Whale shark log sheet data 1995-2001

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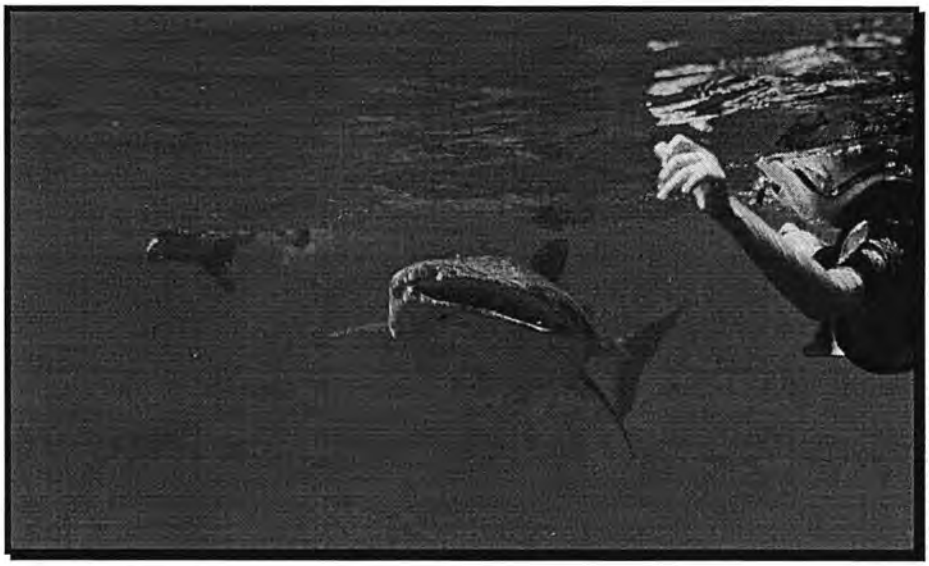

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Summary

In this report, the log sheet data collected by whale shark tour operators in Ningaloo Marine Park during the 1995 to 2001 paying seasons are summarised. CALM issued between 13 and 15 whale shark tourism interaction licences each year and 82% of the 95 licence holders conducted tours between 1995 and 2001. Tour vessels operated during 94% of the 427 days of the 1995 to 2001 paying seasons and a mean of 4.1 vessels operated per day for all years combined. An average of 232 tours were conducted per year and 28% of the maximum of 5,795 tours possible were conducted between 1995 and 2001. Tours averaged about 5½ hours in duration and whale sharks were encountered during 86% of the 1,621 tours conducted between 1995 and 2001.

The number of tours conducted and many elements of tour operations were low in 1999 due to the impact of Cyclone Vance. Many aspects of the industry were also low in 1998, perhaps because whale sharks aggregated south of the usual search area in the absence of the Ningaloo Current, which carries feeding resources northward.

A total of 18,327 passengers participated in whale shark interaction tours between 1995 and 2001 and the total number of passengers per year increased by 45% from 1,920 to 3,505 during that period. The mean number of passengers carried per tour was 11.5 or about half the maximum allowable of 20 under the code of conduct.

There were 3,241 contacts with whale sharks between 1995 and 2001, most commonly at 11:00hrs and the majority of contacts were reported as good or excellent in all years. The mean number of contacts per tour fluctuated between 1995 and 1997, then declined from 2.49 in 1998 to 1.77 in 2001. A correlation indicated that the number of contacts per week was a function of the number of tours per week which was dependent upon the number of people booked on tours per week for all years combined. Mean contact time increased linearly with the mean number of swimmers per contact per day. For all years combined, mean contact time of 24min was below the maximum of 60min allowed and the mean number of swimmers per contact of 9.4 was also below the maximum of 10 swimmers allowed under the code of conduct.

Whale sharks were most commonly contacted in water averaging 37m deep, moving north, south or circling and between Tantabiddi and Osprey Bay in the north and Point Clotes and Coral Bay in the south in all years. The sex of whale sharks contacted was biased toward males in all years and the proportion of sharks contacted that were male was greater in the second half of the paying season for all years combined.

Whale sharks contacted were significantly smaller in 2000 and 2001 than other years and were contacted in significantly deeper water from 1998 to 2001 than other years. On a weekly basis, sharks contacted were significantly smaller during weeks 2 to 4 than other weeks and were contacted in significantly deeper water in weeks 2, 3, 4 and 8 than other weeks of the paying season. Female sharks and those of undetermined sex were contacted in significantly deeper water than male sharks. A correlation between whale shark length, depth of water in which they were contacted and contact time suggested contact time was greater for large sharks which were contacted in shallower water than small sharks.

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1. Introduction

The whale shark was first described by Dr Andrew Smith from the holotype harpooned in Table Bay, South Africa in 1828 (Smith 1828), which is held in the Museum of Natural History, Paris (Compagno 1984). The species belongs to the Order Orectolobiformes, which consists of 33 mostly bottom-dwelling species (Compagno 1988), including nurse sharks (Ginglymostomatidae), leopard sharks (Stegostomatidae) and wobbegongs (Orectolobidae). The whale shark is the only member of the Family Rhincodontidae and is classified according to three prominent ridges along its upper flanks and its checkerboard body patterning (Last and Stevens 1994). Whale sharks have a widespread global distribution around the equator between 30°N and 35°S, occurring in all tropical and warm temperate seas except the Mediterranean (Compagno 1984, Wolfson 1986). In Australian waters, whale sharks are found mainly off Ningaloo Reef in north Western Australia, the Northern Territory and Queensland, with scattered reports from New South Wales and South Australia (Wolfson 1986, Last and Stevens 1994).

Information on the biology and ecology of the whale shark is lacking and consists mostly of anecdotal sightings (Wolfson 1986). The species probably gives birth to live young via an ovo-viviparous mode of reproduction where the egg case hatches *in utero* (Wolfson 1983, Colman 1997b). Very few juvenile whale sharks have been recorded, there are no published records of sharks between 93cm and 3m in length and the largest whale shark ever recorded was around 14m in length (Colman 1997b). Very little is known about the growth rate, ageing and size at sexual maturity in whale sharks (Colman 1997b), but sexual maturity probably occurs at over 9m or 30 years of age and the species may have a life span of over 100 years (Taylor 1994b).

The whale shark is listed as vulnerable under the *Environmental Protection and Biodiversity Conservation Act 1999* and the *2000 IUCN Red List of Threatened Species* (Hilton-Taylor 2000) because the world population has or may potentially undergo a substantial decline in the immediate future due to harvesting. Apart from collisions with vessels, whale sharks are harmless to humans (Compagno 1984) and nature-based tourism industries involving interaction with whale sharks have developed at Ningaloo Reef, the

Galapagos Islands, the islands of the Andaman Sea off the west coast of Thailand and the Sea of Cortez and Baja, California in the eastern Pacific (Colman 1997b).

Up to 400 whale sharks gather in Ningaloo Marine Park from March to June each year in response to a high abundance of coral spawn and other prey organisms (Taylor 1989, Taylor 1990, Taylor 1991, Taylor 1994a, Taylor 1994b, Osborne and Williams 1995). The aggregation of whale sharks on Ningaloo Reef is associated with the seasonal, southerly movement of a warm water mass, known as the Leeuwin Current (Simpson 1991, Taylor 1996, Taylor and Pearce 1999, Wilson *et al.* 2001). A greater number of whale sharks appear to aggregate on the reef in years when the Leeuwin Current is strongest, probably because the current assists in the transport of the sharks and harbours an abundant food source (Wilson *et al.* 2001). On a more local scale, a counter current or the Ningaloo Current, which runs in a northerly direction along the reef front, may disperse coral larvae (Taylor 1996, Taylor and Pearce 1999) and determine the number of sharks on the northern part of the reef (Simpson 1991, Taylor and Pearce 1999). In years when the Ningaloo Current is lacking or running south, low numbers of whale sharks may be present on the reef, while greater numbers appear to be present in years when a strong northerly current flows along the reef front (Simpson 1991, Taylor 1996, Taylor and Pearce 1999, Wilson *et al.* 2001).

