ECOLOGICAL AND SOCIO-ECONOMIC IMPACTS OF DIVE AND SNORKEL TOURISM IN ST. LUCIA, WEST INDIES

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Abstract

Coral reefs provide many services and are a valuable resource, particularly for tourism, yet they are suffering significant degradation and pollution worldwide. To manage reef tourism effectively a greater understanding is needed of reef ecological processes and the impacts that tourist activities have on them. This study explores the impact of divers and snorkelers on the reefs of St. Lucia, West Indies, and how the reef environment affects tourists' perceptions and experiences of them. Observations of divers and snorkelers revealed that their impact on the reefs followed certain patterns and could be predicted from individuals', site and dive characteristics. Camera use, night diving and shore diving were correlated with higher levels of diver damage. Briefings by dive leaders alone did not reduce tourist contacts with the reef but intervention did. Interviews with tourists revealed that many chose to visit St. Lucia because of its marine protected area. Certain site attributes, especially marine life, affected tourists' experiences and overall enjoyment of reefs. Tourists were not always able to correctly ascertain abundance of marine life or sediment pollution but they were sensitive to, and disliked seeing damaged coral, poor underwater visibility, garbage and other tourists damaging the reef. Some tourists found sites to be noisy and over-crowded both with people and boats. Many tourists wanted more information on local marine life and said they would be willing to pay more to visit sites within St. Lucia's marine protected area than was currently being asked. Such funds could enable better protection and management of St. Lucia's reefs. Management recommendations include, among others, that all visitors be supervised on their dive and snorkel trips, that reef use be more evenly distributed throughout the island and that restrictions be placed on the number of people allowed to use sites over a given period. This thesis demonstrates how countries could use visitors to fund a greater proportion of their reef management costs, and that various management strategies could contain and reduce tourism damage to reefs, whilst simultaneously accommodating an expansion in the reef-tourism industry.

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Declaration

Staff employed at Scuba St. Lucia assisted me with my research by giving the briefings on dive and snorkel trips and by carrying out pre-determined intervention measures. Staff members also assisted me with underwater visibility measurements. Professor Callum Roberts and Julie Hawkins collected fish and coral attribute measurements.

Dr Christiane Schelten collected sediment measurements. I undertook all other data collection, underwater observations and interviews with the public and managers of St. Lucia's dive companies. All data analysis and writing of this thesis is my own work with the exception of the bootstrapping programme written by Dr Riccardo Scarpa.

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Chapter 1: Introduction

Since the end of the second world war, tourism has exploded in terms of numbers of people travelling, development and building of associated infrastructure and provision of tourism services. Globally, the tourism industry is expected to grow by 5% per annum between 2002 and 2012 (WTTC, 2002). Some of the fastest growth has been in coastal and marine areas (Miller, 1993; Orams, 1999), particularly those with coral reefs (Hoegh-Guldberg, 1999). Coral reefs are biologically rich and diverse, generally found in shallow waters and naturally erode to maintain some of the finest beaches in the world (Bryant et al., 1998). As such they provide the ideal environment to host the rising trend in activity and sport based holidays (Tabata, 1992; Dignam, 1990; EIU, 1994; Goodhead & Johnson, 1996) including scuba diving (BSAC, 2002; PADI, 2002) and snorkeling, and people's increased interest in the environment (Ceballos-Lascuráin, 1993).

The economic benefits from tourism associated with coral reefs are significant, notwithstanding their role as a resource for fishing (Munro, 1996), building materials, coastal protection and their use for development of drugs and biochemicals (Carte, 1996). Coral reef tourism generates approximately US$1.1 billion in Australia (Done et al., 1996), US$1.8 billion in Florida, USA (Birkeland, 1997) and US$102.9 billion throughout the Caribbean (Jameson et al., 1995) (values inflated by US GDP deflator 2002 = 100, World Bank data, 2003). One hundred million tourists visit the Caribbean each year and scuba diving in the Caribbean alone is projected to generate almost US$1 billion by the year 2005 (US Department of State, 1998 cited in Hoegh-Guldberg, 1999).

Despite the obvious importance of coral reefs to people, between 50% and 80% of reefs are at risk (Bryant et al., 1998) from human pressures brought about by human activities (Spalding, 2001). Almost half a billion people, 8% of the total global population, live within 100 km of a coral reef. Human activities that are destructive to coral reefs include extractive ones such as mining and fishing and non-extractive ones such as land clearance for agriculture and construction. Bare soil due to land-based activities increases the potential for sediment and nutrients to enter the drainage system, eventually bringing them into the marine environment. This can cause change in species composition, decrease coral growth and adversely affect water quality (Sladek Nowlis et al., 1997). Users such as divers and snorkelers may also contribute directly to reef degradation (Rouphael, 1995; Harriott et al., 1997; Muthiga & McClanahan, 1997; Hawkins et al., 1999; Zakai & Chadwick-Furman, 2002).

Human activities need not be 'in-situ' such as around coastal areas – but can be from distant sources spanning the whole globe. Mid-1997 to 1998 saw the biggest 'bleaching' event in history. Bleaching refers to the white calcareous skeleton of the coral that can be seen through the coral's tissue after its symbiotic algae, usually coloured, are expelled from the animal. Bleaching was blamed on increased water temperatures caused by global warming and affected corals in the Middle East, East Africa, the Indian Ocean, South, Southeast and East Asia, far West and far East Pacific, the Caribbean, and the Atlantic Ocean (Wilkinson, 1998). In the Maldives and Sri Lanka, losses in revenue due to bleaching in 1998 were estimated at US$3 million and US$ 200,000 respectively (Westmacott et al., 2000). Costs estimated from willingness of visitors to pay extra to experience unbleached reefs were an order of magnitude higher, with an estimate of US$19 million for the Maldives and US$2.2 million for Sri Lanka (Westmacott et al., 2000).

The costs of reef degradation from local and global sources of pressure are therefore significant. At the local scale, a starting point for countries relying on their reefs for tourism, fishing, coastal defence and other uses, is to manage them to obtain maximum benefit at minimum cost. For that to be achieved, impacts on the reefs of the various uses and activities on land and sea need to be understood and quantified.

My study site, St. Lucia, is an island state of 43km long by 23km wide in the eastern Caribbean, that relies on its reefs for its dive and snorkel tourism industry. The island has 160km^2 of reefs that fringe much of the coast (Spalding et al., 2001), with the best-developed and most used reefs in the south-west. Tourism is one of St. Lucia's main industries and in 2001 accounted for 53% of GDP (WTTC, 2002). Little is known of the impacts of diving and snorkeling on the island's reefs nor how the quality of the reefs may be affecting visitor perception and experience and thus potentially influencing future tourism trends. There is already evidence of reef degradation at certain sites and steps to conserve some of the reefs resulted in the establishment of the island's first marine protected area, the Soufrière Marine Management Area (SMMA) in 1995. Dive companies also formed an association 'Anbaglo', Creole for 'underwater', to promote safe and sustainable sport diving in St. Lucia. Anbaglo's objectives include improvement and expansion of the dive industry, promoting sport diving as a non-extractive use of reefs, fostering harmony between sport diving and other uses of reef resources, and assistance in training. Baseline information on diver behaviour underwater is a prerequisite to further develop management policy for the marine park and assist Anbaglo in achieving its objectives.

My research explored how the quality of coral reefs is affected by human activities, including both the effect of divers and snorkelers themselves and the implications of land-based activities, and whether coral reef quality affects visitor perception. I hypothesised that damage to reefs could be predicted from visitor, dive type and site characteristics, and that the ecological integrity of a reef would affect visitors' appreciation of it and hence affect local community tourism revenue. Should these hypotheses be true then the implication is that it is in the interest of stakeholders in the reef to see that reefs are well managed. It became obvious early in my research that reef quality does affect visitor perception, so I wanted to know how the visitors' appreciation of the reef was related to biological and physical attributes which could be measured, since that would affect the kind of management action that would be appropriate. In addition, the value of protected areas was measured by eliciting visitors' willingness to pay for marine park entrance fees and I investigated whether visitors were prepared to pay above the current fee. By measuring diver and snorkeler expenditures and the economic gains of dive companies, I was able to ascribe a monetary value to the reef. That could be used to build further support for managing the reefs and to develop measures to prevent other activities, such as those on land, from damaging them.

My research objectives were therefore to:

1. determine what damage divers and snorkelers were doing to the reefs and whether damage could be predicted from visitor, dive or snorkel leader, or site characteristics;

2. determine what the economic gains from dive and snorkel tourism were to the country's tourism industry, to the dive and snorkel companies and to the marine park, and whether visitors would be willing to pay more to use sites within the marine park than they were currently paying;

3. determine whether the quality of the reef environment affected visitor appreciation and how it compared to measured biological and physical attributes;

4. estimate the capacity of the various sites for diving and snorkeling taking into account the information gathered on diver and snorkeler ecological impacts.

My results are divided into five chapters, Chapters 2 to 6. In Chapter 2 I quantify diver damage and show that certain diver and dive site characteristics increased the likelihood of a diver damaging the reef. The time of dive and whether or not dive leaders intervened when they saw a diver damaging the reef also appeared to influence levels of damage. In Chapter 3 I quantify snorkeler damage and reveal that certain snorkeler characteristics influence their level of damage to the reef. I show that although their levels of damage were lower than that found for divers, higher densities of snorkelers at some sites could result in as much damage as that expected from a few divers. In Chapter 4 I calculate the economic benefits of coral reef tourism to St. Lucia and its dive businesses and, using visitors' maximum willingness to pay for marine park fees, I estimate the potential for tourists to fund more of the marine park's management costs. From my interviews with visitors I show in Chapter 5 factors that influenced visitors' perceptions and appreciation of St. Lucia's dive and snorkel sites. I compare visitors' perception of certain reef attributes with measurements taken by other researchers and myself, and show which attributes were correctly perceived and which were not. Finally, in Chapter 6, I summarise issues of reef resource use and the management tools that could help managers reduce tourist damage to coral reefs. These include carrying capacity estimates for St. Lucia's reefs and the importance of other factors such as distribution of tourism over sites, increasing number of sites available, managing visitor behaviour and monitoring the ecology of the reef.

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Chapter 2: Scuba diver behaviour and the management of diving impacts on coral reefs

2.1 ABSTRACT

Coral reefs worldwide are attracting increasing numbers of scuba divers leading to growing concern about damage. There is now a need to manage diver behaviour more closely especially as many dive companies are offering unlimited, unsupervised day and night diving from shore. I observed 353 divers in St. Lucia noting all their contacts with the reef during their entire dive to quantify rates of damage and seek ways of reducing it. Divers using a camera versus those not using one caused significantly more contacts with the reef (mean 0.4 versus 0.2 contacts min^{-1}), as did shore versus boat dives (mean 0.5 versus 0.2 contacts min^{-1}), and night versus day dives (mean 1.0 versus 0.4 contacts min^{-1}). I tested the effect of a dive briefing given by local staff and the effect of dive leader intervention on rates of diver contact with the reef. Briefing alone had no effect on diver contact rates or the probability of a diver breaking living substrate but dive leader intervention when a diver was seen to touch the reef did. This reduced mean contact rates from 0.3 to 0.1 contacts min^{-1} for both shore and boat dives, and from 0.2 to 0.1 contacts min^{-1} for boat dives. Given that briefings alone are insufficient to reduce diver damage, I suggest that divers need close supervision and dive leaders must manage diver behaviour in situ.

2.2 INTRODUCTION

Coral reefs are renowned for their beauty, diversity and the spectacular array of life that they support and provide many important services to people. These include coastal defence, fisheries, a focus for tourism and products for construction and medicinal compounds. Despite their obvious value, coral reefs are in global decline from a wide range of anthropogenic stresses. Pollution from sediment (Hodgson, 1993; Sladek Nowlis et al., 1997; Carias, 1998; Nemeth & Nowlis, 2001), chemicals (Guzmán & Holst, 1993; Negri et al., 2002) and sewage (Walker & Ormond, 1982; Bell, 1992; Koop et al., 2001) has led to a decrease in growth, reproduction and survival rates of corals and other reef-associated species. The decline in reefs comes at a time when marine tourism is greatly expanding. Technical advances in equipment in addition to a rising interest in nature, conservation and environmental matters (Ceballos-Lascuráin, 1993; Orams, 1999) have resulted in the increased popularity of coral reef recreation, particularly scuba diving (Dignam, 1990; Tabata, 1992).

Financial gains from coral reef tourism can be significant, ranging from US$2 million per year for the tiny 11km^2 Caribbean island of Saba (Fernandes, 1995), to US$682 million gained in 1991-2 from tourists to the Great Barrier Reef, Australia (Driml, 1994). However, diving, once thought to be benign (Tilmant & Schmahl, 1981; Talge, 1992; Hawkins & Roberts, 1992, 1993) is not necessarily so. Signs of diver damage such as broken coral fragments, dead, re-attached and abraded corals have been reported at heavily used dive sites throughout the Caribbean, Red Sea and Australia (Muthiga & McClanahan, 1997; Hawkins et al., 1999; Tratalos & Austin, 2001; Zakai & Chadwick-Furman, 2002). Diver damage differs depending on the type of corals present. Branching corals appear to sustain most of the breaks (Rouphael & Inglis, 1997; Garrabou et al., 1998) although Hawkins et al. (1999) found that due to their faster growth, percentage cover of branching corals in Bonaire increased by 8.2% in heavily dived areas, their expansion being at the expense of slower growing corals.

Certain dive and diver characteristics have also been linked to diver damage. Inexperienced divers, those with only basic training for example, have been found to be more likely to damage the reef (Roberts & Harriott, 1994). That finding is not universal though, as other studies found no such trend (Harriott et al.,1997; Rouphael, 1997).

Although studies indicate that 70-90 % of divers contact the reef during their dive only a minority of them do most of the damage (Talge, 1991; Rouphael & Inglis, 1995; Harriott et al., 1997). In Florida, less than 2% of divers caused any discernible damage to corals (Talge, 1991) and Rouphael & Inglis (1995) calculated that a similar percentage (2%, consisting of 5 divers) caused more than 50% of the damage they recorded. Male divers, camera use and the initial phase of the dive have also been found to be associated with increased levels of reef damage (Rouphael & Inglis, 2001). Fins are most often involved in contact and damage to the reef, followed by hands, knees and equipment gauges. In Rouphael's study (1997), fins accounted for 58% of contacts with the reef and 95% of the damage. Divers also kick up sediment with their fins which then can settle on surrounding corals (Rouphael & Inglis, 1995; Zakai & Chadwick-Furman, 2002). One way of reducing diver damage is by education. Medio et al. (1997) showed that divers did less damage after they were given a 45min illustrated dive briefing covering reef biology, contacts caused by divers and the concept of a protected area, followed by an in-water demonstration lasting a few minutes. Divers were shown the different forms of live reef cover and non-living substrate, such as rock and dead coral, to illustrate areas of the reef that could be touched safely.

The impact of divers is not just negative. Positive impact comes from their help towards paying for reef management through user fees. Marine parks such as Saba and Bonaire in the Caribbean have, through a fee system, become self-financing (Dixon et al., 1993; D. Kooistra, 2002 pers. comm.). Though divers may be willing to pay park fees such a system is pointless if, in the process, they destroy what they have come to see.

It is clear that coral reefs are a valuable but vulnerable asset to the dive tourism industry. This study quantifies diver damage in St. Lucia, one of the Windward Islands of the Eastern Caribbean (Fig. 2.1) and seeks ways to reduce it.

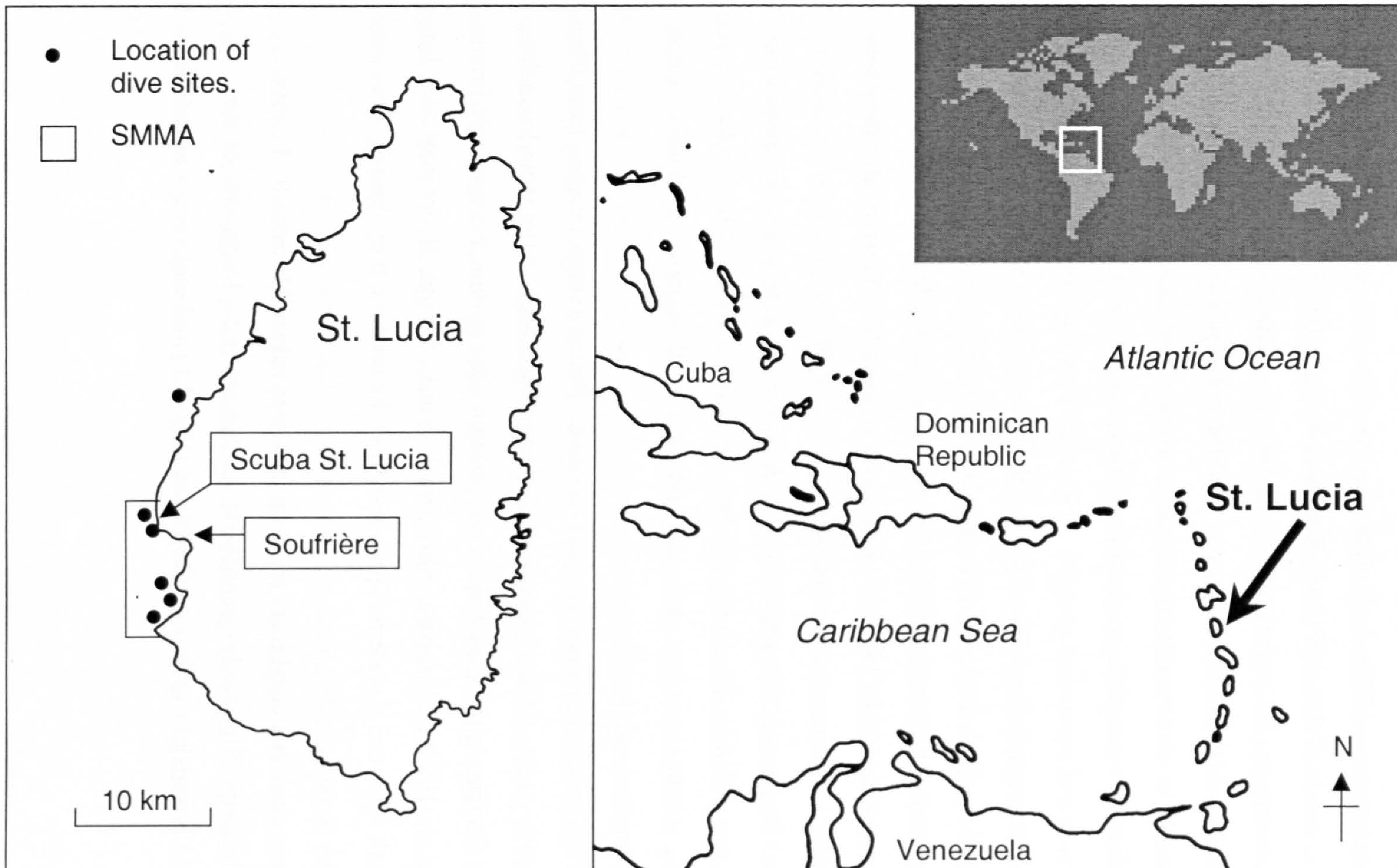

Fig. 2.1 Location of study site. Boxed area on west coast of St. Lucia on left half of figure shows the boundaries of the Soufrière Marine Management Area (SMMA). Dots show approximate locations of dive sites and each dot encompasses several sites.

