources of sighting records and attempt to test how valuable such information may be. The opportunistic sighting information (OSI) presented in this chapter relates to sightings in the Bay only and is derived from four sources, none of which involved dedicated surveys to search for dolphins. As such it is not possible to determine with certainty any estimates of effort from each of these sources nor therefore dolphin sightings per unit effort. Consequently no attempt has been made to further verify this information nor make direct statistical comparisons between these and my own survey findings. However, I felt it was important to consider a) any trends suggested in this independently collected information which spanned the same period as my studies, and b) whether these were reflected in my results.

The variables considered in this chapter are: the minimum recorded estimate of the total number of dolphins sighted at any one sighting event; calf sightings, where this information was regularly recorded; depth; substratum; the general location of the sighting (i.e. quadrant or zone); season and time of day. Hence, where data were available and sample sizes allowed, statistical analyses of these variables within each data set have been carried out. For the variable calf generally no description in terms of size or any other parameter was provided for most sightings. Hence, at best this information can only be interpreted as individuals that were visually recognisable as smaller than other animals present, and thus probably includes some juveniles.

Also, the opportunity is taken here to consider the small number of feeding observations I recorded as no previous data are available on prey items from south east NSW. The data on fisheries in the Bay are included in order to consider the animals' habitat usage in terms of the type, abundance and distribution of their potential prey resources. Some background and description of the different data sources are provided.

Results are presented separately for the four OSI sources, i.e. NSW Fisheries Research Institute (FRI) Sightings (Section 7.2.1.1); Land based Sightings (Section 7.2.2.1); Vessel based Sightings (Section 7.2.3.1); and "Dolphin Watch" Cruise Sightings (Section 7.2.4.1).

Appendix 7 contains the detailed statistical analyses of all data presented in this Chapter (TABLES A7.1 - A7.10). The results presented in this Chapter refer to Summary Tables at the end of the Chapter (see Tables 7.6-7.8). A line reference using roman numerals is included to assist referral to these Tables (e.g. Table 7.6-liii).

7.2 Opportunistic Sighting Information (OSI)

7.2.1 NSW Fisheries Research Institute (FRI) Sightings - Data Description

The Australian Department of Defence (DoD) funded a multidisciplinary research program, the Jervis Bay Marine Ecological Studies (JBMES), which involved a number of specific projects conducted by a range of organisations, between 1988-1991. An initial report by The Ecology Lab Pty Ltd & Travers Morgan Pty Ltd (1988) reviewed the available information on marine mammals in the Bay and indicated that the primary research need was to establish the "...resident status and habitat utilisation of Bottlenose dolphins..." within Jervis Bay.

Consequently the FRI collected data on the distribution and abundance of these animals in the course of surveying done for a recreational fisherman and diver's study. The results of these observations were reported as an appendix to the above survey project (Williams *et al.*, 1993). The survey was conducted for 12 of the months between October 1988 and February 1990 and involved two circuits of the Bay made on each of ten days per month. The direction of these surveys was randomly altered. It was noted that as the circuit took from two to three hours; it is possible that some double counting occurred. The number of animals sighted and their location were reported in terms of the fourteen zones used by FRI for their DoD studies. Ten zones were relevant for comparison with my surveys inside Jervis Bay (i.e. the four outstanding zones being north and south of the entrance, and offshore of the Bay, Fig. 7.1). The surveys were equally distributed across these fourteen zones and across times of day, using stratified random sampling (Henry *et al.*, 1990). It was noted that many sightings were made at a distance and it was assumed that the species sighted was the bottlenose dolphin; and that it was not possible to determine the precise location of animals within a zone. No information was recorded concerning calf sightings.

7.2.1.1 Results and Comments

Williams *et al.* (1993) reported that bottlenose dolphins were observed in the Bay throughout the year and presented a summary of their data (Fig. 7.2). Hence, as only the total number of animals sighted per month is given no information on the number of sighting events nor mean sighting size can be derived.

I suggest the extremely high number recorded in April 1989 may be the result of the inclusion of common dolphin, *Delphinus delphis,* sightings, because this total included three sightings on three consecutive days of groups estimated to number 100 animals (NSW Fisheries unpub. data). While bottlenose dolphins are known to aggregate in large groups, the largest group I sighted in the Bay was estimated to be of 50 animals (as a minimum). However, sightings of common dolphins in the Bay which I have made, ranged in estimated size from 20 to greater than 100. Furthermore my one sighting of 100+ took place in April 1990.

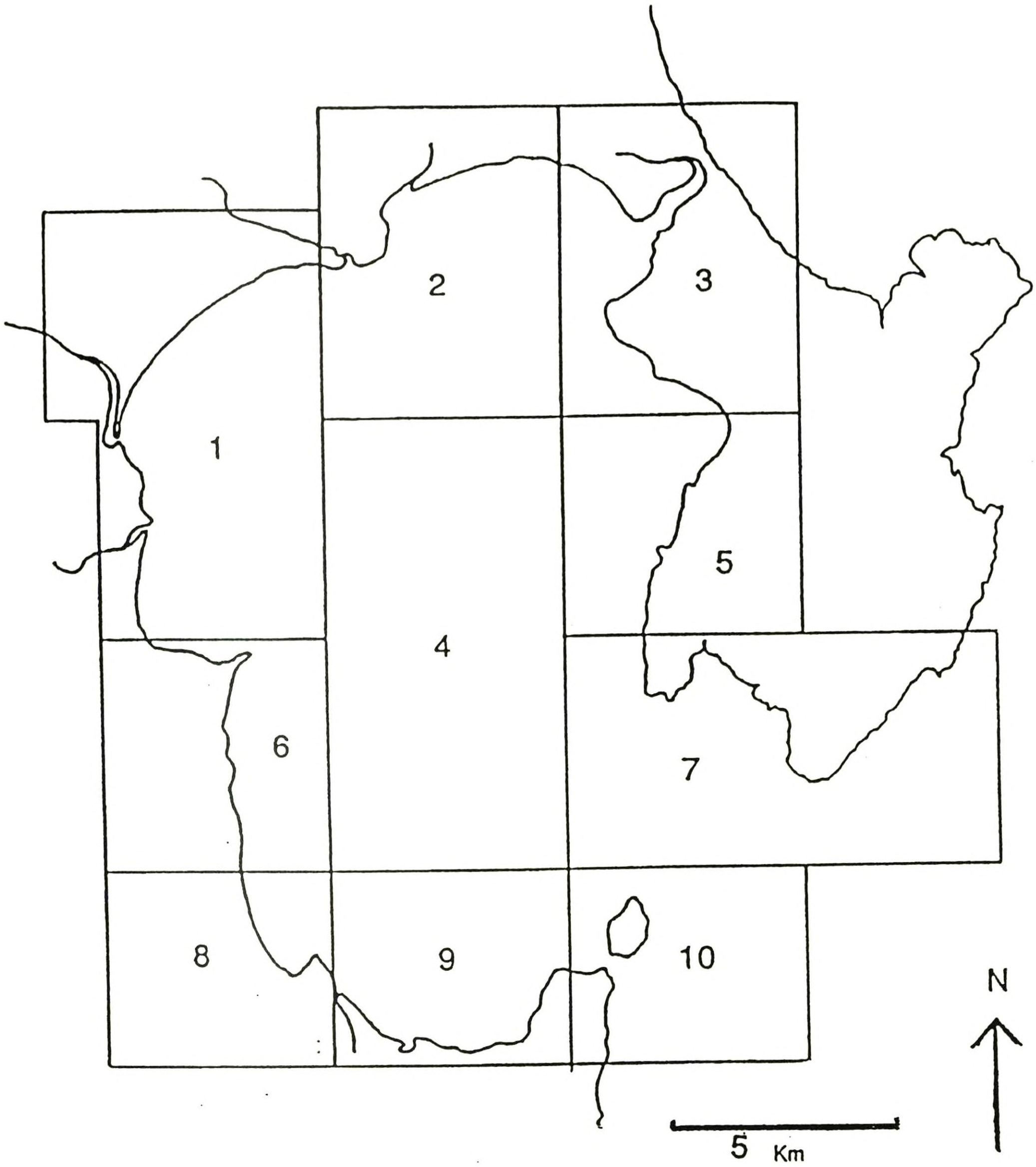

Figure 7.1: Map indicating ten of the commercial and recreational fishing and diving zones in Jervis Bay used by FRI for the DOD, JBMES (adapted from Fig. 5.1. in Henry *et al.*, 1990).

Excluding the extreme result in April 1989, there appears to be an increase in the number of dolphins sighted in summer (1988-89) and winter (1989), although the summer peak in 1990 appears lower than the previous year (Fig. 7.2).

This report noted that "...Dolphins appeared to be most prevalent around the northern shore (Areas 1,2,3...) and declined in number around the eastern and western shorelines..." (Fig. 7.3). Obviously these zones and the demarcation of quadrants used in my work (see Fig. 2.1) are not directly comparable, but it is interesting that the zones noted for a high number of dolphin sightings include almost all of my NW quadrant and part of the NE quadrant. The NW quadrant has the highest number of sightings and total number of dolphins recorded in both the S&E and NTS data sets (see Section 4.4.2). The remaining zones along the shoreline with the lower sighting numbers represent primarily the southern half of the Bay in my study which had fewer sightings and total number of dolphins recorded than the northern half the Bay.

Williams *et al.* (1993) also reported that "...Few dolphins were observed in the central part of the Bay or around the northern entrance...[and that]...no dolphins were observed outside the Bay, although fewer surveys were conducted in outside waters compared to within the Bay...". These observations are consistent with my findings.

Because no information on individual sighting events was presented and only the zone given in terms of general location (i.e. no details on site, distance offshore or depth), no analyses of depth or substratum can be carried out on this data set.