The annual congregation of whale sharks on Ningaloo Reef led to the development of a nature-based tourism industry in Ningaloo Marine Park in 1989 (Colman 1997a). The industry is managed by the Department of Conservation and Land Management (CALM) which has obligations to facilitate the development of sustainable tourism in the park while ensuring that the whale sharks are not subject to an unacceptable level of disturbance (Colman 1997a). The industry is managed by licensing a limited number of charter vessels for whale shark interaction tours and by a code of conduct under the *Wildlife Conservation Act 1950* and *Conservation and Land Management Act 1984* (Colman 1997a). Compliance with licence obligations and the code of conduct is monitored by CALM officers via boat patrols, aerial surveillance and an operator log book (Colman 1997a). The log book, which was first introduced in 1995, contains log sheets which are filled out by tour operators on a daily basis and is used to record information on tours, passengers, contacts with whale sharks and the whale sharks themselves. The

information collected on the log sheets is used by CALM to monitor the industry, to provide feedback to licence holders on their operations and to manage the industry (Colman 1997a). In this report the log sheet data collected by whale shark tour operators during the 1995 to 2001 paying seasons are summarised.

2. Methods

In Ningaloo Marine Park, whale shark tours are operated under the Code of Conduct - Commercial Whale Shark Interaction Tours (*Conservation and Land Management Act 1984, Section 101, Conservation and Land Management Regulations 1992, Part 5*) and the Wildlife Conservation Close Season for Whale Sharks Notice 1996 (*Wildlife Conservation Act 1950*). The legislation states that a maximum of 20 passengers may be carried per tour vessel, only one vessel may operate at a time within the contact zone of a 250m radius around the whale shark for no more than 90 minutes and at a speed of no more than 8 knots; vessels may approach the shark no closer than 30 metres; swimmers are limited to a maximum of 10 in the water at one time and interaction between whale sharks and swimmers must not exceed 60 minutes; swimmers must not attempt to touch, ride a shark or impede its movement; swimmers must not approach a shark closer than 3 metres from the head or body and 4 metres from the tail; and swimmers must not take flash photography or use motorised propulsion aids.

Among other means, compliance with licence obligations and the code of conduct is monitored via a log book which is filled out by tour operators (Colman, 1997a). The log book scheme was first introduced during the 1995 paying season to record information on the number of vessels and tourists participating in tours and data on whale shark contacts and the sharks themselves (Colman, 1997a). An example of the log sheet is shown in Figure 2.1 below.

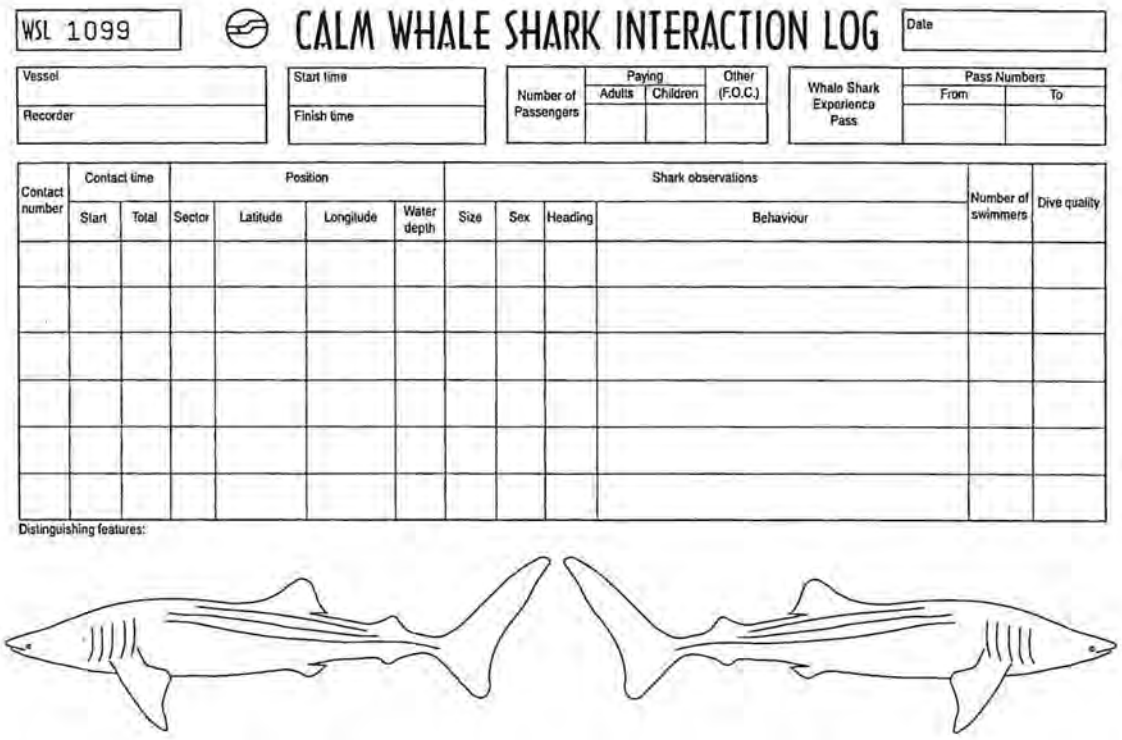
The majority of tour vessels sail from the boat ramp or mooring near Tantabiddi Passage and two tour companies operate from Coral Bay. On departure, vessel staff record the date, vessel name, name of the person recording the information (for validation of the data by CALM), range of whale shark experience pass numbers, time the vessel departed from the jetty/ramp and the number of adult, child and passengers carried free of charge

(including those who did not see a whale shark on a previous tour and associates of vessel staff) on the log sheet (Figure 2.1). At the end of the tour, vessel staff record the time the vessel returned to the jetty/ramp (Figure 2.1), which is subtracted from departure time to calculate total tour time.

Most whale shark tour boats are about 14-18m in length and usually have a flybridge and large cockpit area (Stevens 1994). A light aircraft is used to locate whale sharks and spotting by this method begins about 09:00hrs and continues until about 13:00hrs when the strength of the sea-breeze limits aircraft operations (Stevens 1994). The skipper of the vessel is directed toward the shark by the pilot and the vessel moves ahead of the shark to allow swimmers to enter the water in front of the approaching shark, either from the vessel itself or from an inflatable boat (Davis 1998). Escorted by vessel staff, groups of swimmers swim with the shark until they become tired and are picked up by the boat (Stevens 1994).

The following data are collected for each whale shark interaction, or contact of the day: time the shark was first contacted; total time of contact; sector (corresponding with a grid map in the log book); geographic position using a GPS; water depth using an echo-sounder; number of swimmers; and quality of the contact (Figure 2.1). In conjunction with tourists, tour operators record the following information on each whale shark contacted: length; sex (by the presence claspers for males or absence for females); behaviour; and distinguishing features such as marks, scars or tissue damage (Figure 2.1).

The log sheet shown in Figure 2.1 was used from 1996 to 2001, but in 1995 the log sheet design differed slightly from that shown as it did not include the breakdown of passengers (only total passengers), number of swimmers per contact, water depth, location of contacts or markings of sharks. From 1995 to 1997, the length of the paying season varied with the timing of coral spawning each year (A. Meyer pers. comm.), but from 1998 to 2001, the paying season was set by CALM from 1 April to 31 May each year. For clarity and ease of comparison, in this report only the period from 1 April to 31 May is taken into account each year, so the results may differ from previous analyses. As the paying season is two months in length, the first eight weeks of the season are seven days in length, while the final or ninth week of the season is five days in length.



WSL 1099

CALM WHALE SHARK INTERACTION LOG

Date

Vessel	Start time	Number of Passengers	Paying		Other (F.O.C.)	Whale Shark Experience Pass	Pass Numbers	
Recorder	Finish time		Adults	Children			From	To

Contact number	Contact time		Position				Shark observations				Number of swimmers	Dive quality
	Start	Total	Sector	Latitude	Longitude	Water depth	Size	Sex	Heading	Behaviour		

Distinguishing features:

Figure 2.1 Whale shark interaction log sheet.

The data collected on the log sheets in Ningaloo Marine Park during the 1995 to 2001 paying seasons were entered into a spreadsheet data base, analysed, tabled and charted to summarise tour, passenger, contact and shark information. Information collected on whale shark markings and behaviour was not presented in this report due to the limited value of data (see Chapman (2001) for a discussion).

Variation in the data and relationships between selected variables were examined using the following statistical analyses (s.e. = standard error). Variation in the mean number of passengers per tour between years was tested using one-way analysis of variance with post-hoc Tukey's Honestly Significant Difference (HSD) test to determine which years varied from the others. The data were normally distributed.

