Monitoring of Whale Shark Tourism in Ningaloo Marine Park by Aerial Survey

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ABSTRACT

Whale shark and tourist boat numbers were recorded during 246 area searches conducted by aerial survey from commercial whale shark spotter planes over Ningaloo Marine Park between 26 March and 14 May 1994. The average number of fish recorded per search was 2.9 during the first three weeks of the monitoring period. The equivalent value for the second four week period was 0.9.

The average proportions of fish in contact with commercial tourist boats were 0.37 for the first three weeks and 0.44 for the last four weeks. A concomitant decline in the number of commercial boats prevented a major increase in industry pressure as the number of sharks declined during the latter period. Values of the proportions of fish in contact with boats could be expected to increase with any increase in the average numbers of boats active per day above the recorded average values of 5.8 and 3.8 for the two time periods respectively.

INTRODUCTION

Whale sharks (*Rhiniodon typus*) are the largest fish in the oceans and an opportunity to dive with one of these gentle giants has long attracted the imagination of recreational divers throughout the world. Usually considered rare with few known predictable aggregations (Wolfson, 1986), divers have relied on chance encounters to fulfil their ambitions.

Ningaloo Marine Park was declared in 1987 and stretches along 260km of coast off the North West Cape of Western Australia (Fig. 1). The occurrence of predictable whale shark aggregations at the northern end of the Park between March and June each year has been well known to local boat operators for many years. However, with increased attention focused on the Park, the phenomenon has now been both formally documented (Taylor, 1989a, 1989b, 1990, 1991; Taylor and Grigg, 1990) and well publicised (Andrewartha, 1993; Taylor, 1994).

In 1993, a lucrative industry developed in Ningaloo Marine Park providing tourists with an opportunity to snorkel and dive with whale sharks. Chartered vessels rely on spotter aircraft to locate the sharks and maximise the potential for diver contact. Whilst still in its infancy, an increased participation level from 1000 person boat days in 1993 to 1500 person boat days during the 1994 season (unpublished data) clearly indicates that the industry has great potential for expansion. With increasing tourism pressure, sound management will be essential both to protect the whale sharks and to ensure the sustainability of the associated industry. With the imminent prospect of limiting the number of commercial whale shark operation licences, information is needed on the size of the Ningaloo Marine Park shark resource, and the likely future pressure of the tourism industry on that resource.

This paper presents a summary of aerial survey data that were gathered to monitor the 1994 whale shark season at Ningaloo Marine Park. The objectives of this monitoring program were;

– to estimate the availability of whale sharks for tourist activities within the commercial area; and

– to estimate the potential impact of tourism on the whale shark population within this area of Ningaloo Marine Park.

METHODS

Both the size of the shark resource and spatial distribution of whale sharks were estimated using a simple area search technique (Buckland *et al.* 1993). Commercial spotter planes flew between 150m and 1000m above sea level and most surveys were conducted between 10.00 and 14.30 hours when surface water reflection is minimal. Surveys were conducted from 27 March to 14 May, and the following information was recorded during each search: date/time; number of whale sharks suitable for tourism; number of commercial whale shark vessels; and number of vessels in contact with whale sharks. The number of commercial whale shark boats that left the harbour each morning ('actual boat number') was also recorded.

To facilitate the aerial searches, the commercial whale shark area was divided into seven (mostly) approximately equal sized sectors, the boundaries of which corresponded with prominent coastal features. Each sector was further divided into three divisions, each a one kilometer wide band running parallel to the coast, and denoted as inner, central or outer (Fig. 1). Density estimates were calculated by treating each division as of equal area. Sector seven was approximately twice as large as the other sectors, and this was taken into account when calculating density estimates. Slight inequities in division areas were considered inconsequential as the pilots conducting the surveys relied entirely on visual perception of coastal features to determine which sector and division they were in.

Temporal changes in whale shark availability were examined by one–way analysis of variance using repeated measures, and pairwise comparisons between individual time periods were made using Tukey's test.