7.2.2 Land-based Sightings by Volunteers and myself - Data Description

A questionnaire requesting records of dolphin sightings was prepared at the commencement of this project. The distribution of these forms (n=180) was through local shops in each of the villages around the Bay and to particular interest groups, e.g. dive clubs. Approximately 34% of forms distributed were returned.

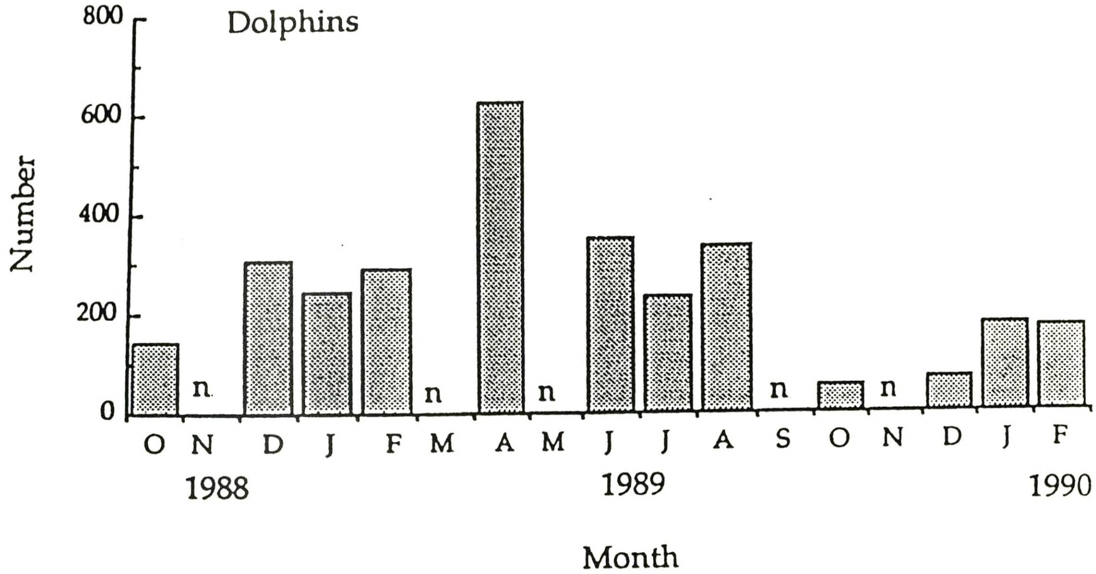

Figure 7.2: Abundance of dolphins in Jervis Bay by month from August 1988 to February 1990, n denotes that no surveys were conducted in this month (adapted from Fig. 5.1 in Williams *et al.*, 1993).

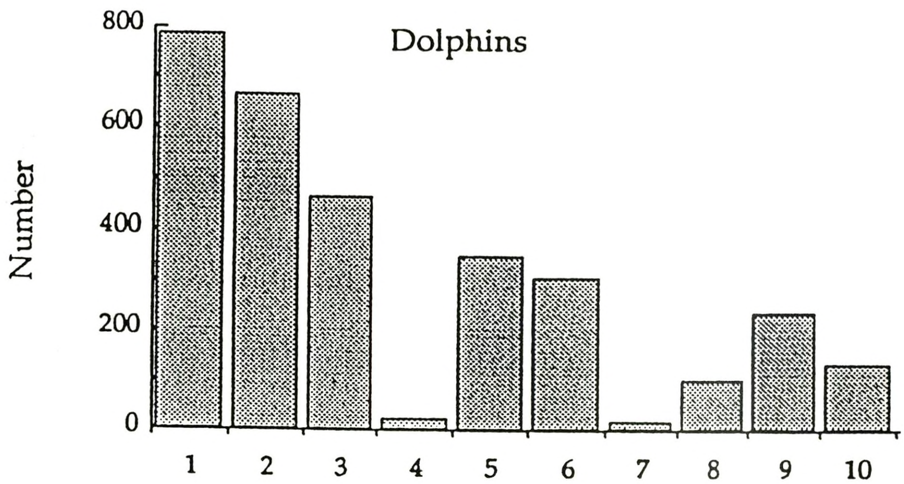

Figure 7.3: Abundance of dolphins by zones from August 1988 to February 1990 (adapted from Fig. 5.2 in Williams *et al.*, 1993).

Returned questionnaires indicated that the opportunity to observe animals for the amount of time needed to respond reliably to the questions was rare. One of the difficulties with data derived from such questionnaire is not getting an accurate appraisal of when or where no dolphins were sighted, that is no nil sighting forms were returned.

A summary of this information is presented in Table 7.1. The total number of animals presented is the minimum estimate where a range was often given, e.g. 5-10. Calves are presented as absent if this question was not filled in, so in effect absent may mean not present or present but not recorded or not observed. The site of the sighting was usually identified as offshore from a particular location on the shore of the Bay, e.g. off Hyams Point, and hence the placement within a quadrant could be derived. Likewise the season could be derived from the date of the sighting. Distance of the animals from land was also usually indicated; however, visual estimation of distance at sea is acknowledged as particularly difficult and so must be considered with caution. Where a range was given for this variable, the midpoint has been derived and is presented. Occasionally estimated depth was given instead of the distance from shore. The substrate type was derived from the estimated distance offshore (or estimated depth), using the Chart AUS 193 and my own knowledge of the substrata in the Bay, but as such must also be considered with caution.

7.2.2.1 Results

In total 77 sightings were recorded (Table 7.1), the majority (almost 60%) of which were by three individuals who either lived in the village of Hyams Beach or worked at the Naval Base, and four by myself. These sites are both located in the southern section of the SW quadrant. As a result of this focus (82%) of reports from the southern section of the SW quadrant, little comment can be made about the distribution of sightings around the Bay.

TABLE 7.1: Summary of information recorded from land-based sightings by Volunteers and myself per sighting event. The * denotes multiple sightings on the same day by different individuals; ** indicates sightings were made from both land and a vessel; ♠ indicates on these days sightings were also recorded from the 'Dolphin Watch' cruise vessel (see Section 7.5); 'Total No' refers to the estimated total number observed; 'IDs' refers to identification numbers of individually identified animals recorded by myself; 'Quad' is the abbreviation for quadrant of the Bay in which sighting occurred; 'Dist. off/s' is an abbreviation for estimated distance of animals offshore from nearest land; on some occasions distance offshore was not given but depth was provided, and is included as (Dep.); 'Sub' is the abbreviation for substratum over which sighting occurred; 'seag' is an abbreviation for seagrass; and - indicates no information given.

Date	Total No	No of Calves & IDs	Site	Quad	Season	Dist. off/s (m) & (Dep.) (m)	Sub	Time Hr:min
1990								
10.2.90	2	absent	NthHyamsBch	SW	SUM	-	-	1134
10.2.90	4	absent	NthHyamsBch	SW	SUM	100	sand	1635
25.2.90	2	absent	NthHyamsBch	SW	SUM	100	sand	1505
25.2.90	7	absent	SthHyamsBch	SW	SUM	200	sand	1540
2.3.90	10	absent	SthHyamsBch	SW	SUM	300	sand	1945
15.3.90	10	absent	HyamsBch	SW	AUT	30	sand	0915
27.3.90	8	absent	HyamsPt	SW	AUT	40	rock	0950
9.4.90	18	1	HyamsPt	SW	AUT	80	rock	0805
9.4.90	22	absent	HyamsPt	SW	AUT	80	rock	1505
22.4.90	1	absent	HyamsBch	SW	AUT	150	sand	0715
24.4.90	18	absent	HyamsBch	SW	AUT	50	sand	0820
7.5.90	55	absent + #29, #31	MidHyamsBch	SW	AUT	150	rock	0920
26.5.90*	36	absent	CaptainsBch	SW	AUT	35	sand	1430
26.5.90	30	absent	HyamsBch	SW	AUT	700	sand	0830
26.5.90	12	1	SthHyamsBch	SW	AUT	700	sand	0830
16.6.90	3	1	CurrambeneCk	NW	WIN	60	sand	0650
17.6.90	10	absent	MidHyamsBch	SW	WIN	120	rock	1210
5.8.90*	4	1	NthHyamsBch	SW	WIN	100	sand	1505
5.8.90	10	absent	ChinamansHd	SW	WIN	100	sand	1730
7.8.90	15	absent + #12	HyamsBch	SW	WIN	300	sand	1301
7.10.90**♠	25	1	SthHyamsBch	SW	SPR	100	sand	1050
7.10.90	8	1	NthHyamsBch	SW	SPR	10	sand	0630
7.10.90	1	absent	HyamsBch	SW	SPR	20	sand	1500
14.11.90	10	absent	HyamsBch	SW	SPR	300	sand	1330
8.12.90♠	22	absent	HyamsBoatRmp	SW	SPR	20	sand	1730