The relationship between the mean duration of contact with whale sharks and the mean number of swimmers per contact per day for all years combined was examined using a linear regression. Mean contact time per day was log transformed to normalise the data and mean number of swimmers per contact per day was normally distributed.

The relationship between the total number of passengers participating in whale shark tours, the total number of tours conducted and the total number of contacts with whale sharks per week for all years combined was examined using Kendall's coefficient of concordance. The relationship between whale shark length, the depth of water in which they were contacted and contact time for each contact for all years combined was also examined using Kendall's coefficient of concordance.

Variation in the length of whale sharks with year, week and sex was tested using repeated measures analysis of variance due to possible repeated observations and the robust nature of the analyses. Variation in the depth of water in which contacts with whale sharks took place with year, week and sex was also tested using repeated measures analysis of variance. Post-hoc Dunnett's test were used to determine which years, weeks and sex categories varied from the others for shark length and the depth of water in which they were contacted.

3. Results

3.1 Tour operations

Between 13 and 15 whale shark interaction licences were issued by CALM to tour operators each year from 1995 to 2001 (Table 3.1). The proportion of licence holders that conducted tours varied widely between years from 38% in 1999 to 100% in 1997 and for all years combined, 82% of the 95 licence holders conducted whale shark interaction tours (Table 3.1).

For most years, the mean number of vessels that operated per day ranged from around 4 to 5, except for 1998 and 1999, when a mean of 3.6 and 2.4 vessels conducted tours per day respectively (Figure 3.1). The mean number of vessels that operated per day ranged from 2.4 in 1999 to 4.9 in 1997 (Figure 3.1) and was 4.1 (s.e. 0.1, $n = 400$) for all years combined.

Table 3.1 Number of licences issued, number of licences used and number of licence holders that conducted tours as a proportion of the total number of licences issued for the 1995-2001 paying seasons.

Year	Licences issued	Licences used	Number of licence holders that conducted tours as a proportion of the total number of licences issued (%)
1995	15	14	93
1996	14	13	93
1997	13	13	100
1998	13	12	92
1999	13	5	38
2000	14	11	79
2001	13	10	77
All years	95	78	82

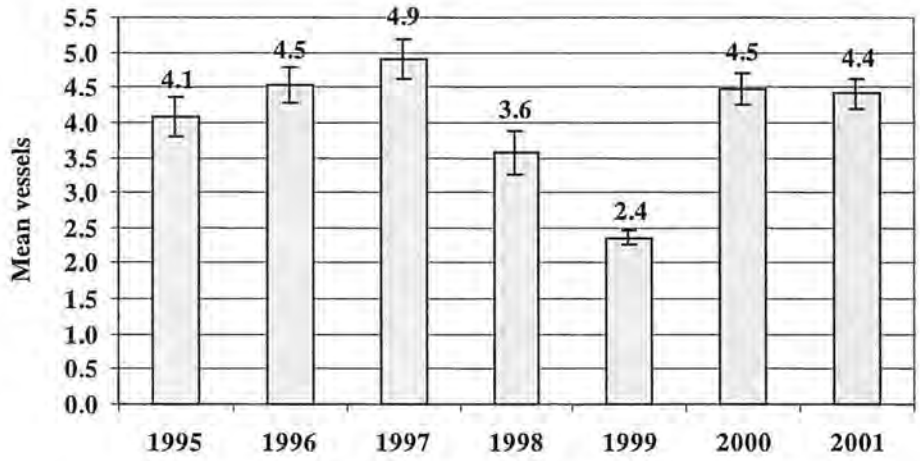


Figure 3.1 Mean number of vessels that operated per day for the 1995-2001 paying seasons (bars show standard error).

Tour vessels operated during 94% of the 427 days of the 1995 to 2001 paying seasons and operated during the majority of the 61 days of the paying season in most years, except in 1998 when vessels operated during 52 days or 85% of the days in the paying season (Table 3.2). The mean number of tours conducted per year was 232 (s.e. 19, $n = 7$) and the total number of tours conducted each year was similar to the mean for all years, except in 1998 when the number of tours conducted was 20% below the average for all years and 1999 when the number of tours conducted was 41% below the average for all years (Table 3.2). The number of tours conducted was below 35% of the maximum number of tours

possible each year from 1995 to 2001 (Table 3.2). The number of tours conducted as a proportion of the maximum number of tours possible varied widely between years from 17% in 1999 to 34% in 1997 and 2001 and was 28% for all years combined (Table 3.2).

Table 3.2 Number of days in the paying season, number of days vessels operated, number of licences issued, maximum number of tours possible, number of tours conducted and the number of tours conducted as a proportion of the maximum number of tours possible for the 1995-2001 paying seasons. Maximum number of tours possible was calculated as the number of days in the paying season x the number of licences issued per year.

Year	Days in paying season	Number of days vessels operated	Licences issued	Maximum number of tours possible	Number of tours conducted	Number of tours conducted as a proportion of the maximum number of tours possible (%)
1995	61	59	15	915	241	26
1996	61	58	14	854	263	31
1997	61	55	13	793	270	34
1998	61	52	13	793	186	23
1999	61	58	13	793	137	17
2000	61	57	14	854	255	30
2001	61	61	13	793	269	34
All years	427	400	95	5,795	1,621	28

The proportion of tours that encountered a whale shark, or the strike rate was high in all years, varying by only 14% from 81% in 1995 to 95% in 1996 (Figure 3.2). Whale sharks were encountered during 1,400 or 86% of the 1,621 tours conducted between 1995 and 2001.

The mean duration of all tours conducted from 1995 to 2001 was 5 hours and 42 minutes (Table 3.3) and the duration of tours varied little between years. For instance, tours without a whale shark encounter ranged from a mean of about 6 hours to 7 hours in duration and tours with an encounter ranged from an average of around 5 hours to 6 hours and 15 minutes in duration between years (Table 3.3). For tours without and with a whale shark encounter combined, mean tour time varied by only about 1 hour and twenty minutes between the shortest mean tour time of 4 hours and 58 minutes in 1996 and the longest mean tour time of 6 hours and 18 minutes in 1995 (Table 3.3). For all years combined, mean tour duration was about 1 hour longer for tours without a whale shark encounter than for tours with a whale shark encounter (Table 3.3).

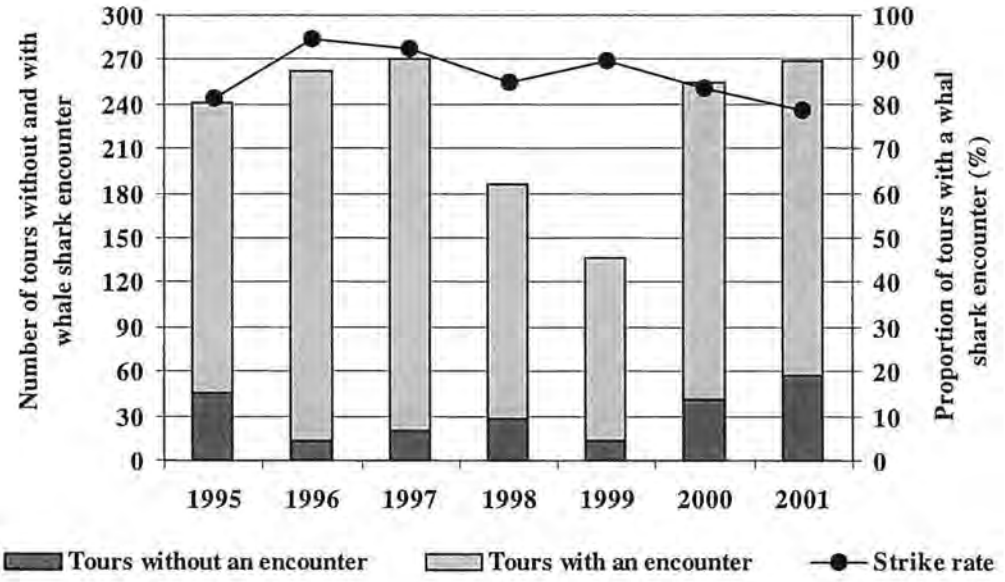


Figure 3.2 Number of tours without and with a whale shark encounter and strike rate for the 1995-2001 paying seasons.

Table 3.3 Mean duration of tours without and with a whale shark encounter, all tours and difference between the mean duration of tours without and with a whale shark encounter for the 1995-2001 paying seasons.