Tourism is one of St. Lucia's main industries (CIA, 2002) accounting in 2001 for an estimated 53% of GDP (WTTC, 2002) and in 2000 annual visitor arrivals numbered over seven hundred thousand (St. Lucia Government Statistics, 2002). Among its natural resources are forests, sandy beaches, thermal springs and coral reefs. Reefs cover 160 km^2 and fringe most of the island (Spalding et al., 2001).

Dive tourism in St. Lucia began in the 1970's with the opening of the island's first dive business (Xavier, 2002, pers. comm.) and has been increasing ever since. By 2001, nine dive businesses sold courses and trips either as part of activities offered by a resort or hotel or as independent companies. Since 1995, dive permits sold for use of sites within the Soufrière Marine Management Area (SMMA), a marine park in the south west of the island, have increased by over 200% (SMMA, 2000). An estimated 137,000 dives are done yearly throughout the island with 60% at sites within St. Lucia's Soufrière Marine Management Area (see Chapter 6, Table 6.2). Dive tourism is heavily reliant on the island's reefs and yet direct impact from dive tourists themselves combined with other sources of stress from human activities could threaten their existence.

In this study I determined the influence of certain characteristics of divers, dives and dive sites on levels of damage caused by divers visiting St. Lucia. Close proximity of dive sites to the dive company and hence time constraints by which the company worked precluded the thorough diver education such as done in Medio et al.'s 1997 study. Instead I tested the effect on diver behaviour of a one-sentence inclusion in the usual dive briefing given by dive leaders asking divers to avoid all contact with the reef. I also tested the effect of intervention by dive leaders if and when they saw a diver contacting the reef. In contrast to Medio et al. (1997), where Medio carried out all briefings and demonstrations himself, I used non-scientifically trained staff employed by the dive company to give the briefings and carry out interventions, this being more realistic.

2.3 Methods

2.3.1 Study site and diver samples

I collected data on scuba divers in St. Lucia for 26 weeks spread over two periods. The first (12 weeks between 13 December 2000 and 11 March 2001) coincided with the high tourist season and the second (14 weeks between 28 June and 7 October 2001) the low season. I accompanied guests diving with Scuba St. Lucia, a dive company situated 2km north of Soufrière in the Soufrière Marine Management Area (SMMA, Fig. 2.1). Stratified random selection was used to decide which divers were to be observed before they got into the water in order to fill chosen sub-groups. Once a sub-group was filled, those individuals in that group were avoided. Sub-groups included: photographers and non-photographers, first day divers and divers on their second or more day of diving, men and women, cruiseship visitors and visitors staying in hotels on the island, visitors diving from the shore and from the boat. On each dive, between one and three divers were discretely observed from a distance of three to four meters underwater. Observations started from the time divers descended from the surface of the water to the point when they began their ascent back to the surface at the end of their dive. To remain anonymous so as to prevent any change in behaviour by the divers due to my presence, I asked the dive staff to treat me as any other guest. My answer to visitors' questions directed at my note taking underwater was that I was collecting information on the fish and corals for the marine park.

2.3.2 Dive sites

The company used 10 dive sites in and two sites outside of the SMMA. I only used the coral reef sites (as opposed to boat wrecks), of which there were eleven, for my diver observations and classed them according to topography: plateau, sloping, wall and varied, the last being for sites that had some combination of the three (Table 2.1). The dive company used sites in rotation but weather or client needs sometimes required certain sites to be used more than others. For all qualified recreational scuba divers diving with the company, their first dive, irrespective of qualification (basic through to instructor), was a 'checkout dive' done from the shore on Anse Chastanet reef. This was the only site accessible from shore. Divers were required to enter the water from shore to a depth of about 2m and perform two tasks: mask clearing and regulator recovery. Observations during Anse Chastanet dives began after those performance requirements had been met. To compare day and night dives, the same divers were observed on both day and night dives at the same single site, Anse Chastanet. This minimised influencing variables that may have resulted from using different sites and different divers. All day dives at the remaining dive sites were accessed only by boat. 353 divers were observed (Table 2.1).

TABLE 2.1 DIVE SITES AND CORRESPONDING SAMPLE OF DIVERS OBSERVED

Dive site categories by topography	Dive site	Number of divers observed
1- Wall	Anse la Raye wall	10
	Piton wall	20
2- Varied: Pinnacles, boulder areas and sloping reef	Pinnacles*	28
	Trou Diable*	37
	Fairyland*	30
3- Sloping reef	Grand Caille*	21
	Coral Gardens*	28
	Jalousie*	39
	Superman's Flight*	17
4- Plateau	Turtle reef*	27
	Anse Chastanet*	96
Total		353

* = Sites within the SMMA

2.3.3 Factors recorded

On each dive I noted a number of factors pertaining to the dive site, dive group and dive leader communication, environment and observed diver behaviour (Table 2.2). Factors such as weather, number of men and women on boat and underwater visibility were collected for the purposes of a separate study on diver perceptions (Chapter 5). The studies were linked to save field costs and respondent burden.

In order to compare my results with previous research on underwater photographers by Rouphael & Inglis (2001) I used similar photographer classes. Divers using single-use and basic model, "point and shoot cameras" I classed as non-specialist photographers (e.g. Sea and Sea MX5 and MX10, Bonica Handy Snapper, Aquion Splashshot and Oceanic Aqua Snap cameras). Divers using bulkier and more expensive camera equipment I classed as specialist photographers (e.g. Sea and Sea MMII-EX, Nikonos and cameras in housings).

I noted all contacts made by divers and whether contacts were intentional or unintentional. Contacts that appeared to have been deliberate, such as a diver steadying themselves on a coral head whilst taking a photograph I classed as intentional. Contacts that appeared to have been made by mistake and without the knowledge of the diver, such as accidentally kicking a gorgonian with their fin, I classed as unintentional. Result of contact, whether minor (touch or scrape), major (breakage) and or resulting in re-suspension of sediment (settled particles), were also noted, as was substrate type. Living substrate included any live organism such as coral, sponge or reef animal (e.g. sea urchins or lobsters). In the case of re-suspended sediment, 'with living substrate' means the impact occurred directly in the vicinity of live organisms as opposed to inert substrate. The latter included sand, rock, dead coral colonies and pieces of dead coral, termed 'coral rubble'.

I made relative measurements of underwater current on each dive using a 1m length of ribbon attached to a pencil. I estimated the time for the ribbon to unthread and lie straight by counting out seconds.

TABLE 2.2 FACTORS RECORDED FOR EACH DIVE DURING WHICH A DIVER WAS OBSERVED

Site, dive and dive group factors:	
1.	Date, Time, Dive site name
2.	Weather (sunny, overcast, rain)
3.	Dive type (whether entry into water from a boat or by foot from shore)
4.	Whether the briefing included reference to not touching the reef
5.	Whether dive leaders were 'on-call' to intervene if and when they saw the observed divers contacting the reef
6.	Number of men and women participating on the dive (including dive leaders and photographic staff)
Factors relating to diver(s) under observation:	
7.	Sex (male, female)
8.	Photographer status (non, non-specialist, specialist)
9.	What protective dive clothing was being worn (gloves, wet suit, none)
Factors relating to observed contacts:	
10.	Time of contact
11.	Whether the contact was intentional or unintentional
12.	Point of contact (body part, equipment, fin, etc.)
13.	What part of the reef was affected (living or inert, type e.g. hard or soft coral, morphology e.g. branching or not)
14.	What the result of the contact was minor (touch or scrape but not broken), major (broken) or whether the sediment was stirred up.
Dive factors (measured only on dives carried out during daylight hours):	
15.	Current
16.	Underwater visibility

My estimates of current rate ranged from 0.08 to 0.94 m s^{-1} (Table 2.3). I used a secchi disk and measuring tape, assisted by the dive leader, to record horizontal visibility. If either current or visibility varied markedly during the dive, several readings were taken and the average used.

TABLE 2.3 CURRENT RATE CLASSES

Current class	None	Low	Medium	High
Count in seconds	No movement	9-12	5-8	1-4
Current rate range (m s^{-1})	0	0.08 ⟶ 0.94		

Following a dive, I asked divers I had observed about their diving experience. I used two questionnaires and filled in their responses to each question. The questionnaires were constructed to determine diver's perceptions of the reef (Chapter 5) and expenditure patterns (Chapter 4). However I was able to embed questions relating to their personal dive history and experience among others, listed in Table 2.4 (Questions: 9-15 in Questionnaire 1, Appendix A and questions 26 and 27 in Questionnaire 2, Appendix B). I tested the questionnaires on colleagues and members of dive clubs from the UK, France and the USA before use to ensure that questions were clear and any ambiguities rectified.

TABLE 2.4 ADDITIONAL INFORMATION GAINED FROM QUESTIONING DIVERS OBSERVED

1. No. dives done so far on trip
2. Total no. dives planned for trip
3. No. dives logged in total dive history
4. Highest diving qualification*
5. Membership of any environmental organisation(s)
6. Whether they read articles on marine life in magazines or newspapers
7. Where they were staying in St. Lucia
8. Country of residence
9. Age

**Dive qualification categories: Basic* = Basic diving skills, not including rescue training; *Advanced* = basic skills including rescue training; *Dive leader; Instructor.*

2.3.4 Statistical analyses

My data were non-normal and remained so despite application of various transformations. Hence I used non-parametric statistical analyses to examine relationships between diver and dive site characteristics and diver contact rates.
I used the Sheirer-Ray-Hare test, a non-parametric equivalent to a two-way analysis of variance (Dytham, 1999) to test the relationship between dive briefings, dive leader intervention during dive and diver behaviour underwater, individually and together.

Box and whisker plots are used to show summary plots based on the median, quartiles and extreme values. Each box represents the interquartile range which contains 50% of values. The whiskers are lines that extend from the box to the 5th and 95th percentiles and dots denote outliers. A line across the box indicates the median.
In order to analyse the effect of a number of covariates on the probability of a diver having a contact with the reef and of causing a breakage during their dive logistic regression was employed. Table 2.5 lists the fourteen variables used in the logistic regression. The first twelve are independent variables and the last two are the dependent variables.

To test the robustness of the parameter estimates a bootstrap procedure was employed. This involved artificially enhancing the sample size by picking random numbers using the seed 123456789 to represent a population of approximately 34,000 divers (my initial estimate of number of divers visiting St. Lucia annually). 10,000 bootstrap replications were computed and the variability of estimates analysed. To supplement this test, density curves for the significant covariates were compared graphically.

In lieu of a suitable non-parametric method, to obtain predicted contact rates for divers, I used multiple regression to explore the relationships between the same twelve independent variables used in the logistic regression, and the number of contacts per minute and the number of coral breakages per minute. Transformation of contact rate by taking the square root improved normality. Other assumptions including multicollinearity, singularity and normality, linearity, homoscedasticity and independence of residuals were checked and did not seem to have been violated.

TABLE 2.5 VARIABLES, THEIR VALUE AND DESCRIPTION USED IN THE LOGISTIC AND MULTIPLE REGRESSION ANALYSES

	Variable	Value	Description
1	INTERV	1	Dive leaders 'on-call' to intervene with divers seen to damage the reef
		0	Dive leaders not 'on-call' to intervene
2	MALE	1	Male diver
		0	Female diver
3	BASIC	1	Basic diving qualification
		0	Non-basic diving qualification i.e. advanced and above
4	PHOTO	1	Photographer
		0	Non-photographer
5	CURR	1	Strong current present
		0	Not strong current i.e. moderate or less
6	BRIEF	1	Instruction on avoiding touching corals given in briefing
		0	Instruction on avoiding touching corals not given in briefing
7	SHORE	1	Shore dive
		0	Boat dive
8	NDIVE	Actual number	Dive number of trip at point of observation
9	TDIVE	Actual number	Total number of dives completed in whole dive history
10	CRUISE	1	Visiting St. Lucia by cruiseship
		0	Not visiting by cruiseship
11	MENV	1	Member of an environmental group or organisation
		0	Not a member of an environmental group or organisation
12	READ	1	Read articles on marine life
		0	Do not read articles on marine life
13	CONTACT	1	Contact occurred during course of dive
		0	No contact occurred during course of dive
14	BREAK	1	Breakage occurred during course of dive
		0	No breakage occurred during course of dive

2.3.5 Constraints of methods used

There were various constraints in the methods I used which may have led to bias in my results.

Dive company

All dives were carried out with a single dive company and work involved collaboration with that company's employees. Their dive schedule, objectives and working methods may be dissimilar to other dive companies on the island. However, the company used was among one of the bigger businesses on the island catering to around 10,000 divers per year. This compares with the range of 450 to 14, 000 divers for other resorts in St. Lucia (personal interviews, 2001, see Chapter 4). The company that I worked with sold dive trips to guests from its own resort, other resorts on the island and to visitors arriving by cruise ship. For this reason, I believe that the sample of divers I observed was representative of the general diving population at that time. Variation among dive leaders may also have had some influence on diver behaviour. However, my main objective was to test the effectiveness of divers being given a briefing that included instructions on not touching the coral, therefore slight differences in delivery of the information by the various dive leaders was not as important as whether or not it was given at all. To keep the influence of intervention as similar as possible, the same dive leader was used throughout to be 'on-call'.

Diver samples

Sample sizes might not have been representative of their respective populations visiting St. Lucia. Virtually all the photographers diving with the company were observed because they were so few, whereas a smaller proportion of non-camera users was observed. My sample of cruiseship visitors was limited to those sending divers to the dive company that I worked with and these visitors may not have been representative of those from other cruise ships diving with other companies.

Diver behaviour

For reasons of safety, it is universally recommended that divers only dive in pairs. In St. Lucia the water visibility was generally 20m or more and diver pairs were able to spread out with several meters between them and still be able to see the dive leader, the latter being a recommendation given in the pre-dive briefing. To ensure a maximum number of observations during my study, and to be close enough to see what if any, contacts divers were having with the reef, I usually observed pairs of divers. Diver pairs ranged from couples to complete strangers. Bias could have been introduced from divers copying each other's behaviour. Although I did not test for this, I observed many couples with opposite behavioural tendencies, e.g. one with poor buoyancy and one with good. Sometimes partners would try and help the other, thus decreasing likelihood of reef damage; but others confounded the situation and appeared to make matters worse. Photography was most often done by only one individual in the pair.

Observation method

Some diver contacts with the reef may have been missed both during the day and at night when I lost sight of divers who went behind reef formations. However, these instances were few and only lasted a few seconds. General low visibility at night may have also led me to miss more diver contacts with the reef than during the day. To compensate for the reduced visibility, I followed divers at a closer distance than during the day (1-1.5m instead of 2-4m). The light from divers' torches typically illuminated an area of a few meters. Divers' attention focused on the illuminated area allowing me to get closer unnoticed.

2.4 Results

2.4.1 Diver characteristics

353 divers were observed underwater throughout their dives and interviewed immediately afterwards. Most divers came from the USA (63.6%), followed by the United Kingdom, Canada, various European countries and Brazil (Table 2.6).

TABLE 2.6 DISTRIBUTION OF OBSERVED DIVERS BY COUNTRY OF RESIDENCE

Country	Number of divers	Percent
United States of America	213	63.6
United Kingdom	72	20.9
Canada	23	6.9
Brazil	1	0.3
Other countries in Europe:		
Austria	3	0.9
France	1	0.3
Germany	13	3.9
Ireland	3	1.5
Luxemburg	1	0.3
Netherlands	3	0.9
Norway	1	0.3
Sweden	1	0.3
Missing data	18	

Slightly more men than women were observed (58.4%) and age ranged from 15 to over 60 years (Table 2.7). The mean and median age class for both sexes from the first sample was 40-49yrs. Age was only noted in the first survey and dropped in the second to compress the questionnaire but my qualitative impression was that the age distribution was similar for both surveys. Proportions of men and women sampled within each age category were similar. 54 out of the 353 observed divers were photographers. 74.1% of photographers were male (n=40) and both sexes had individuals in the non-specialist and specialist categories (Table 2.8).