Date	Total No	No of Calves & IDs	Site	Quad	Season	Dist. off/s (m) & (Dep.) (m)	Sub	Time Hr:min
1991								
2.1.91♠	3	absent	SeamanBch	SW	SUM	-	-	-
9.1.91	10	absent	CaptainsPt	SW	SUM	-	-	-
11.1.91	15	absent	CaptainsPt	SW	SUM	-	-	-
21.1.91♠	10	absent	SeamanBch	SW	SUM	-	-	-
6.2.91♠	12	absent	SeamanBch	SW	SUM	-	-	0600
10.2.91	6	absent	MidHyamsBch	SW	SUM	20	rock	1500
14.2.91	35	absent	NthHyamsBch	SW	SUM	100	sand	0750
22.2.91♠	5	absent	PlantationPt	SW	SUM	1000	rock	0830
25.2.91	10	absent	HyamsBch	SW	SUM	-	-	-
3.3.91♠	5	absent	CallalaBay	NW	AUT	-	-	-
28.3.91	20	absent + #13, #28 #43	SthCallalaBch	NW	AUT	30	sand	0645
9.4.91*	10	absent	SthLongBch	NE	AUT	10	sand	1200
9.4.91	10	absent	GreenPt	NE	AUT	- (6)	seag	1030
10.4.91	10	absent	SthLongBch	NE	AUT	-	-	0930
18.4.91	15	absent	GreenPt	NE	AUT	- (7)	seag	1130
23.4.91	30	absent	GreenPt	NE	AUT	- (10)	seag	1230
25.4.91	10	absent	GreenPt	NE	AUT	- (7)	seag	-
1.5.91	10	absent	RedPt	NE	AUT	- (8)	seag	1315
14.5.91	2	absent	SthHyamsBch	SW	AUT	- (10)	sand	1445
15.5.91	12	absent	HyamsPt	SW	AUT	70	rock	1515
15.5.91	10	absent	HyamsBch	SW	AUT	300	sand	1545
29.5.91	5	absent	SeamanBch	SW	AUT	60	seag	1000
4.6.91	9	2 + #8	HyamsPt	SW	AUT	30	rock	1330
13.6.91*	20	2	HyamsBch	SW	WIN	20	sand	1130
13.6.91	2	absent	CaptainsPt	SW	WIN	50	sand	1700
16.6.91	2	1	IlukaBch	SE	WIN	20	seag	1330
16.6.91	7	absent	NthHyamsBch	SW	WIN	50	sand	1630
19.6.91	5	1	NthHyamsBch	SW	WIN	50	rock	1630
1.7.91	8	2	NthHyamsBch	SW	WIN	20	sand	1400
3.7.91	3	absent	SeamanBch	SW	WIN	80	sand	1430
9.7.91	4	absent	SeamanBch	SW	WIN	15	sand	0815
26.7.91	20	absent	NthHyamsBch	SW	WIN	100	sand	1315
3.8.91	10	absent	Creswell Breakwall	SW	WIN	80	sand	1230
14.8.91♠	30	absent	CaptainsPt	SW	WIN	20	rock	1237
26.8.91	8	absent	SthHyamsBch	SW	WIN	100	sand	0810

Date	Total No	No of Calves & IDs	Site	Quad	Season	Dist. off/s (m) & (Dep.) (m)	Sub	Time Hr:min
1.9.91♠	4	absent	CurrambeneCk	NW	SPR	10	sand	0730
4.9.91	40	absent	CaptainsPt	SW	SPR	20	rock	1450
12.9.91	5	1	MidHyamsBch	SW	SPR	20	sand	0805
11.10.91	3	absent	NthHyamsBch	SW	SPR	200	sand	1045
14.10.91	20	2	SthCollingwood Bch	SW	SPR	50	sand	0630
17.10.91♠	18	absent	SthCollingwood Bch	SW	SPR	100	sand	0630
16.11.91♠	20	absent	NthHyamsBch	SW	SPR	500	sand	1750
2.12.91♠	10	4	SthCollingwood Bch	SW	SUM	150	seag	1930
19.12.91*	20	absent	Creswell Breakwall	SW	SUM	50	sand	0820
19.12.91	20	absent	HuskissonReef	NW	SUM	150	rock	1140
1992								
12.2.92*♠	25	absent + #4,#20	NthHyamsBch	SW	SUM	100	sand	1100
12.2.92	15	absent	NthHyamsBch	SW	SUM	150	sand	2020
13.2.92♠	15	absent	NthHyamsBch	SW	SUM	150	sand	0820
13.2.92	15	absent + #4, #8	NthHyamsBch	SW	SUM	150	sand	0820
18.2.92♠	8	1	HyamsPt	SW	SUM	100	rock	0750
22.2.92♠	20	absent	NthHyamsBch	SW	SUM	100	sand	1230
1.3.92♠	8	absent	MurraysBch	SE	AUT	100	seag	0900

Multiple sightings were only made on 13 out of the 62 (21%) days for which data are presented (Table 7.1). Hence while relatively rare, there is the potential for resightings of the same groups to have taken place but the exact level of resightings is impossible to assess.

The total number of animals sighted was 992 with a mean sighting size of 12.9 (S.E. 1.15) animals. In total, 22 calves were recorded at only 15 sighting events. Calves constituted 2% of all dolphins observed. The maximum number of calves sighted at any one sighting event and on a single survey day was four. There was no significant difference in the mean sighting size of groups with or without calves (Table 7.6-li).

The maximum estimated distance offshore was one kilometre, while the mean was approximately 132 m. Excluding four sightings made at estimated distances between 500 m and one kilometre, all other sightings (95%) were estimated to be in 10 m or less of water, based on Chart AUS 193. It is interesting to note that although the shoreline within the SW quadrant and particularly in its southern section is predominantly sand, a number of sightings were recorded over the relatively rare substrata of rock (21%) and seagrass (13%). Also, ANOVA indicated no significant difference among the total number of animals sighted over the three substrata where this was recorded, or the distance offshore and/or depth allowed this to be determined (Table 7.6-lii). There was no significant difference in the mean number of calves sighted across the different substrata (Table 7.6-lii).

Sightings of bottlenose dolphins in the Bay were made in all months over the three years these 77 sightings were recorded. As indicated previously "survey" effort is unable to be determined; however, within this data set, effort (i.e. returned questionnaires) was found to be equally distributed across seasons (Table 7.6-liii).

There was a marked peak in the total number of animals recorded in autumn in both 1990 and 1991 with the highest monthly totals recorded in May and April, respectively. However, ANOVA indicated no significant difference in the total number of animals sighted across seasons for this data set (Table 7.6-liii). The largest mean monthly sighting sizes were also in April/May during 1990 and in November/December of 1991.

In 1990 calf sightings were recorded in April, May, June, August and October. In 1991 calves were recorded in June, July, September, October and December, whilst they were reported in February during 1992. Hence these reports suggest calves are present in the Bay through most of the year with a possible "visibility peak" in winter. ANOVA indicated no significant difference in the number of calves sighted across seasons for this data set (Table 7.6-liii).

As only three sightings were recorded after 1800 hours, these data were combined in a single "afternoon" category (i.e. $\geq$ 1400 hours), which resulted in three time of day categories for all reported data. There was no significant difference in the distribution of reported sighting events across these different time of day categories where time was recorded (Table 7.6-liv). ANOVA indicated no significant difference in the total number of animals nor the total number of calves sighted at different times of the day (Table 7.6-liv). Hence, for this survey there was an equal likelihood of seeing dolphins during these three time periods with apparently the same total number of dolphins and calves to be seen.

7.2.3 Vessel-based Sightings made by Volunteers and myself - Data Description

Occasionally sightings were recorded by the public whilst fishing or pursuing other boating activities, using the prepared questionnaire referred to above. Also, apart from the pilot surveys and dedicated surveys presented in earlier chapters (n=111), on ten other occasions when I was on the Bay for scuba diving, equipment calibration or transect site investigations, I recorded sightings of dolphins.

The same conditions apply to the variables listed in Table 7.2 as for Table 7.1, except that depth was recorded more frequently than distance offshore. Hence, substratum type is derived from this variable as well as Chart AUS 193 and my own knowledge of substrata in the Bay. Although estimates of depth were probably derived from instruments such as “fish finders”, this information should be considered with some caution because the source was not identified.

7.2.3.1 Results

In total 27 sightings were recorded over 24 days (see Table 7.2). Multiple sightings were only made on 2 out of the 24 days (8%) for which data are presented (i.e. one was a triple sighting). On both of these occasions, all sightings were recorded by the same individual. On four of these days sightings were also made from the Dolphin Watch Cruise vessel (see Section 7.2.4). Hence, while relatively rare, there is the potential for resightings of the same groups to have taken place. The exact level of resightings is impossible to assess.

The total number of dolphins sighted was 312 with a mean sighting size of 11.6 (S.E. 2.0) animals. Sightings were made in all but three months of the two years sightings were recorded. Only four sightings included calves, which involved a total of eight individuals but again the descriptive term calf should be considered with caution. These calves constituted 2.6% of all dolphins observed. The maximum number of calves sighted at any one sighting event and on a single survey day was three. Calf sightings were recorded in May and August, 1990 and a single sighting during March 1991, which appear to coincide with relatively larger sighting sizes (see Table 7.2). However, there was no significant difference in the mean sighting size of groups with and without calves (Table 7.7-li).

The maximum recorded depth was 17 m (east of Plantation Pt), which was

TABLE 7.2: Summary of information recorded from opportunistic sightings in the Bay from the research and other vessels, by myself and volunteers, per sighting event. The symbols, ♠ indicates on these days sightings were also recorded from the "Dolphin Watch" cruise vessel (see Section 7.5); "Total No" refers to the estimated total number observed; "Quad" is the abbreviation for quadrant of the Bay in which sightings occurred; "Sub" is the abbreviation for substratum over which sightings occurred; and "seag" is an abbreviation for seagrass.