Year	Tour duration (hh:mm)									
	Tours without an encounter			Tours with an encounter			All tours			Difference between tours without and with an encounter
	Mean	s.e.	*n*	Mean	s.e.	*n*	Mean	s.e.	*n*	
1995	6:39	0:18	35	6:13	0:09	176	6:18	0:08	211	0:25
1996	5:49	0:22	11	4:56	0:07	231	4:58	0:07	242	0:52
1997	6:38	0:17	16	5:29	0:06	212	5:34	0:06	228	1:08
1998	6:40	0:15	28	5:36	0:08	139	5:46	0:07	167	1:04
1999	5:49	0:25	14	5:18	0:10	113	5:21	0:10	127	0:31
2000	6:25	0:07	40	6:01	0:06	211	6:05	0:05	251	0:23
2001	6:55	0:08	55	5:23	0:08	183	5:44	0:07	238	1:32
All years	6:35	0:05	199	5:33	0:03	1,265	5:42	0:02	1,464	1:01

3.2 Passengers

From 1995 to 2001, 18,327 passengers participated in whale shark interaction tours in Ningaloo Marine Park, including passengers who participated in more than one tour and passengers carried free of charge (Table 3.4). The total number of people that participated in whale shark tours steadily increased between 1995 and 2001 (Figure 3.3), by 45% from 1,920 to 3,505 (Table 3.4). The number of children that participated in tours varied widely between years from 13 in 1999 to 173 in 2001, but excluding 1998 and 1999, the number of passengers carried free of charge ranged between about 500 and 600 each year (Table 3.4).

The most common number of passengers per tour was 10, the mean number of passengers per tour ranged from 8.0 in 1995 to 13.6 in 1998 and was 11.5 for all years combined (Table 3.4). The mean number of passengers per tour varied significantly between years ($F = 40.42$, d.f. = 6,393, $P < 0.0001$) and a Tukey's HSD test showed that the mean number of passengers per tour was highest in 1998, 1999 and 2001 (Table 3.4, Figure 3.3) when the mode of passengers per tour was also high (Table 3.4), second highest in 2000, third highest in 1996 and 1997 and lowest in 1995 (Table 3.4, Figure 3.3).

Table 3.4 Number of adult, child and free of charge (FOC) passengers and total passengers that participated in whale shark tours and mean and mode of passengers per tour for the 1995-2001 paying seasons (*n* for mode is the number of times the value was recorded). The total number of passengers exceeded the sum of adult, child and free of charge passengers in 1998, 2001 and for all years combined because only total passengers was recorded on some log sheets.

Year	Number of passengers				Passengers per tour				
	Adult	Child	FOC	Total	Mean	s.e.	*n*	Mode	*n*
1995	Not recorded			1,920	8.0	0.2	240	6	48
1996	2,086	122	518	2,726	10.6	0.3	258	10	40
1997	2,102	120	598	2,820	10.8	0.3	261	6,10	40
1998	2,054	148	316	2,517	13.6	0.4	185	20	35
1999	1,635	13	130	1,778	13.2	0.4	135	14,16,17	21
2000	2,444	101	516	3,061	12.2	0.3	251	7	26
2001	2,555	173	483	3,505	13.1	0.3	267	17	36
All years	12,876	677	2,561	18,327	11.5	0.1	1,597	10	174

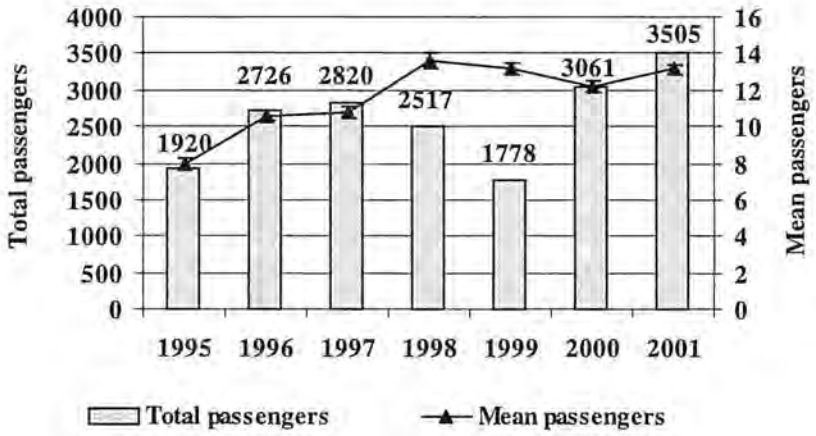


Figure 3.3 Total number of passengers that participated in whale shark interaction tours per year and mean number of passengers carried per tour for the 1995-2001 paying seasons (bars show standard error).

3.3 Contacts

The mean number of contacts with whale sharks per tour was 2.14 for all years combined and varied by 0.80 contacts between years from 1.77 in 2001 to 2.57 in 1996 (Table 3.5). The mean number of contacts per tour fluctuated between 1995 and 1997 (Figure 3.4), then declined from 2.49 in 1998 to 1.77 in 2001 (Table 3.5). The total number of contacts varied widely between years (Figure 3.4) from 296 in 1999 to 710 in 1996 and there were 3,241 contacts with whale sharks between 1995 and 2001 (Table 3.5). Contact with whale sharks occurred between 10:00hrs and 12:00hrs each year and most commonly occurred at 11:00hrs for all years combined (Table 3.5).

Table 3.5 Mean number of contacts per tour, total number of contacts per year and most common time of contact with whale sharks per year for the 1995-2001 paying seasons.

Year	Contacts per tour			Total number of contacts	Most common time of contact (hh:mm)	*n*
	Mean	s.e.	*n*			
1995	1.85	0.06	241	380	11:45	17
1996	2.57	0.07	263	710	10:30	27
1997	1.89	0.05	270	557	10:00	35
1998	2.49	0.08	186	459	11:00	19
1999	2.12	0.08	137	296	11:00	20
2000	2.03	0.06	255	436	12:00	27
2001	1.77	0.05	269	403	11:00	25
All years	2.14	0.03	1,621	3,241	11:00	130

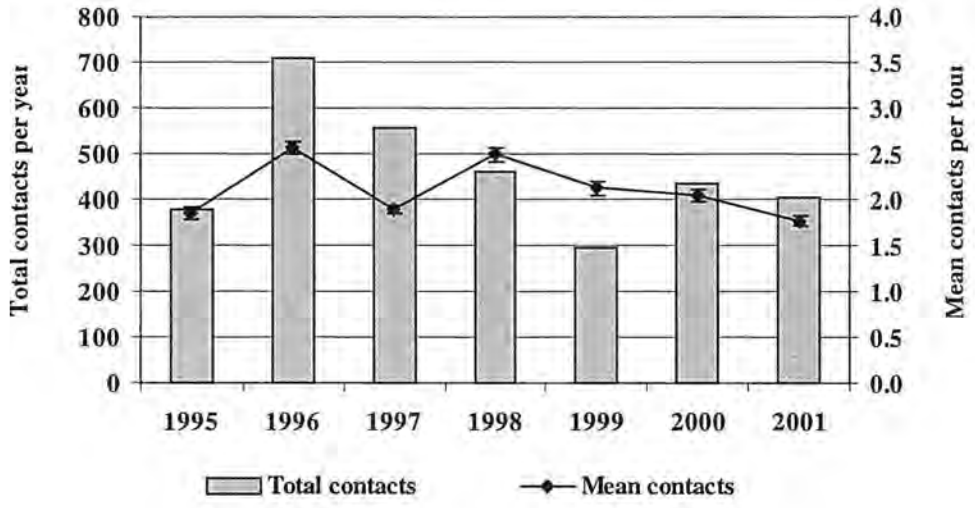
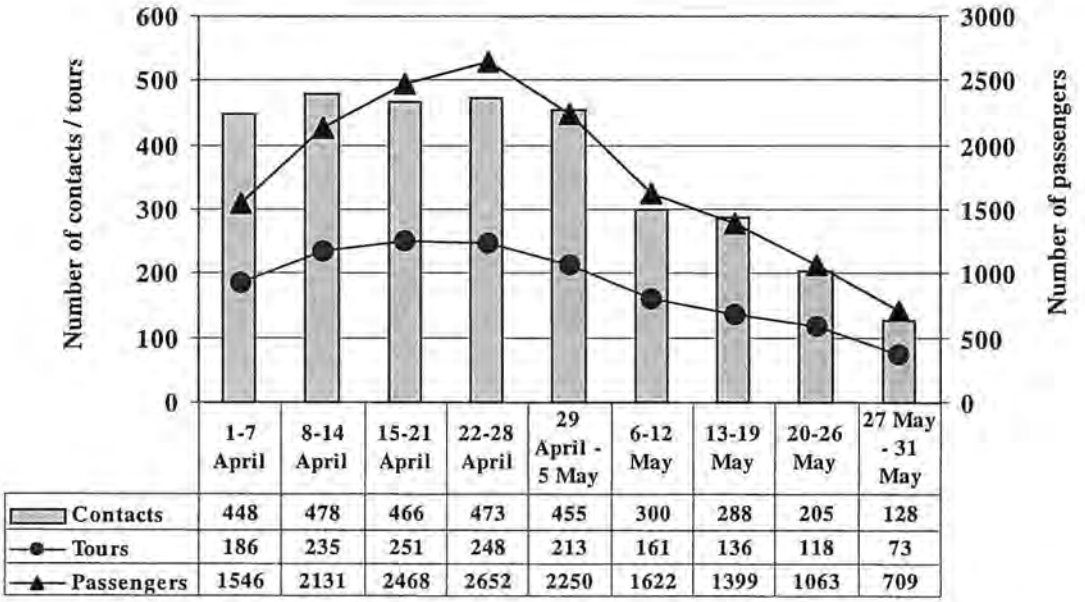