RESULTS

During the seven week sample period, 246 surveys were conducted on a total of 32 days, with a maximum of 39 surveys on a single day (Table 1). A maximum of nine commercial boats were recorded on a single day (1 and 2 April). At least one shark was observed on each sample day.

The highest weekly average of the number of fish observed per sector division search ('fish index value') was 3.56 during week two, and the lowest was 0.52 during week six (Fig. 2). Tukey's test indicated a clear division in whale shark numbers between weeks three and four (Fig. 2), and temporal changes in whale shark numbers may be characterised as 'peak' (weeks 1–3) and 'shoulder' (weeks 4–7) periods. During the peak and shoulder periods the average fish index was 2.9±0.3 (mean±standard error) and 0.9±0.3 respectively. The weekly averages of the proportions of fish in contact with boats were highest during weeks two and five. These high values correspond with the maximum actual boat numbers within each period (Fig. 3). Overall proportions of fish in contact with boats was 0.37±0.06 (mean±95% confidence interval or C.I.) and 0.44±0.09 during the peak and shoulder periods respectively.

The proportion of boats in contact with fish was higher during the peak period (mean =0.92, 95% C.I. = 0.72 to 0.97) and lower during the shoulder period (mean = 0.65 with 95% C.I. = 0.56 to 0.75). Only 0.25 of the boats were recorded in contact during week six.

Comparisons among weekly averages revealed no statistically significant relationship between fish index values and the proportion of fish in contact (Table 2). However, there was a weak positive relationship between fish index values and actual boat numbers. The relationship between fish numbers and boat numbers was stronger when boat index values (number of boats per sector division search) were compared. The proportion of fish in contact bore only a weak relationship with boat numbers.

Although lower fish numbers were recorded during the shoulder period, a pattern of higher densities within the central sectors than at either the northern or southern ends of the commercial area was maintained (Fig. 4). Insufficient surveys precluded comparisons of fish index values in sectors 1 and 7 during the peak period.

DISCUSSION

It is now well established that the seasonal aggregations of whale sharks at Ningaloo Marine Park occur around the same time of year as the annual mass spawning of corals and other reef organisms (Taylor, 1989a, 1990, 1991, 1994). However, these reports and the spotter plane aerial surveys of 1993 (unpublished data) indicate that peak whale shark numbers do not usually coincide directly with spawning but rather follow the spawning events by one to two weeks. It is unfortunate that at the commencement of monitoring on 26 March 1994, a minor spawning event had already occurred (on 6 March). The main spawning event on 3 and 4 April corresponded exactly with the highest weekly mean fish index value. A third, minor spawning event occurred on 4 May, during week six. No increase in shark numbers was recorded during weeks 6 and 7 although a delayed increase may have occurred after monitoring stopped.

Our estimate of the proportion of boats in contact with whale sharks indicate that boats were more likely to be observed in contact with sharks than not in contact. High values recorded during this survey for the proportion of boats in contact are indicative of an efficient industry: as long as sharks were available, the use of spotter planes resulted in boats being able to locate and make contact. With such a high level of efficiency, it would be expected that fish contact rates would increase as fish numbers decrease. This did not occur during the survey period however, primarily because a decrease in the number of commercial vessels operating corresponded with the decrease in fish availability.

Although estimates of the proportion of fish in contact provide a guide for managers, difficulties in determining appropriate licence numbers remain until there is a clear understanding of a) the levels of harassment associated with different fish contact rates, b) the occurrence of peak and shoulder periods, and c) the relationship between vessel numbers and fish contact rates during both peak and shoulder periods.

A continuing increase in tourist demand to view whale sharks has already seen an increase in the number of applications for vessel licences in 1995 (unpublished data). The potential for over–exploitation and harassment of sharks with a consequent deterioration in the tourist experience may necessitate a limit on licence numbers should this trend continue. Aerial survey data from the 1994 season indicate that during the peak period, a proportional fish contact rate higher than 0.37 (95% C.I. = 0.31 to 0.43) can be expected with more than the current average number of 5.8 commercial vessels operating per day. Likewise, during the shoulder period, more than the current average number of 3.8 vessels per day is likely to result in fish contact rates higher than 0.44 (95% C.I. = 0.35 to 0.53).