Date	Total No	No of Calves	Site	Quad	Season	Depth (m)	Sub	Time Hr:min
1990								
4.3.90	10	absent	DartPt	SE	AUT	9	rock	1110
30.4.90	1	absent	CurrambeneCk	NW	AUT	6	sand	1430
3.5.90	2	absent	EastCollingwoodBch	NW	AUT	9	sand	0818
5.5.90	27	3	Honeymoon Bay	NE	AUT	13	sand	1208
8.5.90	15	absent	MusselRaft	NW	AUT	5	sand	1105
8.5.90	15	absent	MusselRaft	NW	AUT	5	sand	1200
8.5.90	15	absent	MusselRaft	NW	AUT	5	sand	1215
23.5.90	10	absent	HoneymoonBay	NE	AUT	10	sand	1620
29.5.90	5	1	GreenPatch	SW	AUT	16	sand	1345
10.6.90	5	absent	DartPt	SE	WIN	12	rock	0750
20.6.90	10	absent	CollingwoodBch	NW	WIN	7	sand	1650
23.6.90	3	absent	EastPlantationPt	SW	WIN	17	sand	1640
24.7.90	25	absent	HuskissonReef	NW	WIN	12	sand	1015
10.8.90	20	3	PlantationPt	SW	WIN	6	sand	0730
7.10.90♠	8	absent	HyamsBch	SW	SPR	5	sand	1200
8.10.90	12	absent	LongnosePt	SE	SPR	-	-	1200
11.10.90	12	absent	CollingwoodBch	NW	SPR	8	sand	1738
1991								
18.3.91	25	1	TapllaPt	NW	AUT	7.3	sand	0910
22.5.91	5	absent	MidCallalaBch	NW	AUT	12	sand	1430
22.5.91	5	absent	PlantationPt	SW	AUT	-	-	1500
15.6.91	4	absent	GroperCoast	SE	WIN	6	sand	1030
26.6.91	10	absent	CallalaBch	NW	WIN	4.5	sand	0700
30.7.91	7	absent	HareBay	NE	WIN	13	sand	1215
13.10.91	3	absent	SthLongBch	NE	SPR	5	seag	1430
23.11.91♠	4	absent	SailorsBch	NW	SPR	5	sand	1600
30.11.91♠	4	absent	SailorsBch	NW	SPR	4	sand	1220
1.12.91♠	50	absent	HareBay	NE	SPR	7	seag	1215

approximately one kilometre offshore, and the mean was 8.3 m. Where depth was recorded, 72% of sightings were in water ≤10 m in depth. When sightings were divided into shallow (≤8 m) or deep (>8 m), there was no significant difference in mean sighting size between these two depths (Table 7.7-lii). Four calves were recorded in waters > 8 m in depth and the other four at ≤ 8 m depth.

Although sand was the main substratum over which sightings were made (85%), sightings were also recorded over both rock and seagrass. When the area of these three substrata throughout the Bay were considered (see Table 2.1), there was no significant difference in the distribution of sighting events (Table 7.7-liii).

Although, as indicated previously, survey effort is unable to be determined, within this data set "effort per sighting day" was found to be equally distributed across the three seasons for which data were available (Table 7.7-liv). That is, no sightings were recorded, because no reports were returned for summer. The largest sightings ($n \geq 20$) were recorded in May, July and August, 1990 and March and December during 1991. However, ANOVA indicated no significant difference in the total number of animals sighted across seasons (Table 7.7-liv). Calves were only sighted in autumn and winter, five in autumn and three in winter.

As the duration of time spent on the water was not recorded, effort in terms of the time of day sightings were made cannot be determined. There was no significant difference in the distribution of reported sighting events across three different time of day categories (Table 7.7-lv). ANOVA indicated no significant difference in the total number of animals sighted at different times of the day (Table 7.7-lv). Four calves were recorded in the morning (i.e. <1000) and four at midday (i.e. between 1000 & 1400).

Because no information on vessel routes was provided, survey effort with respect to quadrants traversed cannot be determined. Although sighting events across quadrants were equally distributed, almost half (48%) were made in the NW quadrant (Table 7.7-lvi). Hence, whether this trend results from uneven distribution of effort, e.g. the most highly used boat ramp is located in this quadrant, or it reflects dolphins' movements remains unknown. ANOVA indicated no significant difference in the total number of animals per sighting event across quadrants (Table 7.7-lvi). Two sightings with calves were made in the SW quadrant and one in each of the NW and NE quadrants.

7.2.4 Sightings from Dolphin Watch Cruise - Data Description

In 1990 a local entrepreneur already involved in sightseeing tours of the Bay began a new venture, involving Dolphin Watch Cruises. He provided a summary of the new vessel's log in which he had requested staff to record dolphin sightings. A number of recording procedures and different types of information were apparently trialled over the first year. By 1991 information appeared to primarily include the date, sighting time, number of dolphins, presence and number of calves and the zone in which the sighting was made. The zones used by this operator are those derived for the FRI studies (see Fig. 7.1). Allocation of sightings to these zones appeared to be based on small maps of the Bay, on which the route and sighting locations were sketched by the recorder. It appears from copies of the maps provided (commencing on 17.11.91), that the zone nomination should be regarded as only a very general indicator of the sighting location.

Unfortunately the information is patchy and any cruises on which dolphins were not sighted were not indicated. Hence, it is impossible to know, when no recordings have been made, whether this was because animals were not sighted, or cruises did not operate, or records of sightings were not able to be made for some other reason. The same conditions apply to the variables called total number of dolphins and calves, listed in Table 7.3, as in earlier tables.

7.2.4.1 Results

In total 444 sightings (Table 7.3) were recorded in the Bay over 239 cruise days from January 1990 to May 1992. Multiple sightings were made on 119 cruise days

TABLE 7.3: Summary of dolphin sightings per month and other information derived from a Dolphin Watch Cruise in Jervis Bay. The (-) indicates not possible.

Date	No of cruise Days	No of Sighting Events	Total No of Dolphins	No of Sighting Events with Calves	No of Calves	Mean No per Sighting Event	Events per cruise
1990							
APR	1	1	1	0	0	1	1
MAY	8	11	132	2	4	12	1.375
JUN	3	3	16	1	1	5	1
JUL	1	1	25	0	0	25	1
AUG	1	2	40	0	0	20	2
SEP	1	1	2	0	0	2	1
OCT	4	4	36	0	0	9	1
NOV	2	2	80	0	0	40	1
DEC	19	51	374	1	2	7	2.68
1991							
JAN	15	38	281	0	0	7	2.53
FEB	6	16	136	0	0	8	2.67
MAR	10	13	139	2	4	11	1.3
APR	4	10	148	1	1	15	2.5
MAY	0	-	-	-	-	-	-
JUN	0	-	-	-	-	-	-
JUL	0	-	-	-	-	-	-
AUG	5	5	68	-	-	14	1
SEP	6	6	59	1	1	10	1
OCT	16	20	329	0	0	16	1.25
NOV	23	44	349	1	1	8	1.9
DEC	23	39	259	0	0	7	1.7
1992							
JAN	24	40	288	1	1	7	1.67
FEB	17	33	285	4	5	9	1.9
MAR	20	42	459	6	6	11	2.1
APR	16	24	185	4	7	8	1.5
MAY	14	38	247	3	3	6	2.7
Total	**239**	**444**	**3938**	**27**	**36**		

(50%). Hence for this information source, the potential level of resightings within cruise days may be quite high but cannot be assessed, as is true also for resighting levels between cruise days. On 17 out of the 86 days (20%) on which the information presented in Tables 7.1 & 7.2 were collected, there were sightings also made from the Dolphin Watch Cruise. Hence a reasonable overlap of sightings, possibly including some of the same individuals, between different "observational platforms" may have occurred on the same day.

The total number of dolphins sighted was 3,938 with a mean sighting size of 8.9 (S.E. 0.4) animals. Sightings of bottlenose dolphins were made in all months of the year. There were a total of 36 calves sighted at 27 sighting events over the two and a half year period reviewed. Calves constituted less than one percent (0.9%) of all dolphins observed. The maximum number of calves sighted at any one sighting event and on a single survey day was three. ANOVA indicated no significant difference in the mean sighting size of groups with or without calves (Table 7.8a-li).

The estimated distance offshore of each sighting was recorded until August 1991 (i.e. 155 sightings). It is assumed this was visually estimated in most cases and where a range was given, I used the midpoint. The minimum and maximum estimated distances offshore in 1990 were 8 m to 2 km, with a mean of 290 m. In 1991, the minimum and maximum estimated distances offshore were 50 m to one kilometre, with a mean of 213 m. Overall, 11 sightings (7%) were greater than 500 m from the shoreline. Because the location on land from which the distance offshore was estimated was not given, it was impossible to estimate depth and substratum for sighting events in this data set.

As indicated previously, survey effort is unable to be determined; however, within this data set "effort per cruise day" was not equally distributed across seasons (Table 7.8a-lii) with most surveys (74%) conducted in summer and autumn. There was also a significant difference in the distribution of sighting events across seasons when this '"effort per cruise day" was considered (Table 7.8a-lii). More sightings were recorded in summer and less in winter and spring than was expected on the basis of the unequal distribution of effort.

There were marked peaks in the total number of animals recorded during: summer, 1990/91; spring, 1991; and late summer/early spring, 1992, which reflect apparent cruise effort. ANOVA indicated a significant difference in the mean total number of animals across seasons (Table 7.8a-lii) with the mean total number in summer, autumn, winter and spring being 7.5 (S.E. 0.48), 9.4 (S.E. 0.75), 13.6 (S.E. 3.48) and 11.1 (S.E. 1.25), respectively. When a pairwise multiple comparison of seasonal means was conducted using the Peritz procedure the result indicated only spring and summer were significantly different from each other (Table 7.8a-lii). This result may also reflect apparent cruise effort. The largest mean monthly sighting sizes per sighting events were during: November, July and June 1990 (see Table 7.3).

Calves were recorded in all but three months of each year (July, August, October), with the highest number from each year recorded in autumn. ANOVA indicated a significant difference in mean calf numbers across seasons for the period i.e. April 1990-May 1992. However, data were heteroscedastic and variances were unable to be stabilised after $\log_{10}$ transformation (Table 7.8a-lii).

As the durations of the cruises were not recorded, effort in terms of the time spent on the water and the time of day sightings were made cannot be determined. Sighting events were unequally distributed across the four time of day categories, of when sightings were made (Table 7.8a-liii). Almost 47% of sightings were recorded in the middle of the day (i.e. after 1000 and before 1400) and a further 34% recorded after 1400 and before 1800. ANOVA indicated no significant difference in the total number of animals nor calves sighted at different times of the day (Table 7.8a-liii).

Unfortunately the route taken on every cruise where dolphins were recorded was not available, but those maps provided did suggest that the route varied greatly depending on the type of advertised or chartered cruise being provided. That is, the route sometimes involved a nearshore circuit of the Bay but on other occasions where a "beachwalk" was included only one or two quadrants were traversed. Yet again, on many other cruises often with a specific focus (e.g. penguin spotlighting, scuba diving), the vessel would travel around the shore one way and then across the middle of the Bay. Hence it is not possible to estimate search effort in terms of the zones traversed on any one cruise.