Figure 3.4 Total number of contacts per year and mean number of contacts per tour for the 1995-2001 paying seasons (bars show standard error).

The total number of contacts with whale sharks was closely related to the total number tours and passengers each week for the 1995 to 2001 paying seasons combined (Figure 3.5). The results of a Kendall's coefficient of concordance showed that the total number of contacts, tours and passengers per week were positively correlated for all years combined (Table 3.6). The correlation suggests that the number of contacts with sharks was a function of the number tours conducted, which was dependent upon the number of passengers booked on tours each week (Figure 3.5).

The duration of contact with whale sharks averaged around 24 minutes for all years combined and ranged from about 26 minutes to 30 minutes between years except for 1997 and 1998, when mean contact time was about 19 minutes and 13 minutes respectively (Table 3.7). The number of swimmers reported per contact averaged 9.4 for all years combined and varied by 4.4 from 7.5 in 1996 to 11.9 in 2001 (Table 3.7).



	1-7 April	8-14 April	15-21 April	22-28 April	29 April - 5 May	6-12 May	13-19 May	20-26 May	27 May - 31 May
Contacts	448	478	466	473	455	300	288	205	128
Tours	186	235	251	248	213	161	136	118	73
Passengers	1546	2131	2468	2652	2250	1622	1399	1063	709

Figure 3.5 Number contacts with whale sharks, number of tours conducted and number of passengers that participated in whale shark interaction tours each week for the 1995-2001 paying seasons combined.

Table 3.6 Matrix of Kendall's coefficient of concordance (τ) and probability statistics describing the relationship between the number of contacts, tours and passengers per week for the 1995-2001 paying seasons combined ($n = 9$ for the correlation). Significant probability values are shown in bold.

	Contacts	Tours	Passengers
Contacts	-	**P = 0.0018**	**P = 0.0035**
Tours	$\tau = 0.8333$	-	**P = 0.0018**
Passengers	$\tau = 0.7778$	$\tau = 0.8333$	-

Table 3.7 Mean contact time and mean number of swimmers per contact for the 1995-2001 paying seasons.

Year	Contact time (minutes)			Number of swimmers		
	Mean	s.e.	*n*	Mean	s.e.	*n*
1995	29.3	1.1	377	Not recorded		
1996	27.4	0.9	686	7.5	0.1	580
1997	19.4	0.8	535	8.3	0.2	507
1998	13.1	0.6	457	10.9	0.2	446
1999	25.8	1.3	290	9.9	0.3	282
2000	26.6	1.4	415	9.2	0.2	420
2001	29.9	1.5	362	11.9	0.2	376
All years	24.2	0.4	3,122	9.4	0.1	2,611

Mean contact time increased linearly with the mean number of swimmers per contact per day for all years combined (Figure 3.6, $r^2 = 0.041$, d.f. = 1,306, F = 13.24, P = 0.0003) and the prediction equation was log(contact time) = 1.17007 + 0.017774(swimmers).

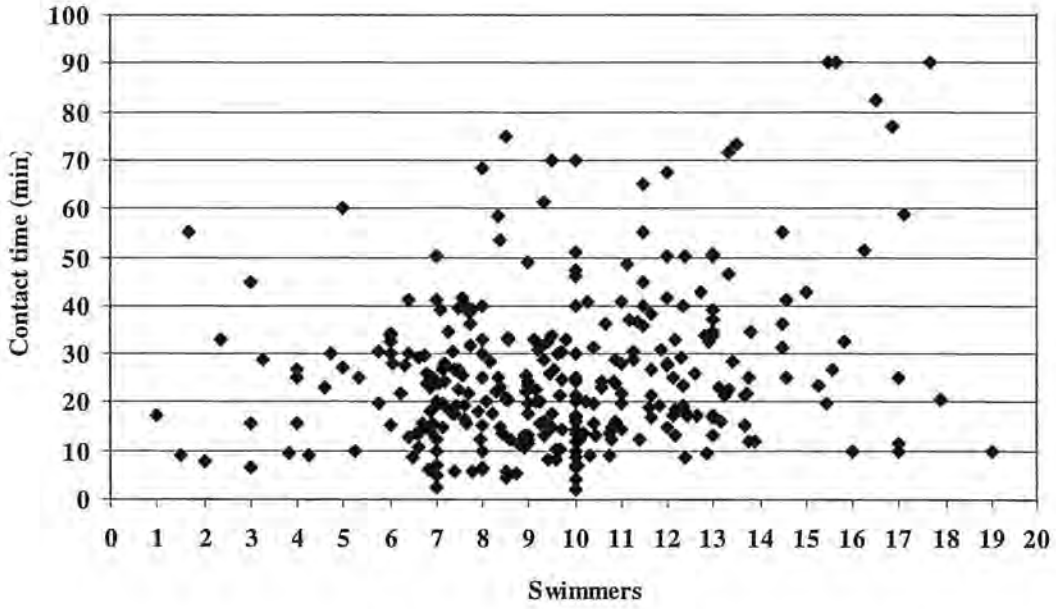
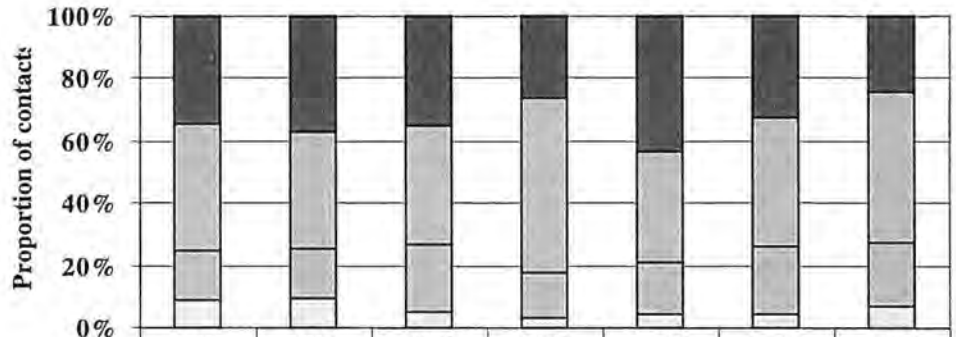


Figure 3.6 The relationship between the mean number of swimmers per contact and mean contact time per day for the 1995-2001 paying seasons (n = 308 and the prediction equation was: log(contact time) = 1.17007 + 0.017774(swimmers)).

The majority of contacts with whale sharks were recorded as being of good or excellent quality by tour operators each year from 1995 to 2001 (Figure 3.7). A similar number of contacts were reported as poor, average, good and excellent by tour operators each year, except for in 1998 when a greater proportion of contacts were recorded as good than poor, average or excellent (Figure 3.7).



	1995	1996	1997	1998	1999	2000	2001
Excellent	121	235	180	117	120	138	86
Good	144	240	197	252	99	173	173
Average	56	99	110	67	45	92	73
Poor	32	62	26	13	13	18	24

Figure 3.7 Proportion of contacts reported as excellent, good, average and poor for the 1995-2001 paying seasons (n = 3005 records).