TABLE 2.7 AGE AND SEX DISTRIBUTION OF OBSERVED DIVERS OVER THE FIRST SAMPLE PERIOD

	Age in years						No data
	15-19	20-29	30-39	40-49	50-59	60+	
% of male divers	0.8	13.7	25.8	28.2	23.4	2.4	5.6
% of female divers	3.8	13.9	26.6	39.2	12.7	2.5	1.3
Overall %	2.1	14.4	27.2	33.8	20.0	2.6	

TABLE 2.8 SEX, AGE AND PHOTOGRAPHER STATUS OF DIVERS

Sample Period 1	Non-specialist photographers		Specialist photographers		Non-photographers	
Age in years	Male	Female	Male	Female	Male	Female
15-19	1				0	3
20-29	1				16	11
30-39	6	2	3	1	23	18
40-49	5	2	7	2	23	27
50-59	2		2	1	25	9
60+		1			3	1
Missing	2				5	1
Sample period 2	8	3	3	2	71	63
Total	25	8	15	6	166	133

The dive on which divers were observed varied from their first to their 29th of the trip. Sampling spanned the range of number of dives people planned to make on their trip to St. Lucia (Fig. 2.2). The two outliers on the bar chart are divers whose trip consisted of visiting multiple islands and who had completed 20 dives prior to arriving in St. Lucia. Dives lasted from 21 to 53 minutes with a mean and median of 42 minutes.

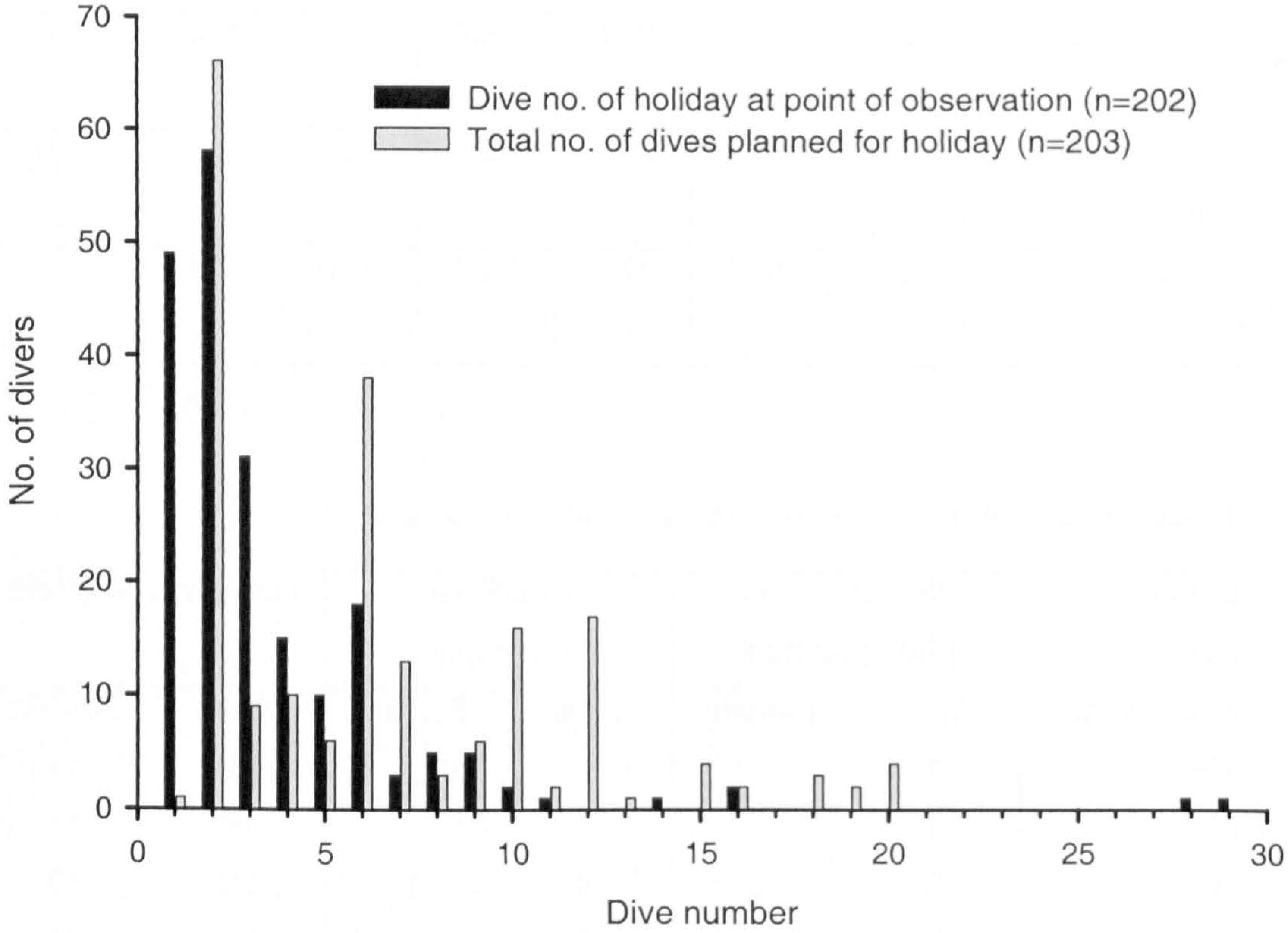

Fig. 2.2 Number of dives completed by observed divers and expected number of dives to be undertaken during their stay in St. Lucia.

2.4.2 Dive site characteristics and diver behaviour underwater

Overall, 261 of the 353 observed divers (73.9%) made at least one contact with the reef during their dive with a mean contact rate (number of contacts per minute) of 0.25 ± 0.04 (95% CI) and a median of 0.09 contacts per minute.

Contact rates of divers were significantly different between sites of different topography (Kruskal-Wallis Test: both sample periods combined $p<0.001$, Fig. 2.3).

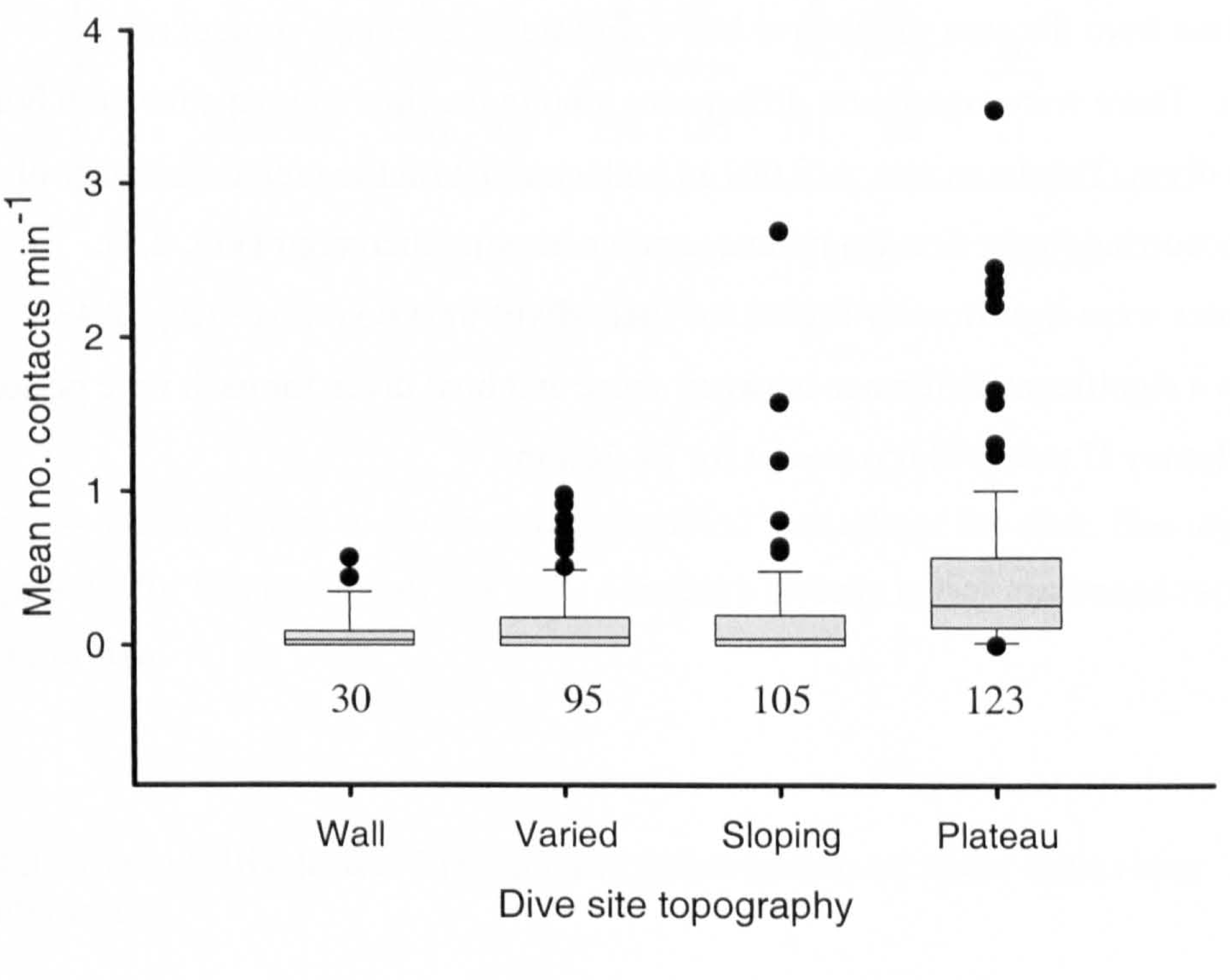

Fig. 2.3 Contact rates by divers according to dive site topography. Boxes represent the interquartile range which contains 50% of values. A line across the box indicates the median. The whiskers extend to the 5th and 95th percentiles and filled circles are the outliers. Numbers directly below the boxes represent sample size.

Sites typified by plateaus had a higher rate of diver contact than other sites. Only Turtle Reef and Anse Chastanet belong to this category. Both are equally close to shore, but only Anse Chastanet was dived from the shore. To determine whether the shore dive caused the significant difference seen, calculations were re-run excluding Anse Chastanet and the result proved to be non-significant (Kruskal-Wallis test, $p=0.464$). Further analyses therefore considered shore and boat dives both separately and together.

Many more divers (97.9%) caused a contact on shore dives compared to boat dives (65.0%). Divers also produced statistically significantly higher contact rates (median of 0.35 contacts per minute) when diving from the shore than from a boat (median of 0.13 contacts per minute; Mann-Whitney U test $p<0.001$).

Time from the start of the dive had a significant effect on contact rates (Fig. 2. 4). There were significant differences among the time intervals for both boat and shore dives (Friedman test, $p<0.001$ in both cases) with the greatest number of contacts occurring in the first ten minutes and decreasing thereafter (Fig. 2.4). Contact rates were significantly higher for shore dives than boat dives (Fig. 2.4). There was a significant difference between shore and boat dives for each time period (Mann-Whitney U test, $p<0.05$) except for 21-30mins.

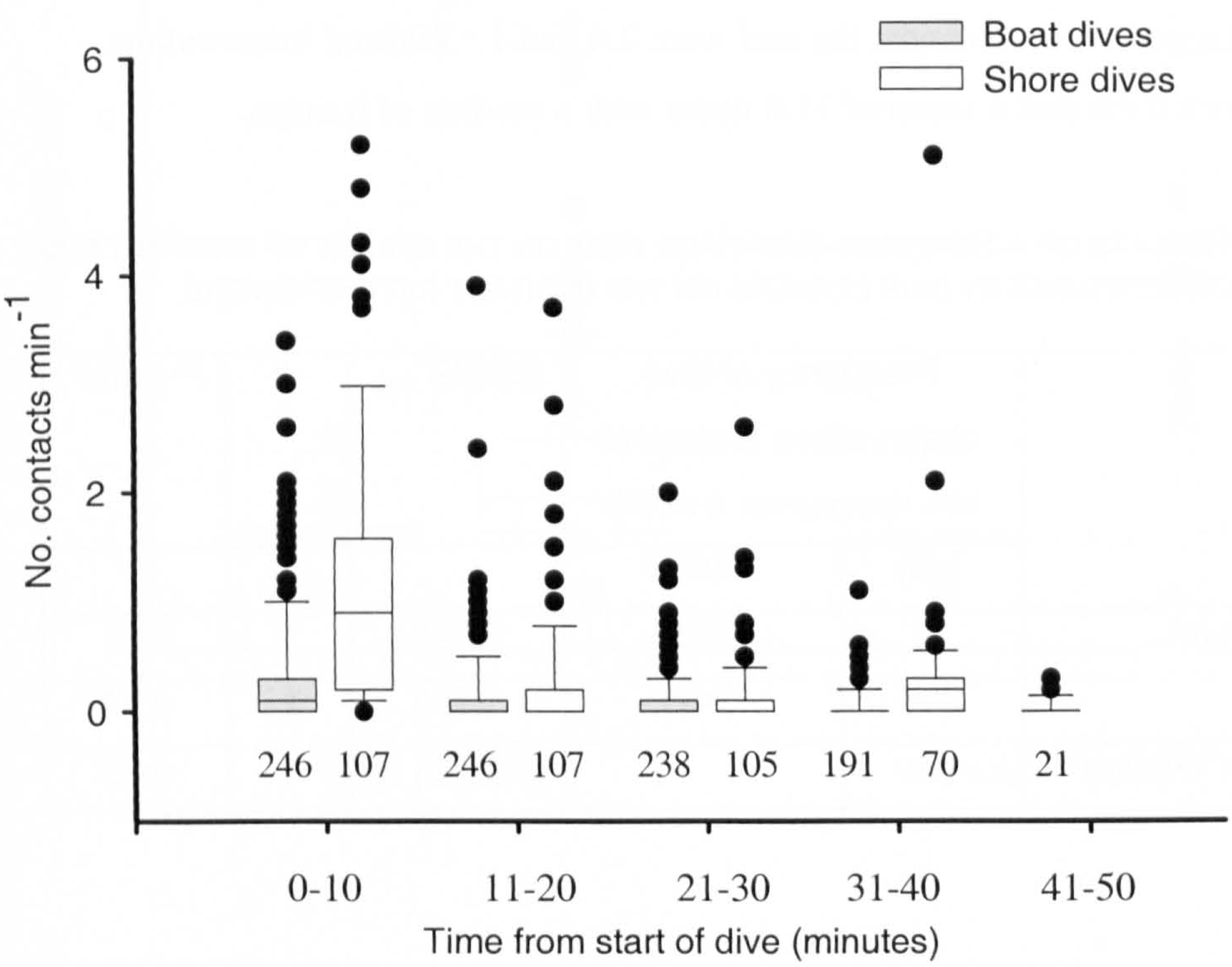

Fig. 2.4 Contact rates of divers and time period throughout the dive. See legend to Figure 2.3 for explanation of box plot. Numbers directly under the boxes represent sample size.

2.4.3 Effect of dive leader briefing and intervention on diver behaviour underwater

Divers given a briefing (Appendix E) had slightly higher contact rates than divers not given a briefing, but not significantly so (Table 2.9). However, there was a significant difference between contact rates of divers with regards to dive leader intervention (Table 2.9). Divers whose damaging behaviour was brought to their attention by dive-leaders had five times fewer contacts per dive than divers who were not notified (Fig. 2.5). For a 40-minute dive with intervention, mean and median number of times divers contacted the reef were 2.4 and 1. Without intervention, divers contacted the reef a mean of 11.6 times with a median of 6 times.

TABLE 2.9 RESULTS OF A SCHEIRER-RAY-HARE TEST ON THE EFFECT OF BRIEFING AND INTERVENTION MEASURES BY DIVE LEADERS ON THE CONTACT RATE OF DIVERS

	Frequency of dive observations under the two measures: a and b		SS/MS_{total}	df	P-value
	with	*without*			
Intervention (a)	62	291	6.199	1	0.01
Briefing (b)	206	147	1.386	1	0.24
Intervention*Briefing			0.104	1	0.75

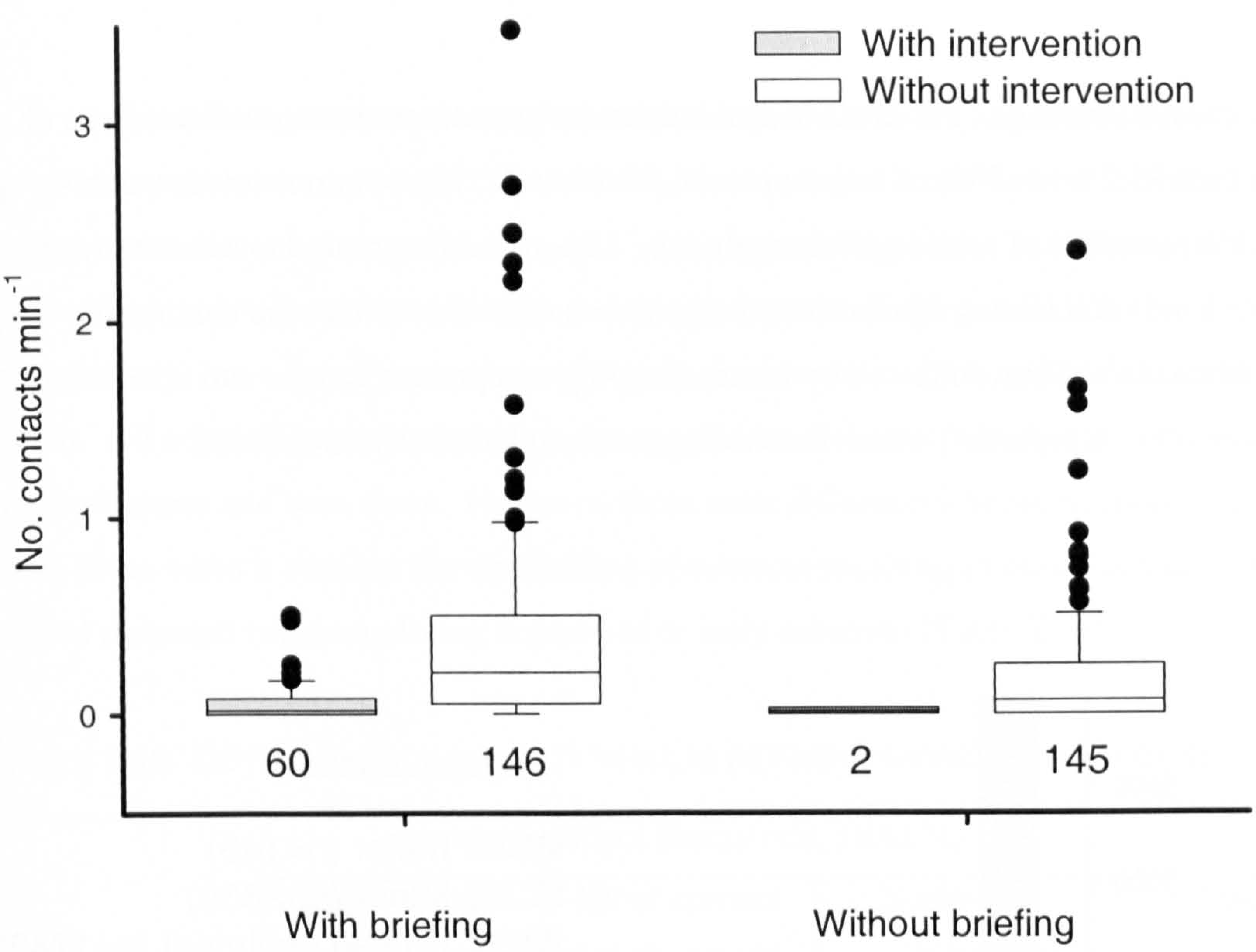

Fig. 2.5 The effect of briefing and intervention by dive leaders on diver contact rate. See legend to Figure 2.3 for explanation of box plot. Number below each box represents sample size. Only two instances occurred where divers were not given a briefing but where the divemaster intervened. Both divers had low contact rates and the sample size was not large enough to draw confidence intervals.