However, sighting events were unequally distributed across zones, both within years and across all three years, where this information was recorded (Table 7.4). Of the 76 recordings from 1990, 43% were in zone 1 (see Fig. 7.1). The next highest number of sightings were in zone 6 (14%). In 1991, 35% of the 190 sightings were in zone 1 with the next highest sighting zones being 6 and 2, both representing about 14%. In 1992 the pattern was similar with 43% of 175 sightings being found in zone 1 and the next highest sighting zones again being 6 and 2, representing 17% and 16%, respectively. Zones 1, 2, 3, and 5 are wholly within the northern half of the Bay as I defined it (see Fig. 2.1 & 7.1). The majority of sightings (i.e. 68%) were in the northern half of the Bay. As zone 4 overlaps the northern and southern half of the Bay, counts from this zone were excluded from this comparison, losing only 14 (3%) of all sightings. Furthermore ANOVA indicated a significant difference in the mean number of animals recorded across zones (Table 7.8a-liv). The mean number in Zones 1, 2, 3, 4, 5, 6, 7 ,8 ,9 and 10 were 7.1 (S.E. 0.57), 11.3 (S.E. 1.25), 12.4 (S.E. 1.76), 9.9 (S.E. 2.67), 14 (S.E. 2.12), 6.8 (S.E. 0.7), 11.2 (S.E. 3.9) 6.2 (S.E. 1.33), 9.1 (S.E. 1.45) and 9.8 (S.E. 2.66), respectively. The Peritz procedure indicated a complex result with Zone 1 being different from Zones 2, 3 and 5; Zones 3 and 6 were different as were Zones 5 and 6. The majority of calves (64%) were also sighted in the northern half of the Bay (i.e. from zones 1, 2, 3, and 5). Also, zone 1 recorded the highest number of calves (36%) followed by zones 5 (17%) and then 6 (14%). However ANOVA indicated no significant difference in the mean number of calves recorded across zones (Table 7.8a-liv).

TABLE 7.4: The number of dolphin sightings in each zone of the Bay (see Fig. 7.1) where sightings were recorded, per year made by a commercial dolphin watch operator in the Bay. The (-) indicates no sightings indicated.

			Zone									
Year	**Total No of sighting Events**	**Total No of sighting events indicating the Zone**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1990	76	76	33	7	8	-	8	11	1	1	4	3
1991	191	190	66	26	16	4	15	27	6	9	17	4
1992	177	175	76	28	13	3	5	30	1	4	5	10
Total	**444**	**441**	**175**	**61**	**37**	**7**	**28**	**68**	**8**	**14**	**26**	**17**

Because this data set spanned the period of my surveys, I thought it was important to investigate any pattern in abundance and density estimates where data allowed, to see if similar trends to my data were evident. There was no significant variation in the total number of animals sighted across the three years of the cruise records when "cruise effort", i.e. the annual distribution of cruise days, was accounted for (Table 7.8b-li). There was, however, a significant variation in the total number of calves sighted across the three years of this data set when cruise effort was considered, with a significantly larger number of calves sighted in 1992 than expected on the basis of effort and fewer in 1991 (Table 7.8b-lii). Whether this larger number of calves in 1992 reflects a real increase relative to other years or is related to total cruise effort (i.e. total number of cruises undertaken in any year is unknown), or relative effort across seasons or areas of the Bay traversed, remains unknown.

There was a significant difference in the total number of animals sighted across seasons when survey effort was considered (Table 7.8b-li). The highest number of animals was recorded in summer (41%), although this was less than expected on the basis of cruise days. The next highest number was recorded in autumn (33%) and this was significantly higher than expected on the basis of cruise days. Hence, while the highest number of dolphins was recorded in summer, reflecting the greater number of cruise days, a real peak appeared in autumn.

There was also a significant difference in the total number of calves sighted across seasons when survey effort was considered (Table 7.8b-lii). The highest number of calves was recorded in autumn (69%) which was higher than expected on the basis of reported cruise effort, while summer and spring had significantly lower numbers of calves than expected on the basis of cruise days.

While it is accepted that each cruise did not traverse the whole Bay, the whole Bay is the area used to determine density so as to allow some comparisons with estimated densities derived from S&E and NTS data sets (i.e. 0.13 *Tursiops*/sq. km and 0.12 *Tursiops*/sq. km, respectively). All of my surveys also covered less than the whole Bay and used different areas of the Bay on any one survey day, but the whole Bay was the basis of my density estimates. The mean density estimate for the whole study area (117.2 sq km) based on the total number of animals (n=3,938) was 0.14 *Tursiops*/sq. km. This is extremely close to my estimates. Also, resighting levels within and between cruise days is unknown, hence density estimates should be regarded with caution.

7.3 Feeding Observations

7.3.1. Data Description

I have no data, in terms of stomach content analysis, on the actual species eaten by dolphins in Jervis Bay. Only two strandings occurred in the Bay during my study (Llewellyn *et al.*, 1994) and, unfortunately, I was not notified and so was unable to collect stomach samples. As far as I can determine, no analysis of gut contents of these individuals was carried out. Hence, knowledge of the animals' possible items of prey in the Bay are restricted to a small number of feeding observations made on my Search and Encounter (S&E) and Transect Surveys which are summarised in Table 7.5. While this data is limited it in included because it represens the first data from south east NSW.

Across the two data sets a total of 21 pods were reported to be involved in either "feeding" or "feeding/travel" (see Appendix 2). Where multiple pods were involved in the same activity, at the same sighting the activities of the pods have been summarised together in Table 7.5, for ease of presentation (i.e. n=15).

7.3.2 Comments

These observations suggest a range of searching and feeding strategies are employed by the dolphins in the Bay over a variety of different habitats which suggests a variety of prey items are likely consumed. Observations of both individual and apparent cooperative feeding strategies were observed in shallow

TABLE 7.5: Summary of feeding observations from Search & Encounter (S&E) and Transect Surveys (TS). The variables distance offshore ('Dist. offs'), substratum ('Sub') and depth are from the time 'feeding behaviour' was first reported. * indicates minimum estimate of number of dolphins (Ds) presented.

Date	Location	Dist. offs(m)	Sub	Depth (m)	Total No	No of Calves	Spatial Pattern	Description of Behaviour (see Appendix 2 for definitions)
5.1.90	Montagu Pt	500	sand	12	5	1	clumped	"baitfish" at surface, Ds lunging at surface at different angles
5.1.90	Montagu Pt	500	sand	10	20	2	spread	Ds in dispersed feeding groups moving slowly between, repeated tail-stock & fluke-up dives at each site, gulls feeding
9.6.90	Plantation Pt	400	rock	9	3	0	clumped	repeated circling & shallow diving, remaining at same site, large fish (30cm+, sp?) jumping
28.7.91	Hyams Bch	100	sand	3	30	2	clumped in 3 pods, in line behind the other	slow travel along surfline, sporadic quick lunging at "baitfish" then diving into centre, regroup continue travel, repeat
19.1.92	Plantation Pt	20	rock	6	2	0	clumped	repeated tail-stock dives at same site, pied cormorants feeding

TABLE 7.5 contd.

Date	Location	Dist. offs(m)	Sub	Depth (m)	Total No	No of Calves	Spatial Pattern	Description of Behaviour
16.3.91	Murrays Boat Ramp	200	sea-grass	6	40	0	initially in two clumped pods then joined in a line, side by side spread over 500m	travelling west toward Bowen Is. abreast, fast swimming, lunging at surface & leaping; schools of "baitfish" jumping; once fish were "herded" Ds fed in sm. groups in <4m, some pods circling, some individuals upside down
16.3.91	off Bowen Island	1000	sand	27	12	0	clumped	After approx. 30min another pod of 10+ arrived but swam rapidly past to Nth end of Bowen Is. joined by 2 Ds from shallows; swam out to 27m surging, leaping; animals seen with mackerel in mouth, another throwing fish; 4-5 Ds returned to shallows after 20min
13.4.91	Plantation Pt	1000	rock	14	15	2	spread	repeated flukes-up dives, remaining in the same area, fish (sp?) jumped
16.6.91	off Currambene Ck	100	sand	3	10	0	clumped	swimming just below surface in same area, off creek mouth at change of tide, fisherman onshore catching whiting & mullet

TABLE 7.5 contd.

Date	Location	Dist. offs(m)	Sub	Depth (m)	Total No	No of Calves	Spatial Pattern	Description of Behaviour
23.1.92	Plantation Pt	200	rock	9	2	0	clumped	repeated tail-stock dives in same area, head slapping, fish (sp?) in mouth
23.1.92	Hyams Bch	30	sand	3	30	2	clumped in 4 pods, in line behind the other	fast travel along surfline, lunging then diving into central pt, regroup continue travel; upside down swimming; headslap, large fish (sp?) in mouth
28.2.92	Callala Pt	100	rock	8	6	1	clumped into two pods	repeated diving in same area, cormorants diving
8.5.92	Chinamans Bch	50	sand	5	6	1	clumped	moderate travel along surfline, surging, leaping, upside down swimming; pilchards jumping
9.5.92	Callala Bay	100	sea-grass	4	20	1	clumped	moderate travel, leaping, surging; squid in mouth; "baitfish" jumping some pods circling
14.5.92	Creswell Breakwall	20	sand	8	20	0	clumped	moderate travel, shallow diving, lunging; yellowtail jumping

and deep waters. Two strategies were most commonly sighted, the first being repeated diving at a site (*n*=6) by individuals in small clumped or larger spread groups. This behaviour was typically seen over rocky substrata but was also seen over sand. The second strategy was used mainly along the surfline of sandy beaches (*n*=4) where animals travelling in small clumped groups, often behind each other (over variable distances), would suddenly accelerate and lunge, described by Shane (1990) as a "feeding rush", either toward the shoreline or parallel to it. Würsig (1986) suggested that a larger group size may increase the area being searched, and also that "...more dolphins may more effectively feed on schools of prey once they have been found...". While the two general strategies described above may not necessarily require cooperation within and between groups to locate and secure prey, there were marked differences in group size between both.