3.4 Whale sharks

The length of all whale sharks contacted declined by 0.9m between 1995 and 2001 (Table 3.8). The length of male sharks contacted declined by 1.2m between 1995 and 2001 and female sharks and sharks of undetermined sex also declined in size, but their length was more variable between years than male sharks (Table 3.8).

The sex of whale sharks contacted was biased toward males in all years, but the number of male sharks to female sharks varied widely between years from 1.6 in 1995 to around 5 in 1999 and was 2.34 males per female for all years combined (Table 3.8).

Table 3.8 Mean length of male, female, whale sharks of undetermined sex and all sharks and ratio of male to female sharks contacted for the 1995-2001 paying seasons.

Year	Shark length (m)												Sex ratio M:F
	Male			Female			Undetermined			All sharks			
	Mean	s.e.	*n*	Mean	s.e.	*n*	Mean	s.e.	*n*	Mean	s.e.	*n*	
1995	7.0	0.2	106	6.6	0.2	66	6.7	0.2	95	6.8	0.1	267	1.61
1996	7.2	0.1	313	7.0	0.2	107	6.9	0.1	252	7.0	0.1	672	2.93
1997	6.7	0.1	251	6.8	0.2	105	6.5	0.1	168	6.7	0.1	524	2.39
1998	6.8	0.1	233	6.3	0.2	110	5.9	0.2	112	6.5	0.1	455	2.12
1999	6.7	0.1	182	6.3	0.3	38	6.6	0.3	39	6.6	0.1	282	4.79
2000	6.5	0.1	187	5.8	0.1	107	5.5	0.1	130	6.0	0.1	424	1.75
2001	5.8	0.1	178	6.0	0.2	86	5.9	0.2	124	5.9	0.1	400	2.07
All years	6.7	0.0	1,450	6.4	0.1	619	6.3	0.1	920	6.5	0.0	3,024	2.34

For all years combined, male sharks contacted outnumbered female sharks by around 2:1 in the first four weeks of the paying season, but 3-6 times more male sharks than female sharks were contacted in the second half of the season (Figure 3.8).

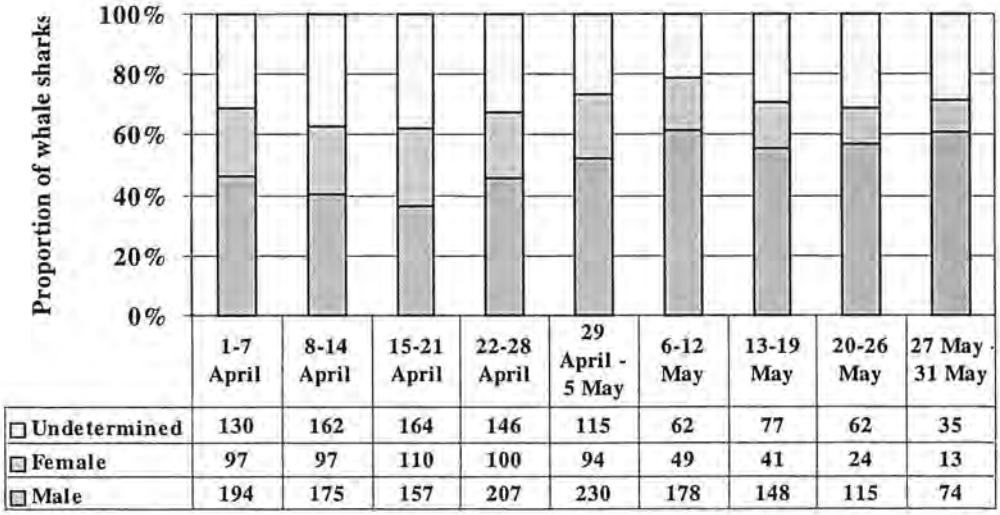


Figure 3.8 Proportion of whale sharks contacted that were male, female and of undetermined sex each week for the 1995-2001 paying seasons combined.

The mean depth of water in which whale sharks were contacted varied by around 18m between years, from 29m in 1996 to 47m in 2000 and was about 37m for all years combined (Table 3.9). The depth of water in which all whale sharks were contacted increased by 10.8m between 1996 and 2001 and male sharks were contacted in shallower water than females and sharks of undetermined sex (Table 3.9).

Table 3.9 Mean depth of water in which male, female, whale sharks of undetermined sex and all whale sharks were contacted for the 1995-2001 paying seasons.

Year	Water depth (m)											
	Male			Female			Undetermined			All sharks		
	Mean	s.e.	*n*	Mean	s.e.	*n*	Mean	s.e.	*n*	Mean	s.e.	*n*
1995	Not recorded											
1996	26.5	0.9	282	26.5	1.5	99	33.2	1.0	242	29.1	0.6	623
1997	30.6	1.0	240	32.9	1.7	98	32.3	1.4	158	31.7	0.7	515
1998	33.0	1.4	229	42.2	2.0	110	45.6	2.2	104	38.2	1.0	447
1999	41.2	0.9	181	36.7	2.3	37	42.0	2.0	39	41.0	0.7	281
2000	43.4	1.4	182	48.3	2.7	100	50.1	2.4	118	46.7	1.2	403
2001	42.3	1.7	176	35.3	2.4	81	40.7	2.0	117	39.9	1.1	385
All years	34.9	0.5	1,290	37.3	0.9	525	38.8	0.7	778	36.6	0.4	2,654

The length of whale sharks and the depth of water in which they were contacted were negatively correlated and the length of whale sharks and contact time were positively correlated for all contacts from 1995 to 2001 (Table 3.10). The correlation suggests that contact times were longer for large sharks which were contacted in shallower water than small sharks.

Table 3.10 Matrix of Kendall's coefficient of concordance (τ) and probability statistics describing the relationship between whale shark length, depth of water in which they were contacted and contact time for all contacts for the 1995-2001 paying seasons combined (n = 2,320 for the correlation). Significant probability values are shown in bold.

	Shark length	Water depth	Contact time
Shark length	-	**P < 0.0001**	**P = 0.0201**
Water depth	τ = -0.1191	-	**P < 0.0001**
Contact time	τ = 0.0312	τ = -0.1145	-

The length of whale sharks contacted varied significantly between year (F = 299.61, d.f. = 6,251, P < 0.0001) and week (F = 2.47, d.f. = 8,256, P = 0.0136), but not sex (F = 0.58, d.f. = 2,256, P = 0.5608) and there was an interaction between year and week (F = 1.77, d.f. = 48,1496, P = 0.0010) and year and sex (F = 1.86, d.f. = 12,500, P = 0.0367). Whale sharks contacted were significantly shorter in 2000 and 2001 than all other years and significantly shorter in weeks 2, 3 and 4 than all other weeks (Dunnett's test, Figure 3.9, Figure 3.10).

The depth of water in which whale sharks were contacted varied significantly between year ($F = 423.66$, d.f. = 5,266, $P < 0.0001$), week ($F = 3.47$, d.f. = 8,270, $P = 0.0008$) and sex ($F = 8.03$, d.f. = 2,270, $P = 0.0004$) and there was an interaction between year and week ($F = 5.18$, d.f. = 40,1322, $P = 0.0003$) and year and sex ($F = 7.54$, d.f. = 10,530, $P < 0.0001$). Whale sharks were contacted in significantly deeper water from 1998 to 2001, than in 1996 and 1997 and significantly deeper water in weeks 2, 3, 4 and 8 than other weeks (Dunnett's test, Figure 3.9, Figure 3.10). Female sharks and those of undetermined sex were contacted in significantly deeper water than male sharks (Dunnett's test, Figure 3.11).