2.4.4 Diver behaviour and influencing characteristics

The distribution of contacts by the various parts of the diver (Fig. 2.6) was similar for shore and boat dives. Kicking and touching the reef substrate with fins was by far the most common form of contact (81.4%) followed by touching and holding with hands (10.1%). Most contacts (79.8%) were 'minor' (touch or scrape), almost half (49.0%) resulted in the re-suspension of sediment and a small proportion (4.1%) were 'major' i.e. caused breakage. Fin kicks accounted for the greatest proportion of each type of contact: 95.2% (n=138) of major contact, 78.5% (n=2228) of minor contact and 90.8% (n=1581) of raised sediment plumes. Divers holding onto the substrate with their hands and resting against the substrate with their knees were the next most problematic actions, followed by loose, dangling equipment (gauges and alternative air sources 'octopuses') which brushed against and knocked into the reef.

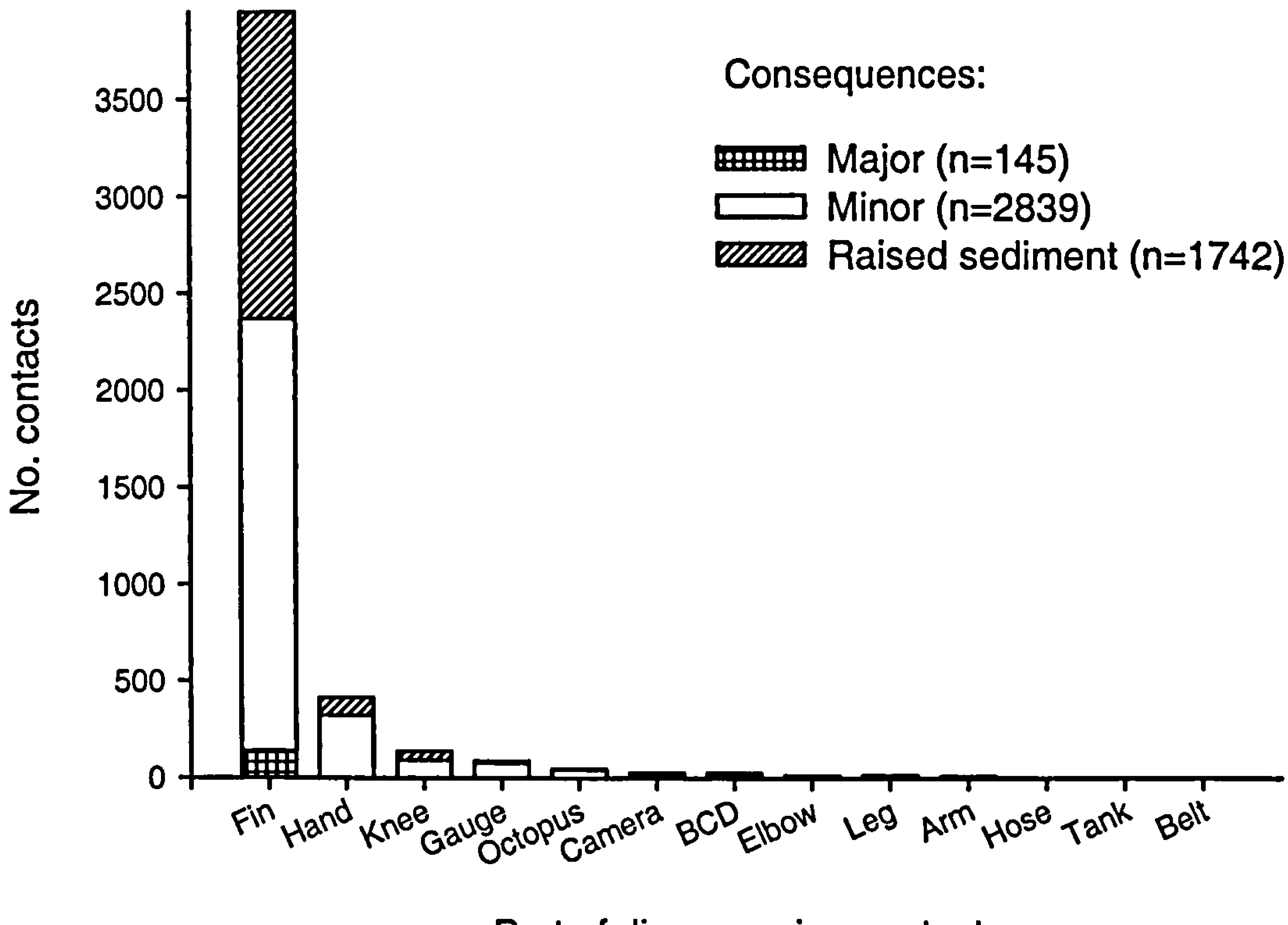

Fig. 2.6 Number of contacts associated with particular parts of the diver's body or their equipment. Contacts are divided according to their consequences (major and minor contacts and raised sediment).

Considering shore and boat dives separately, shore dives had a small proportion of major contacts (1.5%) and roughly equal amounts of minor contacts and raised sediment plumes (51.5% and 47.1% respectively). Boat dives however showed a higher percentage of major and minor contacts (5.6% and 73.4% respectively) but a lower percentage of instances of raised sediment (21.0%) (Table 2.10). All contacts resulting in major contact involved contact with living organisms for both shore and boat dives. However, there were differences between shore and boat dives when it came to the distribution of contacts resulting in minor contact and raised sediment involving living organisms or inert substrate (Table 2.10).

TABLE 2.10 DISTRIBUTION OF CONTACT RESULTS BETWEEN SHORE AND BOAT DIVES

	Result of contact (frequency, *f* and %)							
	Major contact Breakage		Minor contact Touch, scrape		Sediment raised		Total	
	f	%	*f*	%	*f*	%	*f*	%
Shore dive	42	1.5	1479	51.5	1352	47.1	2873	100
-With living substrate		100.0		35.0		19.5		
Boat dive	103	5.6	1360	73.4	390	21.0	1853	100
-With living substrate		100.0		84.5		73.6		

Although most contacts (81.2%, n=2888) were unintentional, the actual distribution of major and minor contacts as well as raised sediment between intentional and unintentional contacts were similar (Table 2.11). The total number of contacts is less than the sum of frequencies of major, minor and sediment damage. This is because some individual contacts resulted in two forms of effect. One fin kick for example, may have resulted in breakage of a coral plus re-suspension of sediment. This one contact would therefore have scored as both a major contact and re-suspension of sediment.

TABLE 2.11 EFFECT OF DIVER INTENT ON CONTACT NUMBER AND RESULT

Contacts	Total number of contacts	Frequency of 'major' contact	Frequency of 'minor' contact	Frequency of re-suspension of sediment
Intentional	670	19 (2.8%)	632 (94.3%)	312 (46.6%)
Unintentional	2888	126 (4.4%)	2207 (76.4%)	1430 (49.5%)

Divers using a camera contacted the reef significantly more than non-camera users (Kruskal-Wallis test $p<0.001$, Fig. 2.7), but there was no significance in whether or not a diver was a 'non-specialist' or 'specialist' photographer (Mann-Whitney U test, $p = 0.632$).

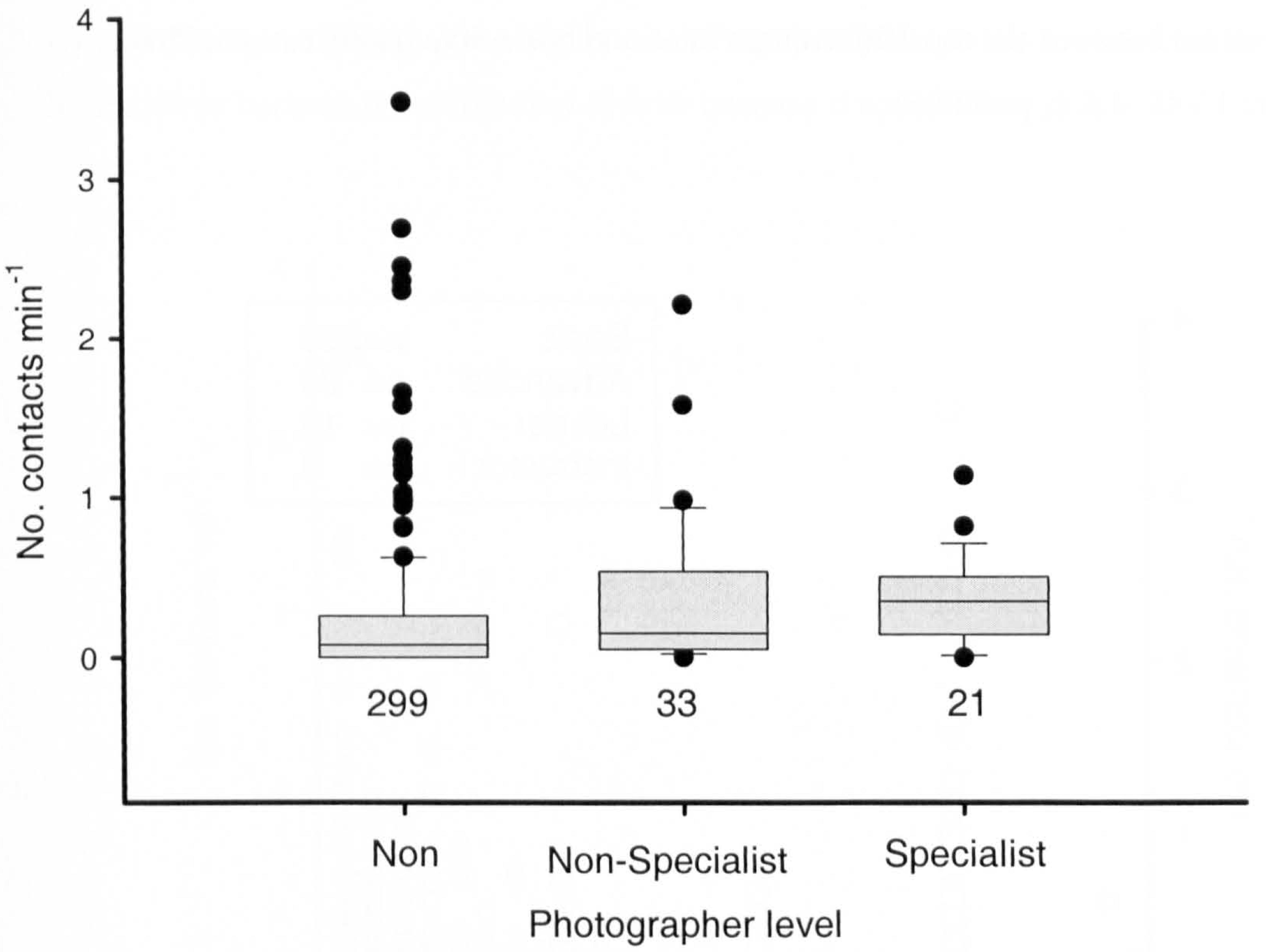

Fig. 2.7 Contact rate of divers taking photographs compared to divers without cameras. 'Non-specialist' photographers were those using point-and-shoot or disposable cameras and 'Specialist' photographers were those using cameras that required a higher technical capability. See legend to Figure 2.3 for explanation of box plot. Numbers under boxes show sample size.

Contact rate did not differ significantly according to level of dive qualification (Kruskal Wallis test, p=0.229), possibly due to much lower sample sizes in the Advanced, Leader and Instructor categories compared to Basic. However, there is generally much greater spread in contact rate among the least qualified divers (Fig. 2.8). Taking the 10% of divers with the highest contact rates, 32 out of the 35 divers (91.4%) had only the basic dive qualification level whereas only 82.7% of the remaining 318 divers had basic qualifications. There was a slight but non-significant association between the top 10% contact rates and basic dive qualification (Chi-square 1.748, d.f. 1, p=0.093).

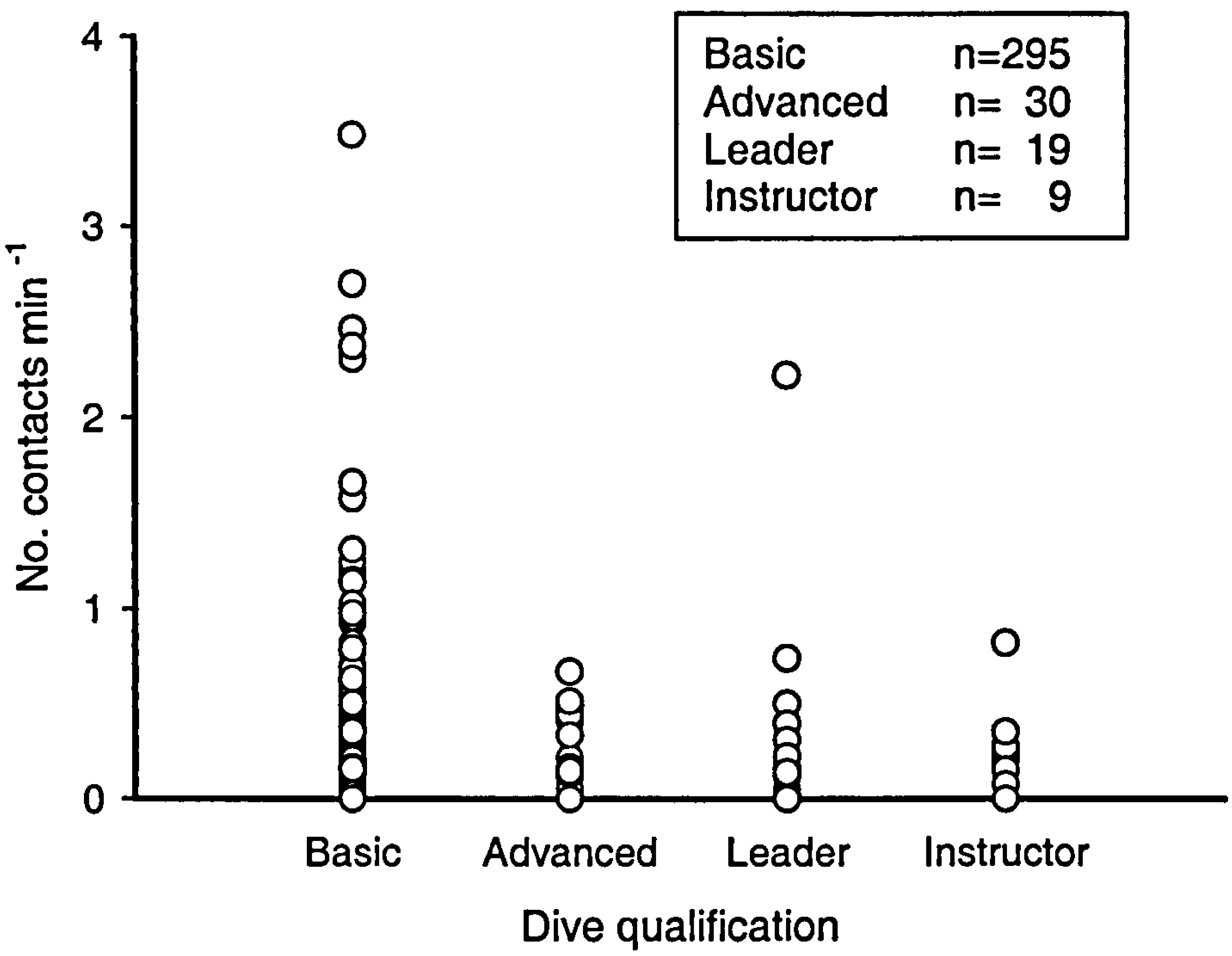

Fig. 2.8 Distribution of diver contact rates according to their level of dive qualification.