In four instances out of six where repeated diving occurred in the same general area over rock, groups were clumped and ranged in size between 2 and 6 individuals. Würsig (1986) noted individual foraging over rock off Argentina. In the other two cases where group sizes were 15 and 20, these dolphins were spread and were located over sand. This may suggest that foraging over this substratum may have involved larger groups although individual securing of prey may then proceed. In the second strategy, on three out of four occasions (i.e. where dolphins were observed feeding along either the shoreline or against a breakwall) group sizes were large, and ranged between 20 and 30. Also, on some occasions after lunging, pods of dolphins would join and circle around their apparent prey in a herding fashion and appear to take turns to dive into the centre of this "holding circle". In one case only was a small group of six individuals observed using this strategy. This apparent cooperative searching and securing of prey may maximise intake of, for example, smaller prey items (e.g. pilchards, "baitfish"). Würsig (1986) reported that when a small group (6 to 8) of dusky dolphins (*Lagenorhynchus obscurus*) found and herded a fish school to the surface, it was unable to hold the school while feeding. "...If however, the small dolphin group is joined by other nearby dolphin groups, the fish ball often becomes larger, and feeding activity may progress for several hours..." Würsig (1986).

The most striking form of apparent cooperative herding was observed at a unique topographical feature in the Bay, a "sand delta" (*sensu* Ivanovici, 1987) west of Bowen Island, where a discrete shallow area of sand (covering an area of approximately one sq. km) stabilised by seagrasses, drops off steeply from a depth of three metres to approximately 17 m (see Fig 2.2). An estimated 40 dolphins abreast, spread initially over approximately 500 m were observed swimming fast and shallow diving, until they converged in an arc along the edge of the delta, where a large school of baitfish appeared to be herded up onto the shallows. Feeding then continued over approximately 20 minutes with a variety of strategies pursued for varying durations, some dolphins in small groups, some individuals at the shoreline upside down (Smuts *et al.*, 1991) and others circling. This particular food-gathering strategy, focused as it was on a particular site, may represent a "local tradition" learnt by succeeding generations (Shane *et al.*, 1986,).

Due to the small number of feeding observations only one analysis was considered applicable and that was the distribution of these observations across quadrants of the Bay. The chi-square goodness-of-fit test indicated there was no significant difference in the number of feeding observations across quadrants (see Appendix 7 TABLE A7.10).

Only on a few occasions could prey species be identified with any confidence but the species suspected to be involved in the reported observations included sand whiting (*Sillago ciliata*), pilchard (*Sardinops neopilchardus*), mullet (e.g. *Mugil cephalus* or *Liza argentea*) and squid (species unknown). Hence, there are two important points to make prior to the presentation of ancillary fisheries data from the Bay. Firstly, the CSIRO and FRI studies indicate a significant degree of spatial and temporal variability in abundance and distribution of the fish and macroinvertebrate faunal resources studied. Secondly, because only potential prey items of bottlenose dolphins can be considered, discussion concerning the possible implications for the presence and distribution of bottlenose dolphins in Jervis Bay is only speculative.

7.4 Ancillary Fisheries Data

7.4.1 Data Description

The results discussed below are some of the findings from four projects undertaken for the DoD in Jervis Bay, as part of the Jervis Bay Marine Ecological Studies (JBMES). The studies were:

1. Mobile Fauna of Sandy Beaches, conducted by CSIRO (1991, 1994).
2. Assemblages of Fish and Macroinvertebrates Associated with Seagrass Habitats (Ferrell *et al.*, 1990 & 1992),
3. Fish Associated with Natural Rocky Reefs and Artificial Breakwaters in Jervis Bay (Lincoln Smith & Hair, 1990; Lincoln Smith *et al.*, 1992); and
4. Commercial and Recreational Fishing and Diving in Jervis Bay (Henry *et al.*, 1990; Williams *et al.*, 1993). The first three of these studies used external reference sites to compare with results obtained in Jervis Bay.

The "Mobile Fauna of Sandy Beaches" study investigated shallow unvegetated habitats off six sandy beaches in Jervis Bay. The lower intertidal zone, surfzone, and nearshore waters of less than 2 m depth were sampled, and all samples were taken above unobstructed sand, shoreward of any *Posidonia* seagrass. Three types of gear were used during both day and night to maximise the range of capture of species. Sampling was confined to high tides during full moons to limit variability due to change in tidal height and moonlight.

The study of "Assemblages of Fish and Macroinvertebrates Associated with Seagrass Habitats" investigated both *Zostera capricorni* and *Posidonia australis* beds and involved "...hierarchical sampling of a number of sites in a number of estuaries over time..." (Ferrell *et al.*, 1990). Seagrass beds are generally considered to be important habitats for fish and macroinvertebrates as "...there is usually a greater diversity and abundance of fish associated with seagrasses than with nearby bare substrata...[and]...many species of fish settle into seagrass from the plankton, thus seagrasses are important nursery habitats for fish..." (Bell & Pollard, 1989). *Zostera* is common throughout most of Australia and within Jervis Bay, although in this estuary it grows mainly in creeks entering the Bay (West, 1987). All of the *Zostera* sampling sites in this study were in creeks feeding the Bay and hence the results discussed in this Chapter relate primarily to *Posidonia. Posidonia* is found in only 20 of the 133 estuaries in NSW (West, 1987). Jervis Bay contains the largest area (687 ha) of this species in NSW, and the largest continuous bed is located in Hare Bay (see Fig. 2.3) (West, 1987). These beds of *Posidonia* are also probably the deepest in the NSW (4-10 m) although the species occurs to greater depths in other states (West, 1987).

The results below for the "Fish Associated with Natural Rocky Reefs and Artificial Breakwaters" study relate to surveys of four natural and four artificial reefs in Jervis Bay. "...Fish were counted one metre either side of a 60 m long transect line laid from a boat. Four transects were swum at each of the 15 sites surveyed; the order of conducting the surveys was randomised as best as possible, given the constraints of weather..." (Lincoln Smith & Hair, 1990). Fish were counted according to their relative sightability, and partitioned into two broad groups, i.e. cryptic or small, site attached fish difficult to locate; and larger, more active species, which were generally easy to locate (Lincoln Smith & Hair, 1990).

Some of the results from the commercial and recreational fishing components of the fourth study are considered here. An overview of the commercial fishing industry was produced from the monthly returns of all NSW commercial licence holders (Williams *et al.*, 1993). As well, a selection of commercial fisherman in Jervis Bay were issued with books in which to record specific details of their daily fishing operations by area (Williams *et al.*, 1993). Biological data were also collected on samples of the pilchard (*Sardinops neopilchardus*) catch (Williams *et al.*, 1993). The recreational fishery of Jervis Bay was examined using a creel survey to obtain estimates of fishing effort, catch per unit effort (CPUE) and anglers fish catch, as well as the use of a questionnaire to estimate anglers' expenditure (Williams *et al.*, 1993). These field data were collected over the interval August 1988 to February 1990.

7.4.2 Results and Comments with respect to recognised Prey species

The location of peak abundances/catches in the Bay of some of the recognised prey species of bottlenose dolphins, derived from the CSIRO and FRI studies are summarised below. See Figure 2.2 for the location of referred sites.

Mullet have been reported as an important prey item of bottlenose dolphins in the literature (Gunter, 1942; Lear & Bryden, 1980; Wells *et al.*, 1987; Shane, 1987). Three species of mullet were reported from the Bay: flat-tail mullet (*Liza argentea),* sand mullet (*Myxus elongatus)* and sea mullet (*Mugil cephalus)*. The first two were recorded in *Zostera* as most abundant in Currambene and Callala Creeks, respectively, by Ferrell *et al.* (1990). CSIRO (1994) regarded both these species as "juvenile through early adult migrants" to shallow sandy habitats, i.e. species whose small juveniles through to young adults were caught in large numbers during part of the year. Large catches of all size classes of sand mullet were also reported by CSIRO (1994) in shallow waters along a number of sandy beaches throughout the Bay (i.e. Hyams, Collingwood, Callala and Long Beaches and in Hare Bay). These data suggested that this species "...spawned over a large part of the year or...more than once a year...". CSIRO (1994) regarded sea mullet as "juvenile migrants" and reported more in creeks than off beaches, but more over sand than *Posidonia.* Unlike any other species recorded from the commercial catch, sea mullet was primarily taken from the northwestern corner of the Bay (Williams *et al.*, 1993). The majority of dolphin sightings reported in my surveys (see Section 4.4.2) and in two OSI sources (i.e. FRI and Dolphin Watch Cruise) were in the NW quadrant.

Shane (1987) noted that although "...bottlenose dolphins are classic generalists...one food item that occurs consistently in their diet is mullet (*Mugil* spp.)...[and that]...The worldwide distribution of *M. cephalus* is almost identical to the distribution of the bottlenose dolphin...". Unfortunately there are no detailed data on movements of these species within the Bay or whether they leave the Bay to move offshore for spawning. The latter event was reported by Shane (1990a) to occur in autumn/winter in the northern hemisphere. Shane (1990a) also noted colder temperatures make some fish sluggish and suggested such species may be the most vulnerable to capture by bottlenose dolphins in winter. However, although she found statistically significant relationships among the mean depth at which dolphins fed or travel/fed, season and temperature, the models were weak and she concluded no biological significance could be detected.