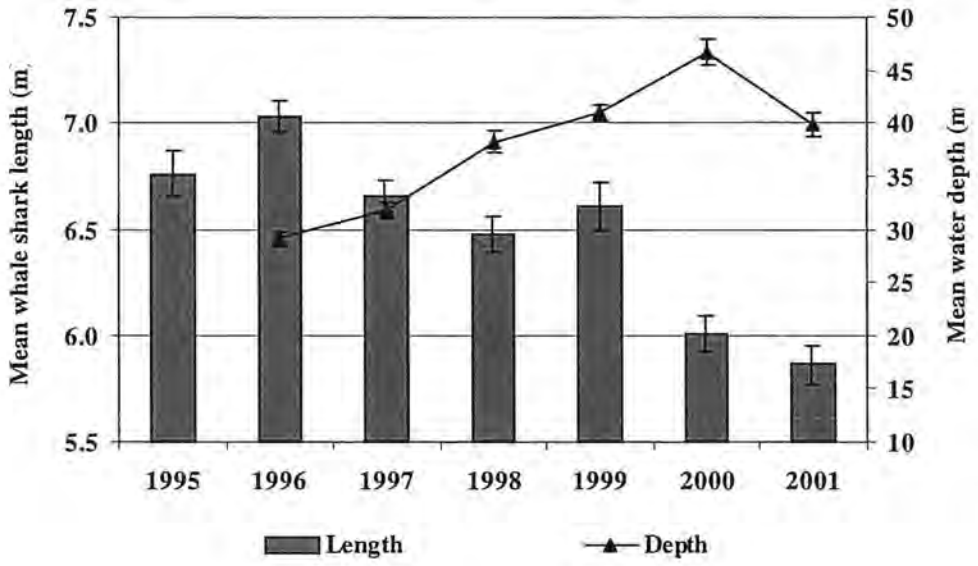


Figure 3.9 Mean length of whale sharks and mean depth of water in which they were contacted for the 1995-2001 paying seasons (bars show standard error).

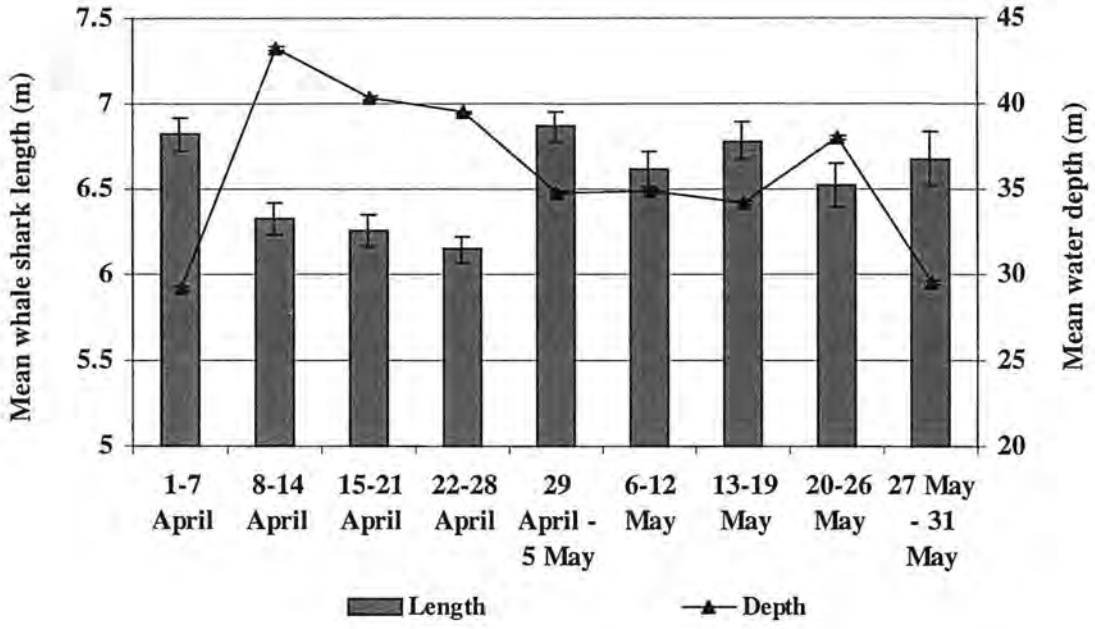


Figure 3.10 Mean length of whale sharks and mean depth of water in which they were contacted each week for the 1995-2001 paying seasons combined (bars show standard error).

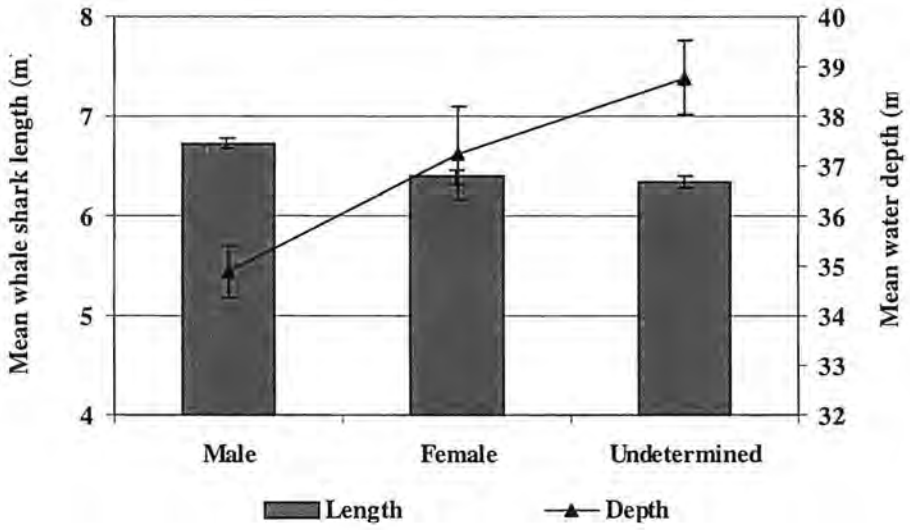


Figure 3.11 Mean length and mean depth of water in which male, female and whale sharks of undetermined sex were contacted for the 1995-2001 paying seasons combined (bars show standard error).

Most whale sharks were recorded moving north, south or circling during contact (Figure 3.12) and the map overleaf shows that most contacts from 1995 to 2001 took place

between Tantabiddi and Osprey Bay in the north and Point Clotes and Coral Bay in the south. In most years, contacts were spread along the northern region of Ningaloo Reef, but in 1999, the majority of contacts took place north-west of Coral Bay because two of the five vessels that operated in that year were based at Coral Bay.

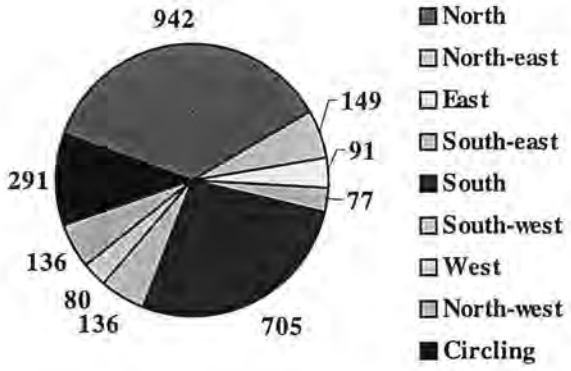


Figure 3.12 Direction whale sharks were recorded moving during contact for the 1995-2001 paying seasons combined (n = 2,607 records).

4. Discussion

CALM issued between 13 and 15 whale shark tourism interaction licences each year from 1995 to 2001 and 82% of the 95 licence holders conducted tours for all years combined. A mean of 4.1 vessels operated per day for all years combined, tour vessels operated during 94% of the 427 days that made up the 1995-2001 paying seasons and an average of 232 tours were conducted per year. About one-third, or 28% of a maximum of 5,795 tours possible were conducted between 1995 and 2001. Of the 1,621 tours conducted between 1995 and 2001, whale sharks were encountered during 86% of tours and the strike rate varied from 81% to 95% between years. The duration of whale shark tours was similar each year, averaging about 5½ hours for all years combined and tours without a whale shark encounter were about one hour longer than those with an encounter.

Cyclone Vance had a negative impact on tour operations in 1999. The proportion of licences used, mean number of vessels that operated per day, total number of tours conducted, number of tours conducted as a proportion of the maximum possible, total passengers carried on tours and the total number of contacts with whale sharks were low in 1999 in comparison with other years due to the impact of the cyclone on the tourism industry. The mean number of passengers per tour was comparatively high in 1999, probably because the five vessels that operated that year carried more passengers per tour than other years. However, elements within tours, such as the strike rate, mean number of contacts per tour and mean number of swimmers per contact were similar to other years in 1999.