The correlation between contact rate and number of dives completed so far was negative (Fig. 2.9, Spearman's rank correlation, $r = -0.399$, $p<0.001$, $n=352$) reflecting the fact that earlier dives in the trip were associated with higher contact rates. The first dive of the holiday resulted in more than twice as many contacts as subsequent dives. As mentioned previously, the first dive was always at Anse Chastanet, the sole site that was dived from the shore. Separate analysis is required to try and distinguish whether the higher rate of contacts seen on the first dive of the holiday was because it was the first dive or because it was a shore dive.

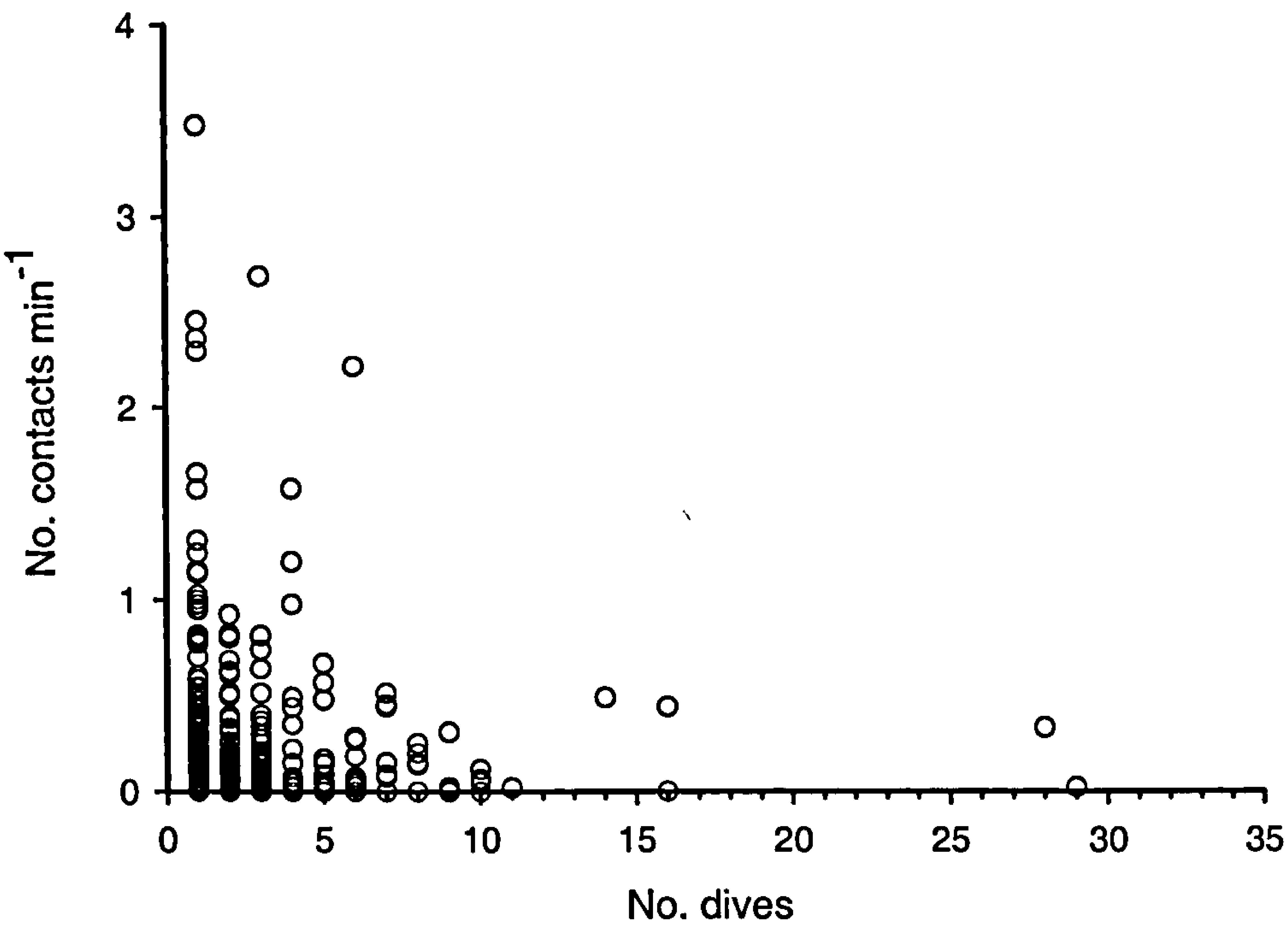

Fig. 2.9 Contact rates of scuba divers and number of dives done on trip (both sampling periods combined).

Taking shore dives only and comparing the contact rates between divers who did this as their first dive versus those who did it as their 2nd, 3rd, or 5th dive (total sample size of 6, no-one did it as their 4th dive), no significant difference between contact rate and dive number were found (Kruskal Wallis p=0.253). Re-coding the dive numbers into either 1st dive or other also showed no significance (Mann-Whitney U, p=0.300). As mentioned, the sample size for 'other' (2nd, 3rd, or 5th dive) was only 6 divers compared to 90 divers observed on their first dive of their holiday, hence the test is very weak. Removing the first dive still gave a negative correlation between contact rate and number of dives completed, but failed statistical significance at the 5% level ($r=-0.088$, $p=0.078$, $n=262$).

Similarly, for boat dives, I found a near significant result for contact rate versus number of dives completed during holiday. This was irrespective of whether the dive was the second, third, fourth or n^{th} dive (Fig. 2.10, Kruskal Wallis test, $p=0.056$). These results indicate that the site and method of entry (shore dive) are probably the greater influencing variable rather than dive number of holiday.

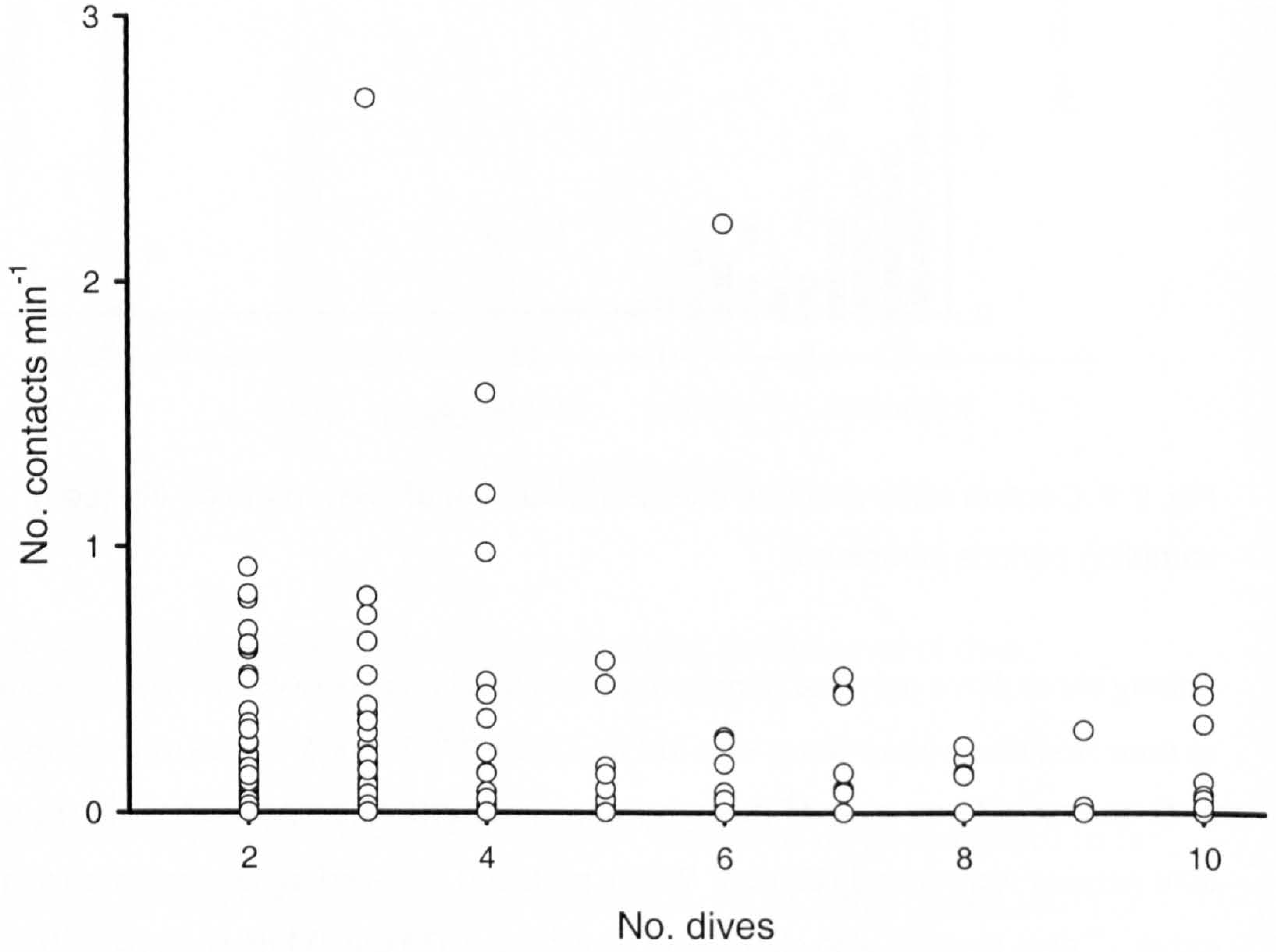

Fig. 2.10 Contact rates and number of dives completed during St.Lucia trip at point of observation. Boat dives only.

Experience, as measured by total dives in whole dive history also had a weak but non-significant negative correlation with contact rate (Spearman's rank correlation: $r = -0.077$, $p=0.147$).

Divers that did the night dive had more than double the contact rate than on day dives made at the same site (median of 0.45 versus 0.26 contacts min^{-1}, Wilcoxon's signed ranks test, $n=33$, $p<0.001$, Fig. 2.11).

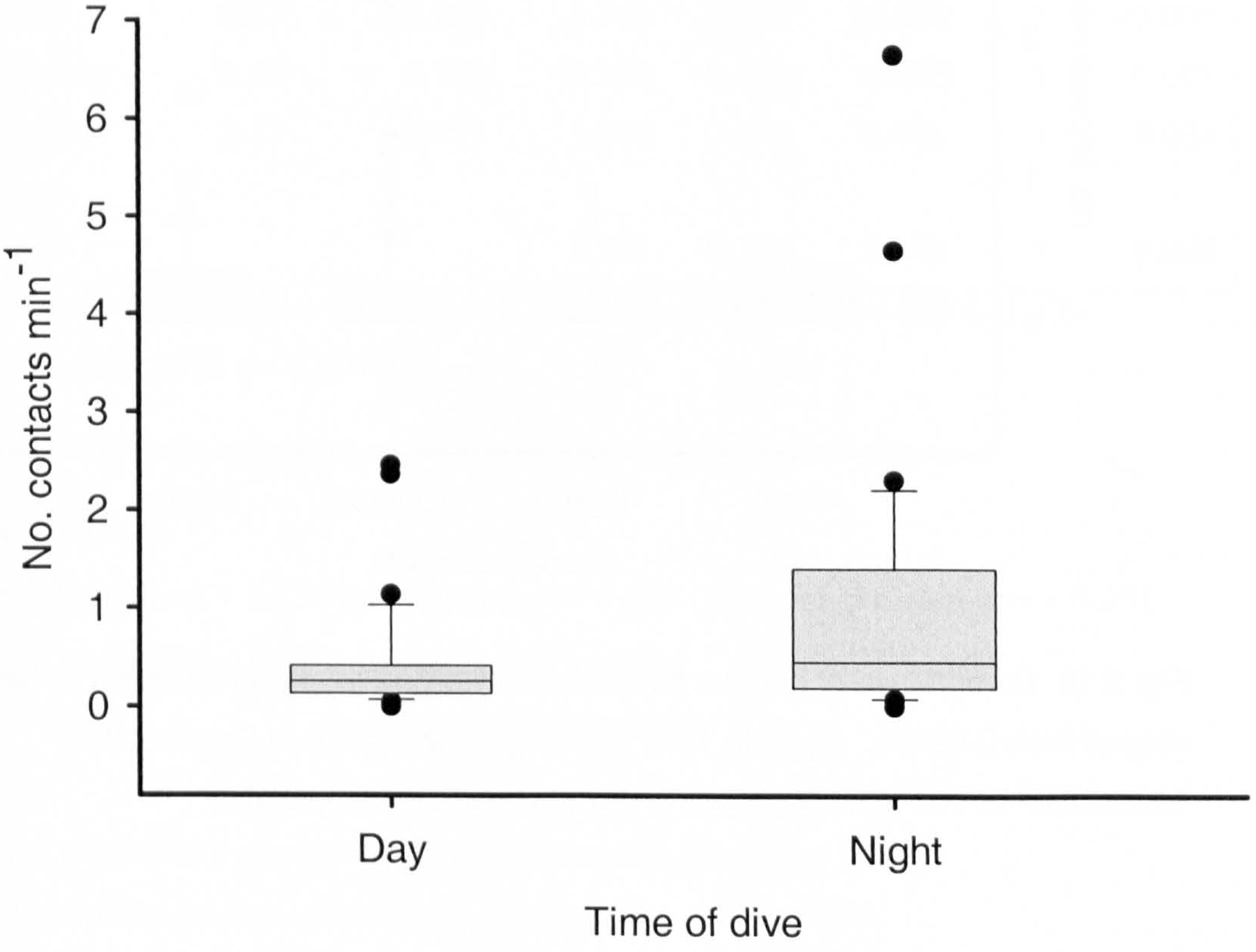

Fig. 2.11 Contact rate and time of dive. Paired data were used, thus the same diver observed during the day dive was then observed on the night dive (n = 33). See legend to Figure 2.3 for explanation of box plot.

Dives without current appeared to have slightly higher contact rates than with light, medium or strong current (Fig. 2.12), but this difference was not statistically significant (Kruskal Wallis test, p=0.121).

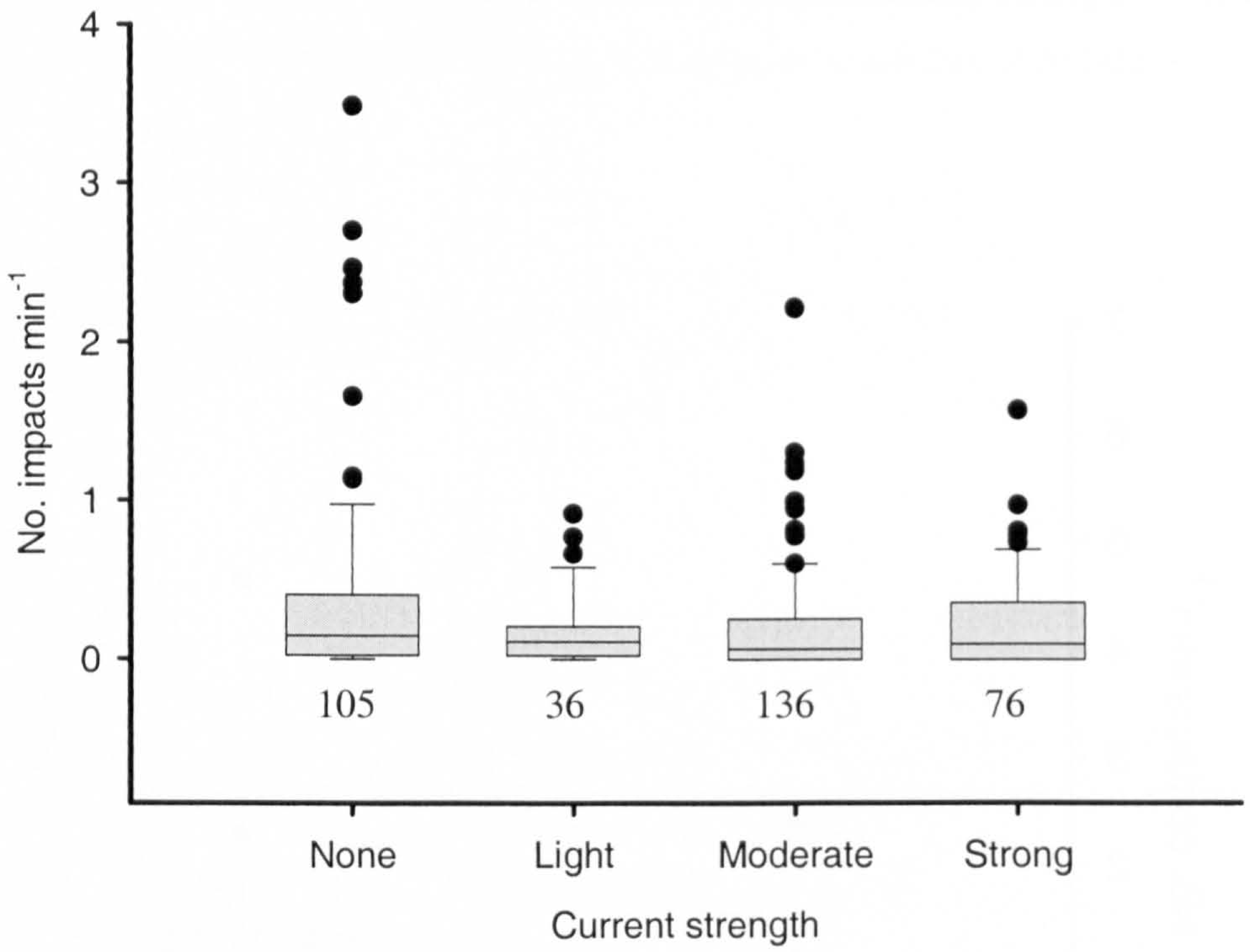

Fig. 2.12 Comparison of contact rates from no current to strong current. Current ranged from 0.08m s^{-1} (light) to 1m s^{-1} (strong). See legend to Figure 2.3 for explanation of box plot. Numbers under boxes show sample size.