Some studies also noted pelagic schooling fish occurring in inshore waters, particularly as juveniles, as important components of the diet of *Tursiops* (Evans, 1980; Barros and Odell, 1990; Cockcroft and Ross, 1990b). The latter authors reported *Trachurus delagoae* and *Scomber japonicus* as major prey items of bottlenose dolphins off the South African coast. Neither of these species were reported from Jervis Bay. However, *Scomber australasicus* (slimy mackerel) was recorded from both the commercial and recreational catch. This species was abundant in the purse seine catch from the middle of the Bay (zone 4) and the majority caught in the recreational catch from zones 3,5, and 9 (Williams *et al.*, 1993). These latter zones include areas of deep *Posidonia* seagrass beds. The recreational fishing study noted higher catches of this and other species (i.e. *Platycephalus* sp. (sand flathead), *Sillago flindersi* (eastern school whiting) and *Loligo* sp. (squid/calamari)) in summer. Williams *et al.* (1993) suggested this may relate to the availability or catchability of fish as well as fishing effort, as these species school in large numbers in the Bay at this time. In reference to catchability, these authors suggested that "...cooler water during winter may be expected to affect the metabolism of cold blooded animals such as fish and cause a reduction in feeding and movement...rendering fish less susceptible to being caught by recreational fishermen...". However, possibly more vulnerable to capture by bottlenose dolphins, as noted previously (Shane, 1990a).

I observed dolphins feeding on what I believe were schooling pilchards (*Sardinops neopilchardus)* in Jervis Bay. The monthly commercial pilchard catch was higher in autumn (and winter) than in spring and were taken mainly from zone 4, but they occurred throughout the Bay (Henry *et al.*, 1990). CSIRO (1991) reported that very small pilchards were caught in large numbers at beaches around the Bay in July and October.

Salmon (*Arripes trutta*) was taken by the commercial fishery but there was some evidence of a decline in production (Henry *et al.*, 1990). Indigenous fishermen believe dolphins follow salmon north along the coast in winter but reported that a decline "in the salmon run" had meant fewer dolphins sighted in recent years. Small catches were made of this species by recreational anglers and these were mainly in zones 10 and 7, at the entrance to the Bay (Williams *et al.*, 1993). CSIRO (1994) reported this species as a "early adult migrant" of shallow sandy beaches in the Bay. Williams *et al.* (1993) referred to this species as a schooling winter fish and attributed a comparatively high catch per effort in winter, on one occasion, to the arrival of this species.

Squid and cuttlefish species are also frequently reported prey items of the bottlenose dolphin (Lear & Bryden, 1980; Barros & Odell, 1990; Cockcroft & Ross, 1990b; Corkeron *et al.,* 1990). Three species were recorded from seagrass habitats in Jervis Bay: *Sepioloida lineolata* (dumpling squid), *Euprymna stenodactyla* (elephant squid) and *Idiosepius notoides* (rocket squid) (Ferrell *et al.*, 1990). The latter species was the most abundant and was recorded from both *Posidonia* and *Zostera* beds, mainly in Moona Moona Creek (zone 1) and in southern *Posidonia* beds at Darling Road (zone 9) (Ferrell *et al.*, 1990). All species were, however, sparse in abundance compared with other estuaries. The commercial fishery identified squid as *Sepia* sp. and the catch was taken at several beaches around the Bay (Williams *et al.*, 1993). The largest catch, in contrast to seagrass studies was from zone 3 in the northeast corner of the Bay, followed by zone 9. The highest recreational catch of squid/calamari, identified as *Loligo* sp., was in zones 9 and 10 (Williams *et al.*, 1993). *Loligo* sp. was reported as one of the most abundant species recorded from this study.

The high proportion of sand flathead, squid/calamari and slimy mackerel in the recreational catch from Jervis Bay is interesting in that these are also noted as common to Port Phillip Bay, Victoria (Williams *et al.*, 1993). Port Phillip Bay is also known for its regular sightings of bottlenose dolphins (Weir *et al.*, 1994). Flathead (*Platycephalus* sp.) was reported by Corkeron (1990) as being taken "occasionally" by dolphins in southern Queensland. However, the reported distribution in deeper waters (i.e. on sandy bottoms at 15-25 m) of this species (Williams *et al.*, 1993) does not coincide with the distribution of dolphin sightings in Jervis Bay. CSIRO (1994), however, classified two species, *P. caerulpunctatus* and *P. fuscus* as "early adult migrants" to shallow sandy habitats and the commercial fishery reported the highest catches of the latter species from zone 3 (Williams *et al.*, 1993).

I also observed whiting at the time dolphins were feeding in shallow waters in Jervis Bay. *Sillago maculata* (trumpeter whiting) was reported by Corkeron (1990), as a prey item in southern Queensland. This species, and four others (i.e. *Sillago flindersi* (eastern school whiting); *Sillago ciliata* (sand whiting); *Haletta semifasciata* (rock or blue weed whiting); and *Sillago bassensis* were recorded from the Bay in the FRI and CSIRO studies. Sand whiting was one of the numerically dominant species and a resident, of sandy beaches (CSIRO, 1994). Peak catches varied between seasons and different sites but all were in the northern half of the Bay (CSIRO, 1994). Sand whiting was taken mainly in zones 3 and 9 by the commercial and recreational fisheries, respectively. Eastern school whiting were also reported in the commercial and recreational fisheries studies from a number of zones around the Bay with peak catches from both fisheries in zone 9. Rock whiting was reported from the commercial catch, mainly from zone 3 with a small number caught by recreational anglers from zone 9.

Fish of the family Sciaenidae (drums and croakers) were reported by Barros and Odell (1990) as an important prey item of bottlenose dolphins in the southeastern United States. However, no species from this fish family were reported in any of the above studies. *Pomadasys olivaceum* and *Pagellus belloti* from benthic habitats (i.e. inshore reef and sandy-bottom, respectively) were reported as important food items by Cockcroft and Ross (1990b). No species from the family Pomadasyidae (grunts) were reported in the above studies from Jervis Bay. However, three species from the family Sparidae (snappers), were recorded in the rocky reef and commercial and recreational fishing studies (Lincoln Smith *et al.*, 1992; Williams *et al.*, 1993), i.e. *Acanthopagrus australis* (yellowfin bream), *Pagrus auratus* (snapper) and *Rhabdosargus sarba* (tarwhine). Lincoln Smith *et al.* (1992) reported that none were dominant species in terms of percentage abundance and tended to be patchy on all reefs. The mean abundances of these three species at rocky reef sites were highest at Bristol and Murrays Points in the south (zone 9). In contrast, the largest reported commercial catches from January to December 1989, were from zone 3 (in the northeast of the Bay) for bream and tarwhine; and zone 11 (outside the Bay) for snapper (Williams *et al.*, 1993).

7.5 Discussion

The results of statistical analyses of opportunistic sighting information (OSI) from within Jervis Bay referred to in this Discussion are presented in the Summary Tables (Tables 7.6 - 7.8), at the end of the Chapter.

7.5.1 Opportunistic Sighting Information (OSI)

As indicated throughout this chapter, all four sources of OSI presented in Section 7.2 have unknown levels of bias, in terms of sampling effort, because none was a dedicated survey to record dolphins (i.e. the Dolphin Watch Cruise also undertook a sightseeing tour). These records were also made by a number of reporters with variable sighting and data-recording experience. Thus, these reports cannot be assumed to be completely accurate.

FRI data (see Section 7.2.1) are excluded from this summary, unless otherwise indicated, as only monthly abundance totals were given. The total number of sightings recorded from the remaining three OSI sources was 548, involving an estimated 5,242 dolphins. These sightings were recorded on 325 days during a 28 month period. On 17 days multiple sightings occurred among the three data sets.

No results were significant in the smaller two data sets, i.e. land-based and vessel-based sightings (see Tables 7.6 & 7.7). However, similar trends in the data across the three OSI sources, where data were available, and significant results from the Dolphin Watch Cruise are summarised below:

Group Composition

* the mean sighting sizes fall within the most common mean group size range (2-15) reported by Wells *et al.* (1990), i.e. the three data sets ranged between 8.8 and 12.9 (S.E. 0.4 to 1.15) dolphins;

* no significant difference was found in the mean number of animals per sighting event with and without calves present;

* the total number of calves per sighting event and per survey day ranged between 0 and 4, with the majority of calf sightings being of one calf per sighting (65% of 46 sighting events); and

* calves represented between <1.0 and 2.6% of all animals observed.

Habitat Variables

* most sightings were in nearshore waters, i.e. < 500m from the shore or in water ≤10 m (91% of 248 sightings with distance or depth records);

Environmental Variables

* there was a significant seasonal difference in the distribution of sighting events for the Dolphin Watch Cruise data set (n=444) when "sighting effort per day" was considered (with almost 49% of sightings recorded in summer and 31% in autumn, both more than expected);

* there was a significant seasonal difference in the mean number of dolphins, for the Dolphin Watch Cruise data set with the mean number in spring significantly more than summer.

* there was a significant seasonal difference in the mean number of calves, for the Dolphin Watch Cruise data set with autumn indicating the greatest mean;

* most sightings were in the northern half of the Bay (61% of 538 sightings using FRI zones 1, 2, 3 and 5 only or using my quadrant demarcation);

* most northern sightings were in the NW quadrant (58% of 328 sightings in FRI zone 1 or the NW quadrant);

* most calves were sighted in the northern half of the Bay (64% of 36 individuals);

* most northern sightings of calves were in the NW quadrant (57% of 23 sightings);

* only seven sightings were recorded in FRI zone 4, i.e. the middle of the Bay (almost 2% of 441 sightings);

* a significant difference was found for the total number of animals sighted across zones, in the Dolphin Watch Cruise data set with zone 5 indicating the greatest mean number followed by zones 3 and 2; and

* the distribution of sighting events were significantly different across time of day categories for the Dolphin Watch Cruise data set. Data suggested this result was related to effort.