Many aspects of the industry were also low in 1998 in comparison with other years. While 92% of the 13 licence holders conducted tours, the mean number of vessels that operated per day, number of tours conducted as a proportion of the maximum possible, total number of tours conducted, total number of passengers carried, total number of contacts with whale sharks and mean time of contact with whale sharks were low in 1998 in comparison with other years. The mean number of passengers per tour was high in 1998 compared to other years, probably because the number of passengers booked on tours was high in relation to the low number of tours conducted. However, the strike rate,

mean number of contacts per tour and mean number of swimmers per contact did not differ greatly from other years in 1998. The performance of the whale shark tourism industry may have been low in 1998 because whale sharks aggregated south of the usual search area, in the vicinity of Yardie Creek (D. Coughran pers. comm.), in the absence of the Ningaloo Current, which runs along the reef front carrying feeding resources northward (Taylor 1996, Taylor and Pearce 1999, Wilson *et al.* 2001).

A total of 18,327 passengers participated in whale shark interaction tours in Ningaloo Marine Park between 1995 and 2001 and the total number of passengers per year increased steadily by 45% from 1,920 to 3,505 during that period. For all years combined, the most common number of passengers carried per tour was 10 and the mean number of passengers per tour was 11.5, or about half the maximum of 20 passengers allowed under the code of conduct.

There were 3,241 contacts with whale sharks between 1995 and 2001 and most contacts took place at 11:00hrs. The mean number of contacts per tour fluctuated from 1995 to 1998, then declined from 2.49 in 1998 to 1.77 in 2001 and was 2.14 for all years combined. Examination of a correlation between the number of tours, passengers and contacts per week for all years combined suggested that the number of contacts per week was a function of the number of tours conducted per week, which was dependent upon the number of tourists booked on tours. The quality of contacts was high as most were recorded as good or excellent in all years and few were recorded as average or poor, but the definition of quality is open to interpretation by tour operators (Chapman 2001).

Both the mean contact time of 24 minutes and mean number of swimmers per contact of 9.4 for all years combined were below the maximum allowable of 60 minutes contact and 10 swimmers per contact under the code of conduct. The linear relationship between the mean number of swimmers and mean contact time per day for all contacts from 1995 to 2001, can be used by CALM officers to predict the impact of changes in the number of swimmers per contact on contact time. For instance, if the number of swimmers per contact were reduced, contact time would decline but if the number of swimmers were increased, contact time would also increase (Figure 4.1).

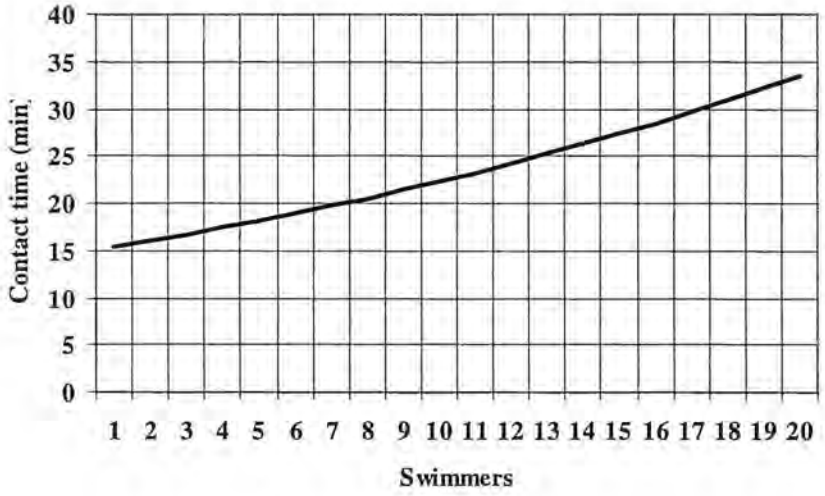


Figure 4.1 Model of the relationship between the mean number of swimmers per contact and mean contact time per day for the 1995-2001 paying seasons. The prediction equation was: log(contact time) = 1.17007 + 0.017774(swimmers).

Whale sharks were most commonly contacted in an average water depth of 37m, moving north, south or circling, between Tantabiddi and Osprey Bay in the north and Point Clotes and Coral Bay in the south. The sex of whale sharks contacted was biased toward males in all years and the proportion of sharks contacted that were male was greater in the second half of the paying season for all years combined. Whale sharks were significantly smaller in 2000 and 2001 than other years and were contacted in significantly deeper water from 1998 to 2001 than other years. On a weekly basis, whale sharks contacted were significantly smaller in weeks 2, 3 and 4 than other weeks and were contacted in significantly deeper water in weeks 2, 3, 4 and 8 than other weeks. Female sharks and those of undetermined sex were contacted in significantly deeper water than male sharks. An examination of the relationship between whale shark length, the depth of water in which they were contacted and the duration of contact suggested that contact time was greater for larger sharks which occurred in shallower water than small sharks.

5. References cited

Chapman, T. (2001) The whale shark tourism industry in Ningaloo Marine Park: summary of the 2001 paying season. Department of Conservation and Land Management, Exmouth.

Colman, J. (1997a) Whale shark interaction management with particular reference to Ningaloo Marine Park 1997-2007. Western Australian Wildlife Management Program No. 27. Department of Conservation and Land Management, Marine Conservation Branch, Fremantle.

Colman, J.G. (1997b) A review of the biology and ecology of the whale shark. *Journal of Fish Biology* **51**: 1219-1234.

Compagno, L.J.V. (1984) FAO Species Catalogue. Sharks of the world. An annotated and illustrated catalogue of shark species known to date. Volume 4. Part 1 - Hexanchiformes to Lamniformes. *FAO Fisheries Synopsis* **125**: 209-211.

Compagno, L.J.V. (1988) *Sharks of the Order Carcharhiniformes*. Princeton University Press, New Jersey.

Davis, D. (1998) Whale shark tourism in Ningaloo Marine Park, Australia. *Anthrozoös* **11**: 5-11.

Hilton-Taylor, C. (2000) 2000 IUCN red list of threatened species. pp. xviii and 61 In IUCN, Gland, Switzerland and Cambridge, UK.

Last, P.R. and Stevens, J.D. (1994) *Sharks and Rays of Australia*. CSIRO, Melbourne.

Osborne, S. and Williams, M.R. (1995) Monitoring of whale shark tourism in Ningaloo Marine Park by aerial survey. Unpublished report. Department of Conservation and Land Management, Como.

Simpson, C.J. (1991) Mass spawning of corals on Western Australian reefs and comparisons with the Great Barrier Reef. *Journal of the Royal Society of Western Australia* **74**: 85-91.

Smith, A. (1828) Descriptions of new, or imperfectly known objects of the animal kingdom, found in the south of Africa. *South African Commercial Advertiser* **3**: 2.

Stevens, J.D. (1994) Whale sharks at Ningaloo Reef, northern Western Australia. *Chondros* **5**: 1-3.

Taylor, J.G. (1989) Whale sharks of Ningaloo Reef. A preliminary study. Unpublished report. The Australian National Parks and Wildlife Service, Canberra.

Taylor, J.G. (1990) The whale shark. *Australian Natural History* **23**: 282-283.

Taylor, J.G. (1991) Whale sharks of Ningaloo Reef. Unpublished report. The Australian National Parks and Wildlife Service, Canberra.

Taylor, J.G. (1994a) Gentle giants of the deep. *Australian Geographic* **34**: 93-103.

Taylor, J.G. (1994b) *Whale sharks: the giants of Ningaloo Reef.* Angus and Robertson, Sydney.

Taylor, J.G. (1996) Seasonal occurrence, distribution and movements of the whale shark, *Rhincodon typus*, at Ningaloo Reef, Western Australia. *Marine and Freshwater Research* **47**: 637-642.

Taylor, J.G. and Pearce, A.F. (1999) Ningaloo reef currents: implications for coral spawn dispersal, zooplankton and whale shark abundance. *Journal of the Royal Society of Western Australia* **82**: 57-65.

Wilson, S.G., Taylor, J.G. and Pearce, A.F. (2001) The seasonal aggregation of whale sharks at Ningaloo Reef, Western Australia: currents, migrations and the El Niño / Southern Oscillation. *Environmental Biology of Fishes* **61**: 1-11.

Wolfson, F.H. (1983) Records of seven juveniles of the whale shark, *Rhiniodon typus*. *Journal of Fish Biology* **22**: 647-655.

Wolfson, F.H. (1986) Occurrences of the whale shark, *Rhincodon typus*, Smith. pp. 208-226 In *Indo-Pacific Fish Biology: Proceedings of the Second International Conference on*

Indo-Pacific Fishes. Uyeno, T., Arai, R., Taniuchi, T., and Matsuura, K. (eds.) Ichthyological Society of Japan, Tokyo.