2.4.5 Prediction of the likelihood of a diver causing a contact

To verify among the boat dives whether any of the four different site topographies were useful predictors of contact or breakage, the logistic regressions were run using three dummy variables for sloping reef, varied reef and wall dive. None were significant and so I did not include them in the final model. Contact rates of non-specialist and specialist photographers did not differ significantly so I pooled the two categories. Photographer status and diving from the shore were key predictors of the likelihood of divers contacting the reef, while being a cruise-ship passenger had a near significant effect (Table 2.12).

TABLE 2.12 RESULTS OF A LOGISTIC REGRESSION OF INFLUENCES ON THE PROBABILITY OF A DIVER CAUSING A CONTACT DURING THEIR DIVE (N=340)

	Mean	Variance	B	S.E.	Wald	df	*P*
Variable							
Shore dive	0.27	0.199	3.340	0.730	20.922	1	<0.001
Photographer	0.15	0.130	2.229	0.617	13.055	1	<0.001
Cruise-ship passenger	0.13	0.111	1.205	0.649	3.443	1	0.064
Constant			0.251	0.147	2.910	1	0.088

Overall model classification accuracy, 73.8%. −2 Log likelihood = 308.841, Chi-square=82.088, df=3, $p < 0.001$

Equation 1

Estimated logistic

= 3.340 (shore dive) + 2.229 (photographer) + 1.205 (cruise-ship passenger) + 0.251

$$\textit{Predicted probability (P)} = \frac{\exp(\text{estimated logistic})}{1+\exp(\text{estimated logistic})}$$

Predicted probability of a contact occurring on any given dive for:

Shore dive, photographer, cruise-ship passenger	0.999
Shore dive, photographer, non-cruise-ship passenger	0.997
Shore dive, non- photographer, cruise-ship passenger	0.992
Boat dive, photographer, cruise-ship passenger	0.976
Shore dive, non- photographer, non-cruise-ship passenger	0.973

Boat dive, photographer, non-cruise-ship passenger	0.923
Boat dive, non- photographer, cruise-ship passenger	0.811
Boat dive, non- photographer, non-cruise-ship passenger	0.562

All divers had a greater than 50% chance of causing a contact during their dive irrespective of dive location, camera use or whether or not they were cruise-ship passengers. Shore dives, camera use and being a cruise-ship passenger all result in a predicted probability of greater than 80% of a contact occurring on the dive.

Bootstrapping confirmed that dive site and photographer status were robust predictors of contact (Appendix F).

2.4.6 Prediction of the likelihood of a diver breaking coral

When predicting the likelihood of a diver breaking a coral or not, photographer and cruise-ship status were found to be statistically significant important predictors whilst intervention by dive guide had a near-significant effect (Table 2.13).

TABLE 2.13 RESULTS OF A LOGISTIC REGRESSION OF INFLUENCES ON THE PROBABILITY OF A DIVER BREAKING A CORAL DURING THEIR DIVE

	B	S.E.	Wald	df	*P*
Variable					
With intervention	-1.780	1.039	2.936	1	0.087
Photographer	1.855	0.367	25.537	1	<0.001
Cruise-ship passenger	0.977	0.421	5.370	1	0.020
Constant	-2.463	0.246	100.06	1	<0.001

Overall model classification accuracy, 86.8%. –2 Log likelihood = 218.874, Chi-square=39.269, df=3, p <0.001

Equation 2

Estimated logistic

= -1.78 (with intervention) + 1.855 (photographer) + 0.977 (cruise-ship passenger) – 2.463 (constant)

Predicted probabilities of a breakage occurring on any given dive for:

Photographer, without intervention, cruise-ship passenger	0.591
Photographer, without intervention, non-cruise-ship passenger	0.353
Photographer, with intervention, cruise-ship passenger	0.196
Non-photographer, without intervention, cruise-ship passenger	0.185
Photographer, with intervention, non cruise-ship passenger	0.084
Non-photographer, without intervention, non cruise-ship passenger	0.078
Non-photographer, with intervention, cruise-ship passenger	0.037
Non-photographer, with intervention, non cruise-ship passenger	0.014

These probabilities predict that a breakage caused by a diver during their dive is overall an unlikely event. However, camera use in combination with no preventative action taken by dive leaders, plus if divers are from a cruise-ship, tips the probability to above 0.5, making this combination of diver attributes likely to result in a breakage. Bootstrapping confirmed that photographer and cruise-ship status were significant predictors of breakage (see Appendix F). The bootstrap analysis shows a small variability with these two variables plus the constant. However, a large variability was found with intervention status, illustrated by two peaks in the Kernel density estimates (Appendix F).

Confounding variables

Six instances of confounding variables are evident (Table 2.14).

- Brief and intervention: positive correlation due to dive leaders having to give a briefing in order that divers were told the sign that would be given to them if they were seen to be damaging the reef.
- Shore dive and brief: positive correlation due to dive leaders always remembering to include information on avoiding touching the corals during their briefings. This was because the briefing for the shore dive was done using a board with listed information on the dive site, likely species that divers would encounter, safety issues and diver protocol.
- Number of dives completed on trip and shore dives: negative correlation due to dive number one always being the shore dive and all subsequent dives, other than a handful, being boat dives.
- Total number of dives in whole dive history and basic level of dive qualification: negative correlation. Divers with a basic level of dive qualification had done fewer dives than divers with advanced or greater- dive qualification.
- Contact occurrence and shore dive: positive correlation, likely due to shore dive characteristics, e.g. entry from shore and commencement of dive in shallow water increasing the likelihood of divers coming into contact with the benthos or stirring up sediment.
- Breakage occurrence and photographers: positive correlation.

TABLE 2.14 CORRELATION MATRIX FOR VARIABLES USED IN THE LOGISTIC REGRESSIONS

	INTERV	MALE	BASIC	PHOTO	CURR	BRIEF	SHORE	NDIVE	TDIVE	CRUISE	MENV	READ	CONTA	BREAK
INTERV	1.000	-0.022	-0.071	-0.092	0.101	**0.345**	-0.261	0.090	-0.013	-0.156	0.099	0.167	-0.194	-0.133
MALE	-0.022	1.000	-0.086	0.137	-0.014	-0.039	-0.078	0.031	0.122	0.106	0.000	-0.001	0.043	0.132
BASIC	-0.071	-0.086	1.000	-0.177	-0.053	0.046	0.135	-0.153	**-0.380**	0.043	-0.097	-0.165	0.048	-0.076
PHOTO	-0.092	0.137	-0.177	1.000	0.013	-0.085	-0.096	0.036	0.255	0.100	-0.016	0.069	0.206	**0.349**
CURR	0.101	-0.014	-0.053	0.013	1.000	0.139	-0.067	0.005	-0.034	-0.042	-0.101	-0.045	-0.021	0.024
BRIEF	0.345	-0.039	0.046	-0.085	0.139	1.000	**0.338**	-0.179	-0.066	-0.053	0.007	0.041	0.093	-0.137
SHORE	-0.261	-0.078	0.135	-0.096	-0.067	0.338	1.000	**-0.423**	-0.067	0.156	-0.022	-0.134	**0.340**	-0.081
NDIVE	0.090	0.031	-0.153	0.036	0.005	-0.179	-0.423	1.000	0.104	-0.144	-0.077	0.072	-0.166	-0.005
TDIVE	-0.013	0.122	-0.380	0.255	-0.034	-0.066	-0.067	0.104	1.000	-0.061	-0.008	0.133	0.062	0.090
CRUISE	-0.156	0.106	0.043	0.100	-0.042	-0.053	0.156	-0.144	-0.061	1.000	0.022	-0.099	0.158	0.152
MENV	0.099	0.000	-0.097	-0.016	-0.101	0.007	-0.022	-0.077	-0.008	0.022	1.000	0.099	-0.013	-0.004
READ	0.167	-0.001	-0.165	0.069	-0.045	0.041	-0.134	0.072	0.133	-0.099	0.099	1.000	-0.060	-0.004
CONTA	-0.194	0.043	0.048	0.206	-0.021	0.093	0.340	-0.166	0.062	0.158	-0.013	-0.060	1.000	0.225
BREAK	-0.133	0.132	-0.076	0.349	0.024	-0.137	-0.081	-0.005	0.090	0.152	-0.004	-0.004	0.225	1.000

Key:

INTERV	: with intervention	SHORE	: shore dive
MALE	: male diver	NDIVE	: number of dives completed on trip
BASIC	: basic dive qualification	TDIVE	: total number of dives in dive history
PHOTO	: photographer	CRUISE	: cruiseship passenger
CURR	: strong current	MENV	: member of an environmental group or organisation
BRIEF	: with briefing	READ	: read articles on marine life
CONTA	: occurrence of a contact	BREAK	: occurrence of a breakage

2.4.7 Predicting the rate of contacts

Multiple regression analysis using the same independent variables as the logistic regression, on the dependent variable, contacts per minute confirmed that dive type, photographer and intervention status made the strongest contribution to explaining the dependent variable (Multiple regression, Table 2.15, F=45.786, P<0.001, R^2=0.282).

TABLE 2.15 VARIABLES WITH SIGNIFICANT INFLUENCE ON DIVERS CAUSING A CONTACT DURING THEIR DIVE

	Unstandardised coefficients		Standardised coefficients Beta	t	Sig
	B	S.E.			
Shore dive	0.348	0.037	0.448	9.405	<0.001
Photographer	0.211	0.044	0.220	4.790	<0.001
With intervention	- 0.114	0.043	- 0.126	- 2.636	0.009
Constant	0.260	0.023		11.332	<0.001

<u>Equation 3</u>

Predicted contact rate (no. contacts min^{-1})

$$= [0.348 \text{ (shore dive)} + 0.211 \text{ (photographer)} - 0.114 \text{ (with intervention)} + 0.260]^2$$

Predicted contact rates (no. contacts min^{-1}) for any one dive:

Shore dive, photographer, without intervention	0.671
Shore dive, photographer, with intervention	0.497
Shore dive, non- photographer, without intervention	0.370
Shore dive, non- photographer, with intervention	0.244
Boat dive, photographer, without intervention	0.222
Boat dive, photographer, with intervention	0.127
Boat dive, non- photographer, without intervention	0.068
Boat dive, non- photographer, with intervention	0.021

2.4.8 Predicting the rate of breakage

Photographer status was the sole significant predictor of breakage rate of all the independent variables for boat and shore dives (Table 2.16, Multiple regression, $F=20.873$, $P<0.001$, $R^2=0.056$), although the regression was weak. Breaks by divers were few but it appears that when they did occur, being a photographer had some, albeit small, influence.

TABLE 2.16 INFLUENCING VARIABLE ON THE RATE OF BREAKAGE BY DIVERS

	Unstandardised coefficients		Standardised coefficients	t	Sig
	B	S.E.	Beta		
Photographer	0.026	0.006	0.237	4.569	<0.001
Constant	0.006	0.002		2.851	0.005

<u>Equation 4</u>
Predicted number of breaks per minute:

$= 0.026 \text{ (photographer)} + 0.006$

Predicted number of breaks per minute for any one dive:

Photographer 0.032

Non-photographer 0.006

Confounding variables

Confounding variables are highlighted in Table 2.17 and are virtually identical to those found in the logistic regressions. They include:

- Brief and intervention*:* positive correlation due to dive leaders having to include in their briefing information on not touching including the sign they would give divers if they witnessed a diver causing damage.
- Shore dive and brief: positive correlation due to dive leaders always remembering to include information on avoiding touching the corals during their briefings. This was because the briefing for the shore dive was done using a board with listed information on the dive site, likely species that divers would encounter, safety issues and diver protocol.
- Number of dives completed on trip and shore dive: negative correlation due to dive number one always being the shore dive and all subsequent dives, other than a handful, being boat dives.
- Total number of dives in whole dive history and basic level of dive qualification: negative correlation. Divers with a basic level of dive qualification had done fewer dives than divers with advanced or greater- dive qualification.
- Contact rate and shore dive: positive correlation, likely due to shore dive characteristics, e.g. entry from shore and commencement of dive in shallow water increasing the likelihood of divers coming into contact with the reef or stirring up sediment and therefore increasing the contact rate.
- Breakage rate and contact rate: positive correlation. The more a diver contacts the reef the more likely they are to cause a breakage.

TABLE 2.17 CORRELATION MATRIX FOR VARIABLES USED IN THE MULTIPLE REGRESSION

	INTERV	MALE	BASIC	PHOTO	CURR	BRIEF	SHORE	NDIVE	TDIVE	CRUISE	MENV	READ	CONTA	BREAK
INTERV	1	-0.018	-0.057	-0.093	0.136	**0.360**	-0.282	0.113	-0.016	-0.065	0.104	0.146	-0.273	-0.101
MALE	-0.018	1	-0.080	0.135	-0.015	-0.026	-0.078	0.026	0.120	-0.030	-0.017	0.009	0.020	0.126
BASIC	-0.057	-0.080	1	-0.173	-0.060	0.060	0.134	-0.144	**-0.382**	-0.120	-0.093	-0.153	0.065	-0.051
PHOTO	-0.093	0.135	-0.173	1	0.000	-0.088	-0.101	0.035	0.246	-0.053	-0.004	0.046	0.187	0.237
CURR	0.136	-0.015	-0.060	0.000	1	0.142	-0.088	0.016	-0.026	0.130	-0.103	-0.040	-0.019	0.064
BRIEF	0.360	-0.026	0.060	-0.088	0.142	1	**0.323**	-0.171	-0.073	-0.030	0.003	0.030	0.133	-0.050
SHORE	-0.282	-0.078	0.134	-0.101	-0.088	0.323	1	**-0.431**	-0.068	-0.247	-0.024	-0.123	**0.462**	0.016
NDIVE	0.113	0.026	-0.144	0.035	0.016	-0.171	-0.431	1	0.107	0.009	-0.073	0.078	-0.223	-0.017
TDIVE	-0.016	0.120	-0.382	0.246	-0.026	-0.073	-0.068	0.107	1	-0.085	-0.012	0.126	-0.008	-0.011
CRUISE	-0.065	-0.030	-0.120	-0.053	0.130	-0.030	-0.247	0.009	-0.085	1	0.029	0.060	-0.195	-0.022
MENV	0.104	-0.017	-0.093	-0.004	-0.103	0.003	-0.024	-0.073	-0.012	0.029	1	0.068	-0.019	-0.036
READ	0.146	0.009	-0.153	0.046	-0.040	0.030	-0.123	0.078	0.126	0.060	0.068	1	-0.044	-0.002
CONTA	-0.273	0.020	0.065	0.187	-0.019	0.133	0.462	-0.223	-0.008	-0.195	-0.019	-0.044	1	**0.463**
BREAK	-0.101	0.126	-0.051	0.237	0.064	-0.050	0.016	-0.017	-0.011	-0.022	-0.036	-0.002	0.463	1

Key:

INTERV	: with intervention	SHORE	: shore dive
MALE	: male diver	NDIVE	: number of dives completed on trip
BASIC	: basic dive qualification	TDIVE	: total number of dives in dive history
PHOTO	: photographer	CRUISE	: cruiseship passenger
CURR	: strong current	MENV	: member of an environmental group or organisation
BRIEF	: with briefing	READ	: read articles on marine life
CONTA	: no. contacts per minute	BREAK	: no. breakages per minute

2.5 Discussion

Contacts by divers with the reef were common but varied according to dive type, time of day, diver characteristics and dive leader intervention.

The greatest proportion of contacts and the highest contact rate came within the first ten minutes of the dive when divers were adjusting their equipment and becoming familiar with the underwater environment. Contact rate decreased as the dive progressed, a similar finding to that of Rouphael & Inglis (2001). Most contacts (81.4%) were caused by fin kicks as found by other observations on divers at Sharm el Sheikh and Eilat in the Red Sea (Prior et al., 1995; Zakai & Chadwick-Furman, 2002) and Eastern Australia (Roberts & Harriott, 1994; Harriott et al., 1997; Rouphael & Inglis, 2001). Reasons why fins are the cause of so many contacts appear to be due to swimming technique, incorrect weighting and ignorance. Fins add extra length to the diver and consequently bring divers closer to the reef. When divers swim in a non-horizontal position due to carrying too much weight or lack of skill, their fins are more likely to contact the reef or raise sediment. My observations showed that sediment was raised in almost half of all cases of diver contact with the reef, but because the event was happening behind the diver it generally went unseen. Divers in St. Lucia seemed unaware of their impacts and most of their contacts with the reef appeared to be unintentional (81.2%). Interestingly, the distribution between the result of the contact, whether major, minor or sediment damage was similar whether the contact appeared intended or not. Contrary to expectations, divers who intentionally contacted the reef seemed unable to avoid the most damaging impact, breakage.

Camera users were far more likely to contact the reef during their dive and cause a breakage than non-camera users, often whilst holding onto or kneeling on the reef when steadying themselves to take a picture. Medio et al., (1997) and Rouphael & Inglis (2001) also found camera users to be the most damaging, the latter study noting that specialist underwater photographers caused more damage on average (1.6

breaks per 10 minutes) than divers without cameras (0.3 breaks per 10 minutes). In my study, camera users, whether specialist or not were equally as damaging and on average, caused 3.8 contacts and 0.3 breaks per 10 minutes respectively compared to divers without cameras who averaged 2.3 contacts and 0.1 breaks per 10 minutes. These results parallel Rouphael and Inglis's (2001) results with non-camera users having an 81% lower breakage rate than camera users. In Prior et al.'s (1995) study the difference in damage done to corals between camera users and non-camera users was thought to be a function of a greater proportion of the men using cameras compared to women, however my study found no such trend.