Abundance Patterns and Density Estimate

* some dolphins appear to be present in the Bay throughout the year (i.e. across all four data sets there was no single month that animals were not sighted);

* calves were recorded in all months of the year across three OSI data sets;

* a significant difference in the total number of calves sighted across three years was found for the Dolphin Watch Cruise data set when annual cruise effort was considered, with the highest number of calves recorded in 1992 (61%), which was higher than expected on the basis of reported cruise effort;

* a significant difference in the total number of animals sighted across seasons was found for the Dolphin Watch Cruise data set when cruise effort was considered, with the number recorded in autumn (33%) being significantly higher than expected on the basis of cruise days;

* a significant difference in the total number of calves sighted across seasons was found for the Dolphin Watch Cruise data set when cruise effort was considered,

with the highest number of calves recorded in autumn (69%), which was higher than expected on the basis of reported cruise effort; and

* the mean density estimate for the whole study area based on the Dolphin Watch Cruise data set was 0.14 *Tursiops*/sq. km.

The trends described above which were also seen in both my S&E & NTS data sets (see Section 4.4.2) were:

Group Composition

* the mean sighting size for all data sets fall within the most common "group" size range (2-15) reported by Wells *et al.* (1990);

* the majority of calf sightings were of single calves; and

* the maximum number of calves, sighted at any one sighting event and on a single survey day (i.e. both 4), fell within the range of my results (i.e. 3 and 6).

Environmental Variables

* most sightings in nearshore waters, i.e. within 500 m of the shore or in water ≤10 m;

* few sightings recorded from the middle of the Bay; and

* the majority of sightings made in the northern half of the Bay and these mainly in the NW quadrant.

Abundance Patterns

* some dolphins and calves appear to be present in the Bay throughout the year;

* seasonal differences in total abundance, with both summer and autumn having the highest numbers;

* seasonal differences in the total number of calves sighted, with the autumn peak reported for the NTS data set and as a secondary peak for the S&E Survey data; and

* the majority of calves were sighted in the northern half of the Bay.

Density Estimate

* a similar density estimate for the whole study area (i.e. S&E=0.13 *Tursiops* /sq. km; NTS=0.12 *Tursiops* /sq. km).

The proportion of calves observed in each of these data sets (<1.0 and 2.6%) were lower than for my surveys, i.e. 7.6% (S&E) and 5.8%(NTS). I suspect this is less likely to reflect fewer calves in the Bay on these days than differences in observer experience, the duration of observations and boat handling strategies. These differences may also explain the only other contrasting trend between these data sets and my survey results. My data indicated mean sighting sizes were larger when calves were present whereas no differences in sighting sizes with and without calves were found for the above three data sets (see Tables 7.6 - 7.8a).

These different sources of information suggest the possibility of overlap between different observational platforms for sightings made on the same day. While the exact level of repetitive sightings each day of the same group , or groups of similar composition, is impossible to assess without individual identification, this should be noted in terms of managing the increasing tourism activities based on dolphins in the Bay. Currently there is only one primary tourist operator. However, if this was to increase there may be a limit to the amount of time animals will tolerate boat proximity. Such activity may negatively impact in terms of noise disturbance, limiting foraging success or disrupting dolphin social activities. While the difficulty inherent in determining the effects, if any, that such impacts may have is recognised, an important first step would be to determine the number of dolphins using the Bay and to identify potential individual and herd home ranges. This baseline information may provide useful guidance for conservation managers, in terms of the number and type of tourist operations based on dolphins in the Bay that may be able to be sustained by the animals.

7.5.2 Feeding Observations and Ancillary Fisheries Data

The four external reference estuaries used in the CSIRO and FRI studies cover a geographic range along the NSW coast of approximately 225 km. None of these estuaries are known to support a resident population of bottlenose dolphins nor are they anecdotally known to have regular sightings of this species. However, conclusions regarding the degree of "uniqueness" of fish and macroinvertebrate resources in Jervis Bay, in terms of either abundance or diversity, appears to vary between these studies.

The results of the CSIRO (1994) sandy beach study indicated catches from different sites (within Jervis Bay and in other bays) differed more than catches from different bays. The rocky reef study indicated that faunal assemblages were quite similar among bays, although more species were recorded from Jervis Bay as well as a greater proportion of more unique species. *Zostera* was identified as common in NSW estuaries and the "...assemblages of fish and macroinvertebrates associated with *Zostera* in Jervis Bay were not markedly different to those in the external reference areas..." (Ferrell *et al.*, 1992). However, the fauna of *Posidonia* in Jervis Bay was different from the two external reference estuaries (Ferrell *et al.*, 1990). The commercial and recreational fishing studies both noted the diversity of species taken in Jervis Bay and differences in composition of the catch from elsewhere in NSW. Hence, any uniqueness of Jervis Bay as compared with other NSW estuaries, suggested by the above studies, possibly relates to: i) faunal diversity; ii) "apparent" abundance of certain species, i.e. flathead, pilchards, squid/calamari and slimy mackerel; and iii) the distinctive fish fauna of *Posidonia* beds. Whatever the causes of these differences between Jervis Bay and other estuaries, they may be important in explaining the Bay's high usage by bottlenose dolphins. The discussion in this Chapter focuses on the abundance and distribution of potential prey resources and the possible implications for dolphin movements in Jervis Bay.

The FRI and CSIRO studies indicate the great range of habitats throughout Jervis Bay, particularly in the nearshore environment. It is not surprising then that the potential prey items of bottlenose dolphins described previously (see Section 7.4.2) appear spread throughout Jervis Bay. Interestingly, where either sites (from rocky reef, seagrass or sandy beach studies) or zones (from commercial and recreational fisheries studies) were given for these 16 potential prey items (i.e. 14 fish species; squid and cuttlefish species combined as a single group; and flathead sp. combined as a single item), only two species were reported across all studies, to have peak abundances/catches in the northern half of the Bay only (i.e. zones 1, 2, 3 and/or 5). Furthermore, both of these species peak abundances/catches were in the NW of the Bay. *Liza argentea,* was recorded in the *Zostera* studies as most abundant in Currambene Creek (i.e. zone 1); and the large commercial catch of *Mugil cephalus* was reported from zone 1. These peaks probably relate to the fact that the largest four creeks entering the Bay (and in which the *Zostera* study was done) are in the northern half of the Bay, three in the NW quadrant and one in the north of the NE quadrant. If mullet are preferred prey species, then this may explain the focus of dolphin sightings in the NW quadrant. However, only 13% of the few feeding observations made were recorded in this quadrant and only one of these three was over sand, the others were over rock or seagrass substrata (see Table 7.5).

Furthermore, the three reported incidences of "edge feeding" (*sensu* Shane, 1990a) along the surfline may suggest baitfish is an important component of the dolphins' diet in Jervis Bay. CSIRO (1994) indicated that baitfish comprised 95.8% of the total catch of fish from shallow waters off sandy beaches and some species of baitfish are plentiful in these habitats throughout the year. However, CSIRO (1994) also reported that a small number of species may rely on nearshore waters as a nursery, and that other older fish appear to use the habitat for limited periods of the year. Such species were sand whiting and sand mullet which may also be the target species for dolphins feeding in these habitats (e.g. observations made off Currambene Creek and possibly Creswell Breakwall, see Table 7.5). West (1987) indicated that sandy beaches make up approximately 34.5 km of the foreshores of Jervis Bay, approximately 70% of the total coastline. CSIRO (1994), in a review of the literature concerned with the composition of sandy beach fauna, noted that while "...estuaries are typically considered a major nursery for fish and invertebrates...in South Africa and Western Australia, nearshore areas off sandy beaches are a larger part of the coast than estuaries; therefore, nearshore zones may be the most important nursery for many species...".

My survey findings indicated the importance of the rarer substrata of seagrass and rocky complex areas in terms of the distribution of dolphin and calf sightings, abundance, and density patterns (see Section 4.4.2). Also, transect sightings indicated a significantly greater number of calves were recorded over rocky areas at an average depth of 8 m than at any other depth/substratum combination (see Section 4.4.1). This result pertains specifically to Plantation and Callala Points (see Section 4.4.1). Unfortunately neither of these two reefs were used in the main sampling study reported by Lincoln Smith & Hair (1990). Hence, it is impossible to speculate on the possible species taken by dolphins at these reefs.

Thirty-three percent of feeding observations in this study were made over rock, four at Plantation Point and one at Callala Point while only two (13%) were over seagrass (see Table 7.5). Green Point marks the eastern entrance of Hare Bay and Callala Point the western entrance (see Fig. 2.2). CSIRO (1994) noted that protected beaches yielded the greatest number of species and individuals including baitfish and juveniles. CSIRO (1994) reported that Hare Bay was the most protected site with extensive offshore *Posidonia,* and tended to yield the largest numbers of many species, including small fish and new recruits. Green Point was noted for its fish species diversity and abundance. Furthermore, "...several fish species...which occurred as juveniles or adults at Green Point, generally settle as small juveniles in estuarine habitats, such as seagrass beds and mangrove-lined creeks..." (Lincoln Smith *et al.*, 1992). This suggested link between the reef at Green Point and nursery areas (such as seagrasses and creeks) may also be exhibited by Callala Point given its similar location with respect to seagrass beds and Callala Creek. However, this is not likely to explain the species assemblage at Plantation Point because, although a small area of seagrass is adjacent, no creek is present. Plantation Point, due to its location and as the deepest reef in the Bay is likely to have a species assemblage distinct from Green and Callala Points.

In summary, like the distribution of potential prey species indicated by the CSIRO and FRI data, feeding observations also suggest that dolphins forage and feed throughout the Bay, particularly in nearshore waters. However, the majority of dolphin sightings in my surveys and from OSI sources were reported in the northern half of the Bay, mainly in Hare Bay, around Callala Point and along Callala Beach. Hence, I suggest it is not simply the distribution and abundance patterns of potential prey species which contributes to the geographic pattern of dolphin sightings in Jervis Bay. This hypothesis is discussed further in Chapter 8.