Although peak whale shark periods are known to be associated with coral spawning, there are still insufficient data to accurately predict the occurrence of peaks and shoulders in whale shark seasons. In 1995, coral spawning is expected on 23 February, 25 March and 23 April with the main event predicted for 25 March. With peak whale shark numbers expected during or following spawning, daily monitoring would be needed to span the period between the end of February and mid May. Although an expensive commitment, such a monitoring exercise would yield a better understanding of the temporal relationship between coral spawning and whale shark numbers.

Variables affecting aerial surveillance indices include: fish and boat distributions within the commercial area and the frequency of sector division searches both in time and space. With good weather and large numbers of fish available throughout the commercial area, boats tended to disperse, but bad weather and rough seas discouraged dispersal far from the anchorage. Even in good weather, the boats sometimes clustered close together if either the available fish were clustered or the number of fish was so low that boats were queuing for contact with individual sharks. At the beginning and end of each day, the boats were more likely to be close together near the anchorage and although random searches were requested, commercial ties between boats and spotter planes made it unlikely that all sector division searches were completely independent of boating activity. In addition, results of the 1994 survey agree with previous aerial survey data (Taylor, 1991) indicating that higher densities of sharks generally occur in the central sectors than at the northern and southern extremities of the commercial area. Variation resulting from these and other factors serve to illustrate the need for more comprehensive data, if index values from aerial surveys are to accurately predict the impact of varying licence numbers on proportional values for fish in contact.

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Figure 1. The distribution of survey sector divisions within the commercial whale shark watching area at the northern end of Ningaloo Reef, Western Australia.

Figure 2. Numbers (means and standard errors) of whale sharks recorded per sector division search (solid line) and numbers of whale sharks in contact with boats (dashed line) for each week of the monitoring period. Letters indicate means not significantly different ($p = 0.05$) by Tukey's HSD test.

Figure 3. Average weekly actual boat numbers (line) and proportions of fish observed in contact with boats (bars) over the monitoring period. Error bars are 95% confidence intervals.