I also found that divers who were cruise ship passengers were significantly more likely to break the coral and marginally more likely to contact the reef than non-cruise ship passengers. Cruise-ship passengers may be diving on a more 'non-specialist' level than land based-visitors and diving was usually but one of several off-ship activities compared to it being a main holiday activity. They may therefore not be taking it as seriously, not diving as often and be less skilled. However, I found that diver experience in terms of dive qualification and number of dives logged in total dive history did not appear to be linked to contact rate. This supports research by Harriott et al. (1997) who found no significant difference between total number of contacts and experience (measured as less than or more than 100 dives), or dive qualification. However, an earlier study by Roberts & Harriott (1994) found that divers with further training (Advanced and above) had fewer than half the number of uncontrolled contacts compared to divers with basic training although the total sample size for that study was small (n=30, Roberts & Harriott, 1994). The fact that all cruiseship divers only spent one day in St. Lucia also meant that my observations of them included the compulsory first dive from shore and one boat dive at another site. As I found shore dives to increase the likelihood of a diver contacting the reef this may have influenced the results albeit marginally.

The only factor that I found to reduce diver damage in St. Lucia was dive-leader intervention underwater. Contrary to previous research by Medio et al. (1997)

who found that briefing divers prior to the dive on their behaviour and how it can damage the reef reduced contact levels, I found that briefing divers – using the technique mentioned above – in St. Lucia had no such effect. Medio et al. (1997) found that contact rate per 7 minute observation period was reduced by 71% from 1.4 to 0.4 contacts after a single 45-minute environmental awareness briefing and a few minutes in-water demonstration showing divers what they could and could not touch. My test of a much shorter briefing, given by dive leaders added at most a couple of minutes to the length of their usual briefing. This did not reduce contact rate or the probability of a diver breaking living substrate. However dive leader intervention was highly effective, reducing average contacts from 11.6 to 2.4 per 40minute dive (including shore dives), and from 7.5 to 2.4 contacts for boat dives.

Differences in type of briefing given may in part account for the non-significant effect of a briefing alone on contact rates found in this study. The short briefing given by dive leaders was a more realistic commitment for a dive company than the hour-long exercise mounted by Medio et al. (1997), but in isolation was insufficient to reduce diver contacts with the reef. My results indicate that dive companies need to ensure dive leaders brief divers fully and more importantly should intervene when they see divers damaging the reef. Comments to me from divers in St. Lucia included that they disliked seeing other divers, including dive leaders damaging the reef. This reflects badly on dive leaders and their company, so leaders must demonstrate the correct behaviour at all times, take on the responsibility of telling visitors how to avoid damaging the reef and be ready to intervene if they see damaging behaviour. Often, dive leaders are reluctant to approach divers and criticise their behaviour. They feel that it is not their job or that they are not in a position to do so and in some cases, may believe that it will reduce their earnings in terms of gratuities. However, my discussions with divers showed that many appreciate dive leader intervention whether to improve their own diving skills, or those of others so that their dive was not spoilt. This request to see greater policing of divers' behaviour is not exclusive to my study and other researchers have found that people are concerned with the lack of control of diver behaviour (Mundet & Ribera, 2001).

In shallow water, typical of shore dives, dive leaders can prevent divers swimming close to the bottom by ensuring that they swim on the surface until the depth is great enough before making their descent. As I found in my study, contact rates and the probability of a contact occurring were greater on shore than boat dives, largely because divers swam across shallow sandy areas. Divers also tend to mimic dive leader behaviour. In St. Lucia, dive leaders often stopped in the sand and divers in the group tended to copy them, resulting in a lot of direct contact with sand and the kicking up of sediment next to corals. Dive leaders can do much by example. By staying far enough from the reef so that their fins do not stir up sediment or contact corals and by avoiding touching or holding onto any part of the reef they can encourage similar behaviour from tourists.

Even more important is dive leader vigilance during night dives. I found night dives resulted in more than twice as many diver contacts with the reef than during the day, averaging 40 contacts per forty-minute dive during the night compared to 18 during the day. The reason is likely in part due to reduced visibility at night. Divers tend to keep much closer to the reef at night and focus their attention on small things like coral polyps, crabs or starfish. Darkness also makes reading gauges more difficult and holding a torch makes diving more complicated than in the day. The torch illuminates only a few square meters of reef, making it harder for a diver to avoid contacts and reducing the likelihood that they will see the effect of their contacts or those of other divers. Reduced visibility also meant that I had more difficulty observing the divers so my estimate of contact rate is conservative. Encouraging divers to stay well away from the reef and making them aware of their increased likelihood of contacting the reef could help reduce impacts. Knowing divers are more prone to coming into contact with the reef at night, dive leaders need to supervise divers more closely and dive groups may have to be reduced in order that such supervision is feasible.

Although diver impacts can be reduced by education and dive leader intervention underwater, the end result of damaged coral may be unavoidable if large numbers of divers are using an area of reef. In St. Lucia, minor damage and the raising of sediment was widespread (79.8% and 49.0% of contacts respectively) whilst the most obvious contact, breakage of substrate, was perpetrated by a minority (4.1%). This supports Talge's (1991) study of 206 divers in the Florida Keys who found that 90% of divers had one or more physical interactions with the reef but only 2% damaged corals. The minor damage and re-suspension of sediment by most divers may seem trivial but it may compound existing stresses from other human activities, which, according to Nyström et al. (2000), could undermine the resilience of reef ecosystems.

Direct contact with corals and other reef organisms can abrade their protective layer of tissue, but the implications of this are unclear. A laboratory study in Florida simulated diver damage by experimentally touching, with hands or fins, twelve species of coral once per week for 10 weeks (Talge, 1992). Although she detected no lasting influence on eleven of the species after 3, 6 and 11 months of follow-up observations, popular sites in St. Lucia and elsewhere receiving upwards of 10,000 dives per year may have corals being touched much more often than in Talge's experiments. Hall (2001) showed that tissue damage rendered corals more susceptible to colonisation by algae, which could then act as a sediment trap (see also Walker & Ormond, 1982). Damaged corals were also more likely to be infected by pathogens or other invading organisms and had a higher risk of mortality (Hall, 2001). Hawkins et al. (1997) implicate coral disease, facilitated by diver-inflicted lesions on massive corals, in effecting the shift from massive to branching coral dominance in Bonairean dive sites.

Sediment particles in the water decrease light penetration, necessary for the corals' symbiotic algae that provide the corals with energy through photosynthesis. Particles that settle may also abrade the coral tissue leaving them open to infection as noted above. In the literature, sediment pollution is widely reported to reduce coral growth, reproduction and ultimately survival (Visser, 1992; Hodgson, 1993; Hawkins & Roberts, 1994; Carias, 1998; Cox et al., 2000; Nemeth & Sladek Nowlis, 2001). Sladek Nowlis et al. (1997) reported that sediment pollution was an important cause of coral death in St. Lucia. Corals subjected to continuous sediment pollution use their energy to rid the colony of the particles instead of using their energy for growth and reproduction (Richmond, 1996; Dodge et al., 1997; Rogers, 1990). Divers who re-suspend sediment could therefore exacerbate an existing sediment pollution problem.

At sites that are heavily used, Hawkins & Roberts (1992) suggest that these stresses may be rendering the reef ecosystem less able to deal with bigger stressors such as hurricanes, storms and disease. Above a certain threshold of use, estimated at between four and six thousand dives per year, damage levels may increase rapidly (Dixon et al., 1993, Hawkins & Roberts, 1997). This has been seen in the Red Sea where diving intensities of approximately five to six thousand dives per site per year showed significant loss of coral cover and high frequencies of colony damage (Riegl & Velimirov, 1991; Prior et al., 1995). Similarly, at Eilat in Israel, Zakai & Chadwick-Furman (2002) reported a strong relationship between diver numbers and proportion of damaged corals where percentage of diver-damaged coral colonies at low-use levels (4000 dives yr^{-1}) was 8% compared to 66% at high-use levels (more than 30,000 dives yr^{-1}). Although Eilat's estimated annual dive frequencies of more than 150,000 dives are higher than St. Lucia's (estimated at 137,000 dives per annum, see chapter 3), 82,000 of all dives are in the Soufrière Marine Management Area. One site in particular, Anse Chastanet receives around 28,000 dives per year.

I conclude that scuba divers cause damage to coral reefs. While user fees levied on divers can help pay for management, until now, few protected areas do more to manage diver behaviour than post notices urging divers not to touch or remove anything from the reef. More active management is needed and it is evident from this study that short briefings alone are insufficient to reduce damage rates. However, simple measures implemented by dive companies could greatly reduce impacts. They include dive leader intervention underwater when divers contact the reef, leading by example in keeping fins and equipment clear of the reef, and extra vigilance with camera users, on night dives and at the beginning of the dive. Size of dive group will influence the ability of dive leaders to perform their supervisory role so smaller groups are better for the reef, and are preferred by divers in any case (see Chapter 5).

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Chapter 3: Snorkeler behaviour on coral reefs

3.1 Abstract

Tourism, combined with the increased interest in the environment and activity-based holidays is intensifying the use of coral reefs worldwide. Snorkeling tops the list of common activities because it is cheap and easy to do. Its accessibility and popularity however, may be detrimental to reefs. Despite this, few studies exist on snorkelers and their impacts. I observed 180 snorkelers on their snorkel trips in St. Lucia noting all their contacts with the reef and their outcomes. Few (20.6%) snorkelers contacted the reef, averaging 0.05 contacts min^{-1} compared to studies on divers, but the higher number of snorkelers than divers in heavily used sites brings their impacts to similar levels. The highest rates of contact (up to 1.10 contacts min^{-1}) occurred at the beginning of the snorkeling activity and snorkelers using a camera caused more damage and had more than twice as many contacts as non camera users (mean of 0.12 versus 0.04 contacts min^{-1}). Giving snorkelers a briefing did not significantly reduce their contact with the reef but wearing a life-vest reduced mean contact rates from 0.06 to 0.003 contacts min^{-1}. Contact rates were similar whether snorkelers were being guided or not. Protruding, branching and delicate reef invertebrates are more susceptible to, and shallow depths increase the likelihood of, snorkeler damage. Managing areas to reduce impacts by snorkelers requires either restricting access to sites with breakable life forms and shallow areas of reef, or supervision in situ. Visitors should be told how to reduce their impacts and the consequences to marine life if they do not.

3.2 INTRODUCTION

Snorkeling is a popular and easy way to observe the underwater world. It can be done by anyone with a mask and snorkel and basic swimming proficiency, unlike scuba diving, which requires training and expensive equipment. Because of this, snorkeler numbers probably far exceed diver numbers although statistics do not exist to prove this. The rising trend in activity based holidays (Goodhead & Johnson, 1996) and people's increased interest in the environment (Ceballos-Lascuráin, 1993), mean that growing numbers of people go snorkeling every year.

Snorkeling is concentrated in areas of warm, clear water with interesting things to see, so it is no wonder that tropical coral reefs, which thrive in these conditions and support a vast array of species have become favourite destinations for snorkelers. An estimated 4 million people visit the Florida reefs annually (Florida Keys National Marine Sanctuary, 2003) and approximately 1.6 million visitors travel to or through the Great Barrier Reef Marine Park each year (Harriott, 2002). Reefs are however, sensitive to human disturbance which has led to their decline worldwide (Spalding et al., 2001) and yet little is known of the effect of snorkelers.

Nearly 60% of the earth's coral reefs are threatened by human activity (Bryant et al., 1998), the key forms of which include global warming (Wilkinson, 1998), overfishing and destructive fishing practices, pollution and other activities associated with coastal development (Pastorok & Bilyard, 1985; Guzman & Holst, 1993; Sladek Nowlis et al., 1997; MacKinnon, 1998; Makoloweka, 1998; Nemeth & Nowlis, 2001) and tourism (Beekhuis, 1981; Visser & Njuguna, 1992; Price et al., 1998; Hall, 2001; Mills, 2001). While reefs provide billions of people and hundreds of countries with food, tourism revenue, coastal production, and new medications (worth about US$375 billion) each year, they are among the least monitored and protected habitats in the world (Bryant et al., 1998).

Research indicates that corals already under stress are less resilient to other stresses. In St. Thomas, stress from sedimentation resulting from shoreline development may have led to the decline in living coral through a secondary effect of bleaching (Nemeth & Nowlis, 2001). Bleached corals have also been found to have lower coral tissue regeneration and increased mortality rates (Meesters & Bak, 1993). Thus although snorkeling may seem a benign activity, it could be adding stress to reefs and contributing to their decline. It is therefore important to find out what effect snorkelers have on reefs but studies on snorkelers are few and have concentrated on benthic studies rather than direct observation of snorkeler behaviour.

Reefs that are emergent and therefore in shallow water and exposed at low tide are vulnerable to damage by people walking on them. In Australia, live coral cover on reef flats decreased from 41 to 8% in just 18 experimental traverses (Woodland & Hooper, 1977). Walkers also re-suspend sediment and this likely causes additional stress to the reef (Neil, 1990). In the US Virgin islands, monitoring of 50 marked corals at a shallow reef used by snorkelers over a 7 month period showed that only 10 out of 50 were left undisturbed (Rogers, 1988). Certain coral forms are also more susceptible to damage than others. Branching corals, for example, are easily broken, and at intensively used snorkel sites in the Maldives snorkelers were responsible for breaking 17% of them and damaging 7% of total coral cover in one month (Allison, 1996). Despite their susceptibility to breakage, certain species of branching coral grow faster than other forms such as the massive corals. Impacts from divers therefore may cause a shift in reef community structure. This has been reported in the Caribbean island of Bonaire, where impacts from divers in heavily dived areas are thought to have caused the loss of massive corals at the expense of faster growing branching corals (Hawkins et al., 1999).

Qualitative observations in the Maldives report that snorkelers break corals as they kick or stand on coral colonies (Allison, 1996) and that wave motion and snorkelers joining already standing snorkelers amplify this damage. Allison also noted that snorkelers who appeared ill-at-ease broke corals more often than competent snorkelers. He quantified snorkeler damage by measuring recently broken corals along transects and compared this with spatial distribution of snorkeling activity and found a close correlation between breakage and intensity of snorkeling activity. However, to quantify whether physical damage to coral reefs is due to anchors, boat groundings, swells, careless snorkelers or other causes is difficult (Tilmant & Schmahl, 1981; Rogers, 1988), and the only method that ensures correct attribution to damage is to use direct observations. I have not found any studies on snorkeler behaviour that used direct observation despite its importance.

Observations of divers report a link between the beginning of a dive, being male and camera use with increased levels of scuba diver damage (Roberts & Harriott, 1994; Prior et al., 1995; Harriott et al., 1997; Medio et al., 1997; Rouphael & Inglis, 1995, 2001; Zakai & Chadwick-Furman, 2002). What is not known is whether these same trends apply to snorkelers. Damage to the reef by divers has been reduced by giving divers a briefing (Medio et al., 1997), however my studies on divers found that if the briefing was given by non-scientifically trained local staff (in comparison to Medio's study) it had no such effect (Chapter 2). I found that dive leaders had to intervene with divers who were damaging the reef in order to reduce diver damage. Many companies organising snorkel trips give their guests a briefing but we do not know of its effect on their behaviour. Also, snorkelers, unlike divers, are not constrained by dive tables and can therefore spend longer and go more often in the water. This increases the potential for cumulative impact above that of divers if their behaviour is as damaging to reefs as that of divers. The extent of snorkeler impact to reefs therefore needs to be measured to understand the scale of the problem and if snorkelers are damaging reefs, ways must be found to reduce this.

I used direct observation to study snorkelers using coral reefs in the eastern Caribbean island of St. Lucia. I aimed to determine what factors influenced their behaviour and interaction with the reef. I compared (1) supervised versus independent trips, (2) use of a life vest versus none, and (3) education in the form of a briefing given by local staff warning snorkelers to avoid touching or kicking any corals, versus a briefing without the warning.

In light of my findings, I consider the implications of expected increases in snorkeler numbers using reefs worldwide and suggest ways to manage this activity.

3.3 METHODS

I observed 180 snorkelers (89 men, 91 women) in St. Lucia at six sites (Fig. 3.1 Anse Cochon, n=6; Grand Caille, n=6; Jalousie, n=50; Trou Diable, n=17; Anse Chastanet, n=67 and Jalousie-Hilton, n=34) and interviewed 169 of them, over a period of 14 weeks, between June and October 2001. These included snorkelers on guided organised trips that were taken by boat from Anse Chastanet resort beach to one of six sites (Fig. 3.1) and people snorkelling independently from shore. I observed the latter from two beaches located at Anse Chastanet and Jalousie-Hilton resorts (Fig. 3. 1). Snorkelers at both sites entered the water closest to a roped-off area of reef. I positioned myself at those entry points so as to be able to start my observations as soon as a snorkeler entered the water. Immediately after snorkelers exited the water I approached them and asked if they would allow me to interview them. The interview data used here is limited to snorkeler experience (whether it was their first time snorkeling), whether they were members of an environmental group and/or whether they read articles on marine life. Other interview data was used in Chapters 4 and 5. Those not interviewed were refusals, children or unable to understand the questionnaire. Once I had finished my interview I would observe the next snorkeler that approached the snorkel site.

At each snorkel site, prior to my observations, I took underwater visibility and current readings using the methods described in Chapter 2, and throughout my observations, made notes on fish. Collecting these data gave me credibility if asked what I was doing and minimised any effect of my presence on the behaviour of snorkelers.