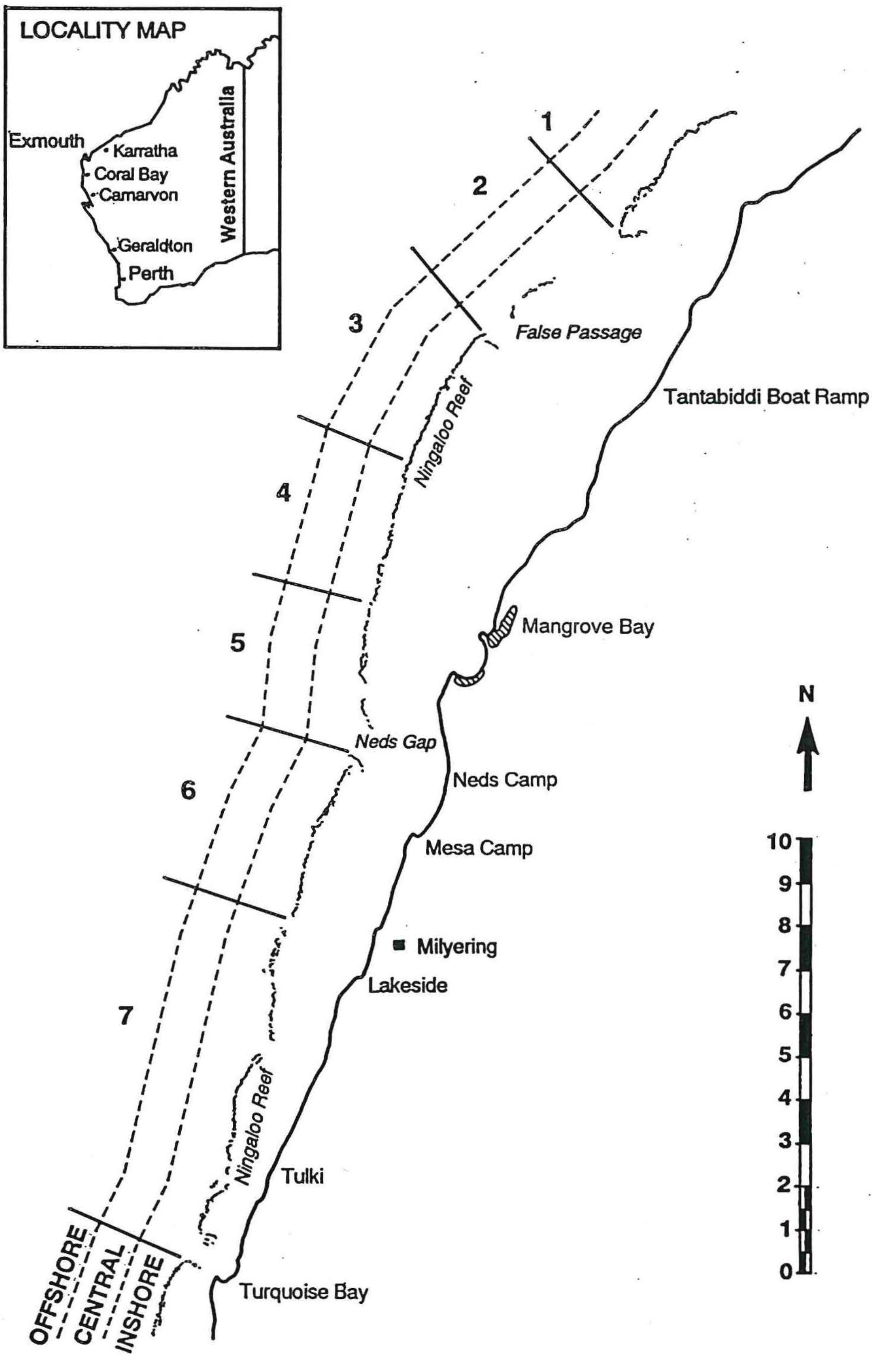
Figure 4. Mean number of fish observed within each sector division during the peak period (weeks 1 – 3).

Table 1. Daily summary of survey observations.

Table 2. Correlation coefficients between weekly fish index values, proportions of fish in contact, actual boat numbers and boat index values.

Date	No. of surveys	Total fish	Fish in contact	Total boats	Boats in contact	Actual boat Nos
26 Mar	2	13.0	2.0	2.0	2.0	–
27 Mar	7	19.0	5.0	5.0	5.0	6
28 Mar	6	18.0	6.0	6.0	6.0	6
29 Mar	3	14.0	9.0	9.0	9.0	6
30 Mar	1	1.0	1.0	1.0	1.0	5
31 Mar	4	7.0	2.0	2.0	2.0	5
01 Apr	0	–	–	–	–	9
02 Apr	1	1.0	1.0	3.0	1.0	9
03 Apr	2	7.0	2.0	2.0	2.0	7
04 Apr	1	6.0	2.0	2.0	2.0	6
05 Apr	1	2.0	2.0	2.0	2.0	–
06 Apr	2	7.0	4.0	4.0	4.0	6
07 Apr	0	–	–	–	–	6
08 Apr	2	9.0	9.0	9.0	9.0	6
09 Apr	3	16.5	7.0	8.0	7.0	7
10 Apr	0	–	–	–	–	7
11 Apr	0	–	–	–	–	5
12 Apr	8	16.0	5.0	5.0	5.0	5
13 Apr	6	11.0	2.0	3.0	2.0	5
14 Apr	12	35.0	12.0	14.0	11.0	5
15 Apr	15	36.0	10.0	10.0	10.0	5
16 Apr	13	28.0	10.0	12.0	11.0	5
17 Apr	4	18.0	12.0	12.0	11.0	6
18 Apr	39	8.5	3.0	6.0	3.0	–
19 Apr	8	14.0	1.0	2.0	1.0	7
20 Apr	14	1.5	1.0	3.0	1.0	5
21 Apr	6	2.5	1.5	1.5	1.5	4
22 Apr	0	–	–	–	–	4
23 Apr	0	–	–	–	–	6
24 Apr	0	–	–	–	–	7
25 Apr	14	6.0	6.0	15.0	6.0	6
26 Apr	0	–	–	–	–	7
27 Apr	4	12.0	5.5	5.5	5.5	5
28 Apr	2	4.0	2.0	2.0	2.0	3
29 Apr	0	–	–	–	–	4
30 Apr	0	–	–	–	–	4
01 May	0	–	–	–	–	4
02 May	0	–	–	–	–	3
03 May	0	–	–	–	–	2
04 May	18	8.5	2.0	8.0	2.0	4
05 May	2	2.0	0	0	0	2
06 May	0	–	–	–	–	3
07 May	0	–	–	–	–	2
08 May	0	–	–	–	–	1
09 May	0	–	–	–	–	1
10 May	20	18.5	6.5	15.5	6.5	2
11 May	2	1.5	1.5	1.05	1.5	1
12 May	22	23.0	12.0	15.0	11.0	2
13 May	2	4.0	3.0	3.0	3.0	–

	Weekly mean fish index (WMFI)	Proportion of fish in contact (FIC)	Boat Numbers (B#)	Boat Index (BI)
WMFI	–			
FIC	.258 (p = .576)	–		
B#	.719 (p = .069)	.265 (p = .566)	–	
BI	.793 (p = .033)	.6 (p = .154)	.742 (p = .056)	–


LOCALITY MAP
Exmouth
Karratha
Coral Bay
Carnarvon
Geraldton
Perth
Western Australia
1
2
3
4
5
6
7
False Passage
Tantabiddi Boat Ramp
Ningaloo Reef
Mangrove Bay
Neds Gap
Neds Camp
Mesa Camp
Milyering
Lakeside
Ningaloo Reef
Tulki
Turquoise Bay
OFFSHORE
CENTRAL
INSHORE
N
10
9
8
7
6
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4
3
2
1
0

to be redone

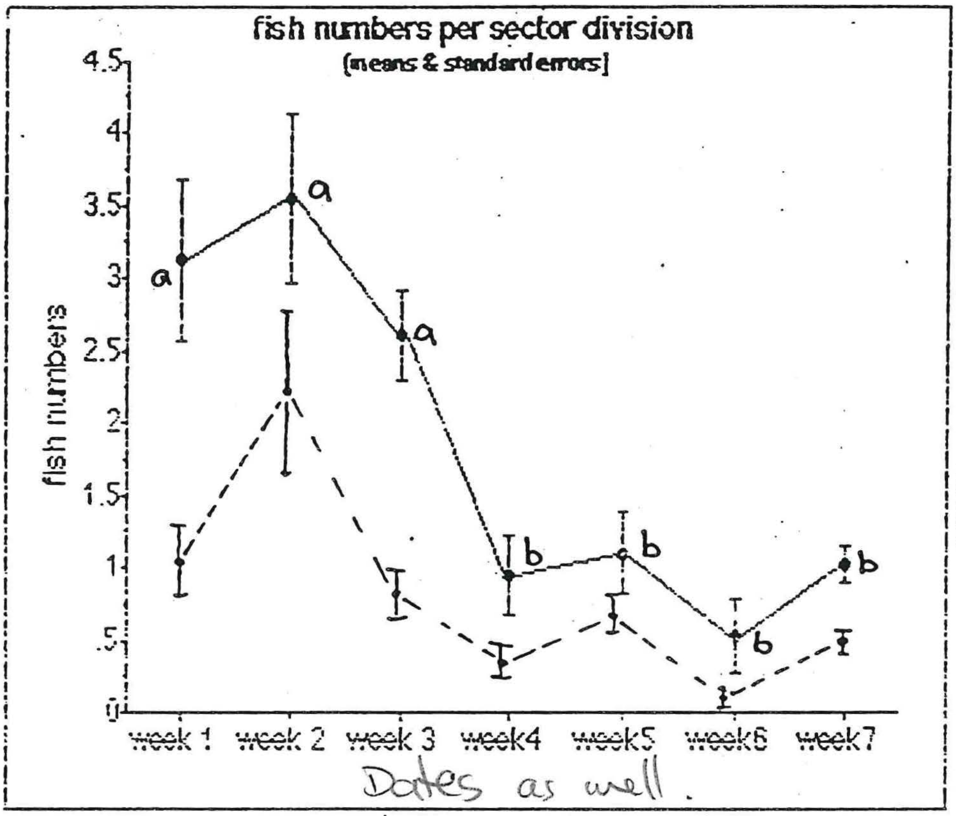

figure 2

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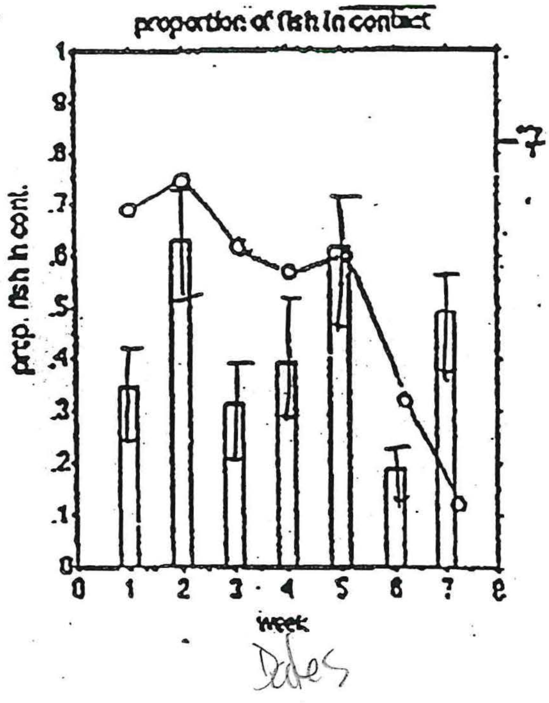

figure 3

to be redrawn

	0	1.2	3.818	3.688	3.42	1.739	3.25

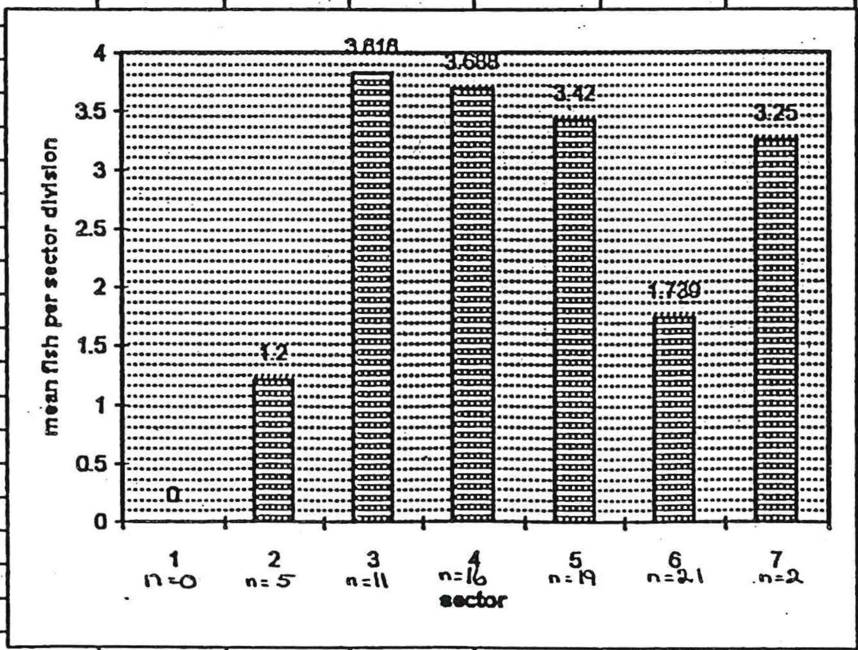

figure 4