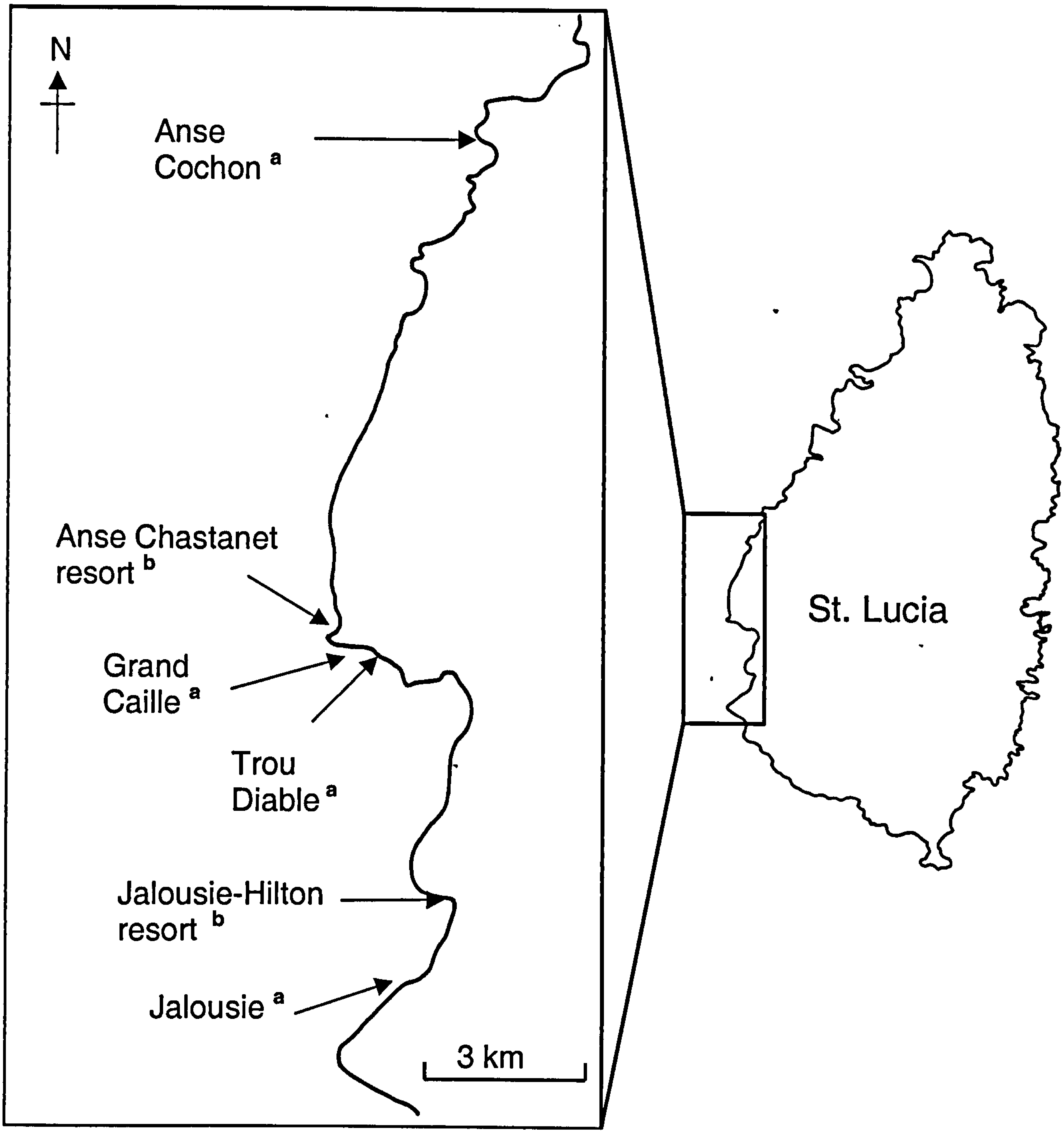

Fig. 3.1 Sites used for 'organised' (a) and 'independent' (b) snorkel trips.

I observed snorkelers from the time they entered to the time they exited, the water. I recorded factors pertaining to the site and to the snorkeler as well as all their contacts and associated consequences (Table 3.1) onto an underwater sheet attached to a slate. Live reef substrate included corals, sponges and other reef invertebrates. Inert substrate included bare rock, dead coral, sand and algal turf. I wrote my notes in code and interspersed with these, names of fish species encountered. This was to disguise my notes of snorkeler observations from any snorkeler who might see my slate.

TABLE 3.1 FACTORS RECORDED DURING SNORKELER OBSERVATIONS

Site and snorkel activity related factors: 1. Underwater visibility (horizontal) 2. Current (raw count) 3. Trip type (organised or independent) 4. Whether the briefing included reference to avoid touching the reef (yes or no. Organised trips only)
Factors relating to snorkeler(s) under observation: 5. Sex (male, female) 6. Use of camera (non photographer, photographer) 7. Use of life-vest (yes or no)
Factors relating to observed contacts: 8. Time of contact 9. Whether the contact was intentional or unintentional 10. Point of contact (body part, fin, etc.) 11. Part of reef substrate affected (living or inert) 12. Result of contact: minor (touch or scrape but not broken), major (broken), or sediment raised.

To test whether number of contacts made by snorkelers with the reef could be influenced by asking them to avoid touching the corals prior to their snorkel, I asked the guide on organised trips to include a few words to their usual briefing to this effect. At the end of each snorkel trip, whether organised or independent, I also asked snorkelers a few questions with regards to their snorkel experience (Appendix C). To test whether experience and environmental awareness were linked to snorkeler behaviour, I asked snorkelers whether this was their first snorkelling experience, whether or not they belonged to an environmental group or organisation and whether or not they read articles on marine life. I also noted whether snorkelers used a life-vest to explore effects this may have had on behaviour.

I used non-parametric statistical analyses to explore relationships between snorkeler characteristics and snorkeler type with their contact rates. Box and whisker plots are used to show summary plots based on the median, quartiles and extreme values. To distinguish which factors had the most influence on snorkeler contacts, I used logistic regression analysis. This regression enabled me to calculate the probability of a snorkeler contacting the reef and I used nine variables (Table 3.2) to predict the outcome.

TABLE 3.2 INDEPENDENT VARIABLES USED IN THE LOGISTIC REGRESSION FOR PREDICTING WHETHER A SNORKELER WOULD HAVE A CONTACT OR NOT DURING THEIR SNORKEL

- Sex (male or not)
- Snorkel experience (first time or not)
- Life-vest worn (yes or no)
- Photographer status (camera user or not)
- Membership of an environmental organisation (yes or no)
- Read articles on marine life in magazines or newspapers (yes or no)
- Given briefing that included details on not touching the corals (yes or no)
- Strong current (raw count of 1-4) present on the snorkel trip (yes or no)
- Snorkel type (from a boat or the shore)

Various constraints in the methods I used may have led to bias. I accompanied visitors on trips arranged through one dive company whose workings may not be representative of other dive companies on the island. I only used two beaches from which to conduct my observations of independent snorkelers. However, they were advertised and perceived locally as some of the best snorkel sites on the island due to having shallow reef and a roped off area thus keeping boat traffic out and giving snorkelers a safe, boat-free site. These sites attracted visitor and dive and snorkel company use from all parts of the island and provided me with a mixed sample of snorkelers.

3.4 Results

Independent snorkelers spent a mean time of 27 ± 2 (95%CI) minutes in the water compared to snorkelers on organised trips who spent a mean of 36 ± 1 (95%CI) minutes in the water, the latter of whom were under a company-imposed maximum time constraint of 40 minutes. Most snorkelers (79.4%) had no contact with the reef. On average, snorkelers contacted the reef 0.05 ± 0.02 (95%CI) times per minute. Contact rates of those that did touch the reef (n=37) followed a non-normal distribution (Kolmogorov-Smirnov statistic 0.233, df 37, p <0.001) with a mean and median contact rate of 0.25 ± 0.09 (95% CI) and 0.14 contacts per minute respectively. The range was from 0.02 to 1.10 contacts per minute.

Higher rates of contact were observed at the beginning of the snorkel trip and decreased significantly the longer snorkelers spent in the water (Fig. 3.2, Friedman Test, p=0.011).

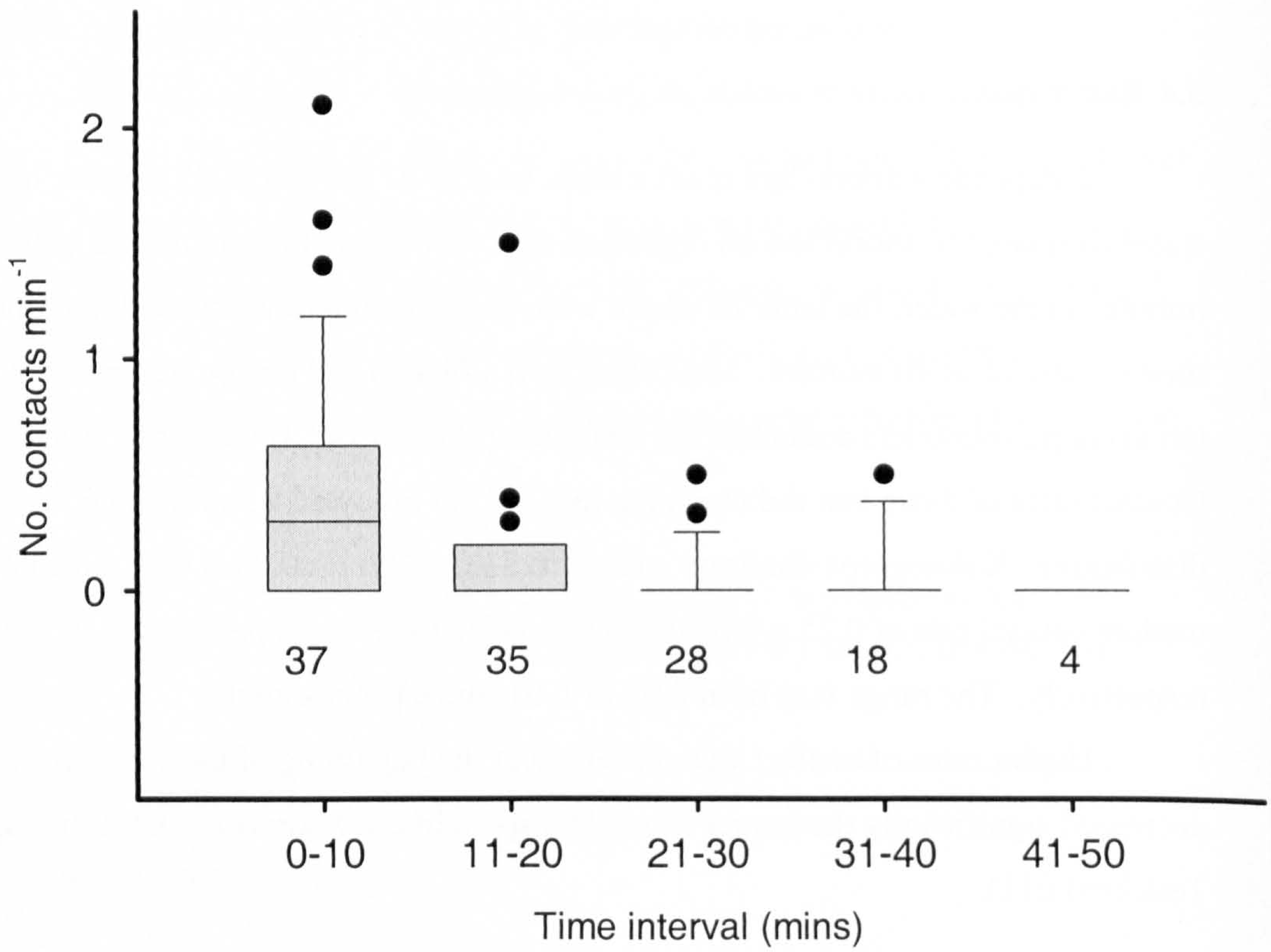

Fig. 3.2 Rates of snorkeler contacts with the reef from start of snorkel. See legend to Figure 2.3 for explanation of box plot. Numbers directly under the boxes represent sample size.

Twenty-nine individuals used an underwater camera and for the majority (93%), this consisted of a point-and-shoot automatic type. Photographers were observed to have more than twice as many contacts compared to non-photographers with mean rates of 0.12 ± 0.10 (95% CI) per minute and 0.04 ± 0.02 (95% CI) per minute respectively (Fig. 3.3, Mann-Whitney U test, p=0.013).

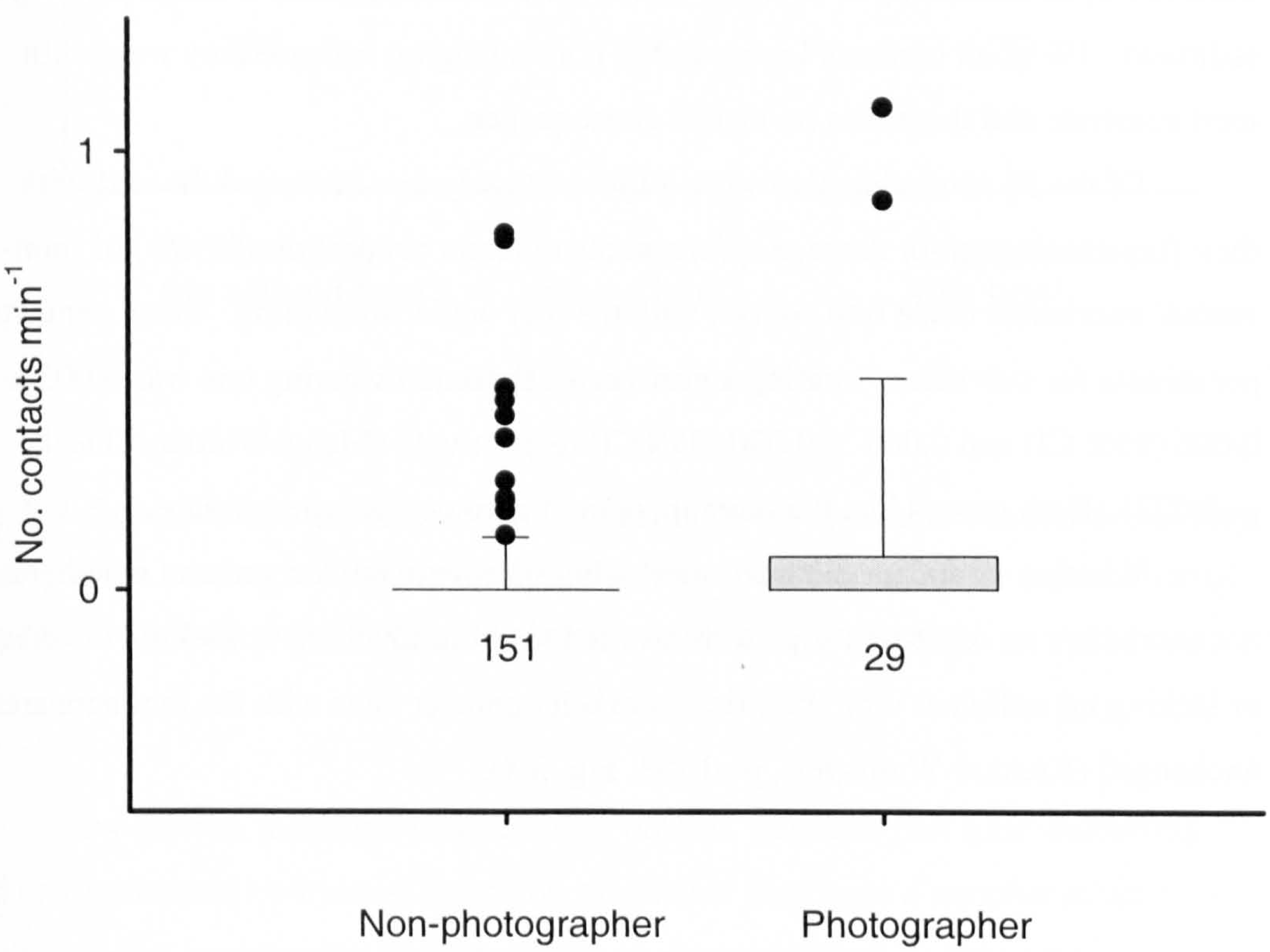

Fig. 3.3 Photographer status and contact rate. See legend to Figure 2.3 for explanation of box plot. Numbers below box and whisker plots indicate sample size.

Of the 216 contacts observed, most (80.6%) appeared to be unintentional. Fins were involved in by far the greatest number of contacts (97%), followed by feet (2% -in the case of snorkelers not wearing fins) and hands (1%). The majority of contacts (73.6%) were with inert substrate including rock and sand. Contacts with live substrate consisted of direct contacts with hard coral (40%), sea fans (28%), sponge (2%) and indirect contacts (30%) through the kicking up of sediment by snorkelers' fins over live reef.

Almost half of contacts (44%) resulted in minor damage (scrape or hit), a third (33%) in the raising of sediment, and a fifth (22%) in minor damage plus raising sediment. 1% of all contacts I recorded as non-damaging because they were with inert substrate and there was no visible consequence.

Of the 26 snorkelers that wore a life-vest, only one contacted the reef with their fins causing minor damage. Conversely, a larger proportion (23.4%) of 'non-vested' snorkelers came into contact with the reef whilst snorkeling. Mean contacts per minute for snorkelers wearing a vest versus those not wearing one was 0.003 ± 0.006 (95% CI) and 0.060 ± 0.030 (95%CI) respectively (Mann-Whitney U test, $p=0.022$). Both groups had the same median of zero contacts per minute.

Whether or not people were snorkeling independently or not, and whether or not snorkelers on organised trips were warned to avoid touching or kicking the corals or kicking up sediment with their fins, snorkeler contact rates with the reef appeared unchanged (Kruskal-Wallis test, $p=0.798$, Fig. 3.4).

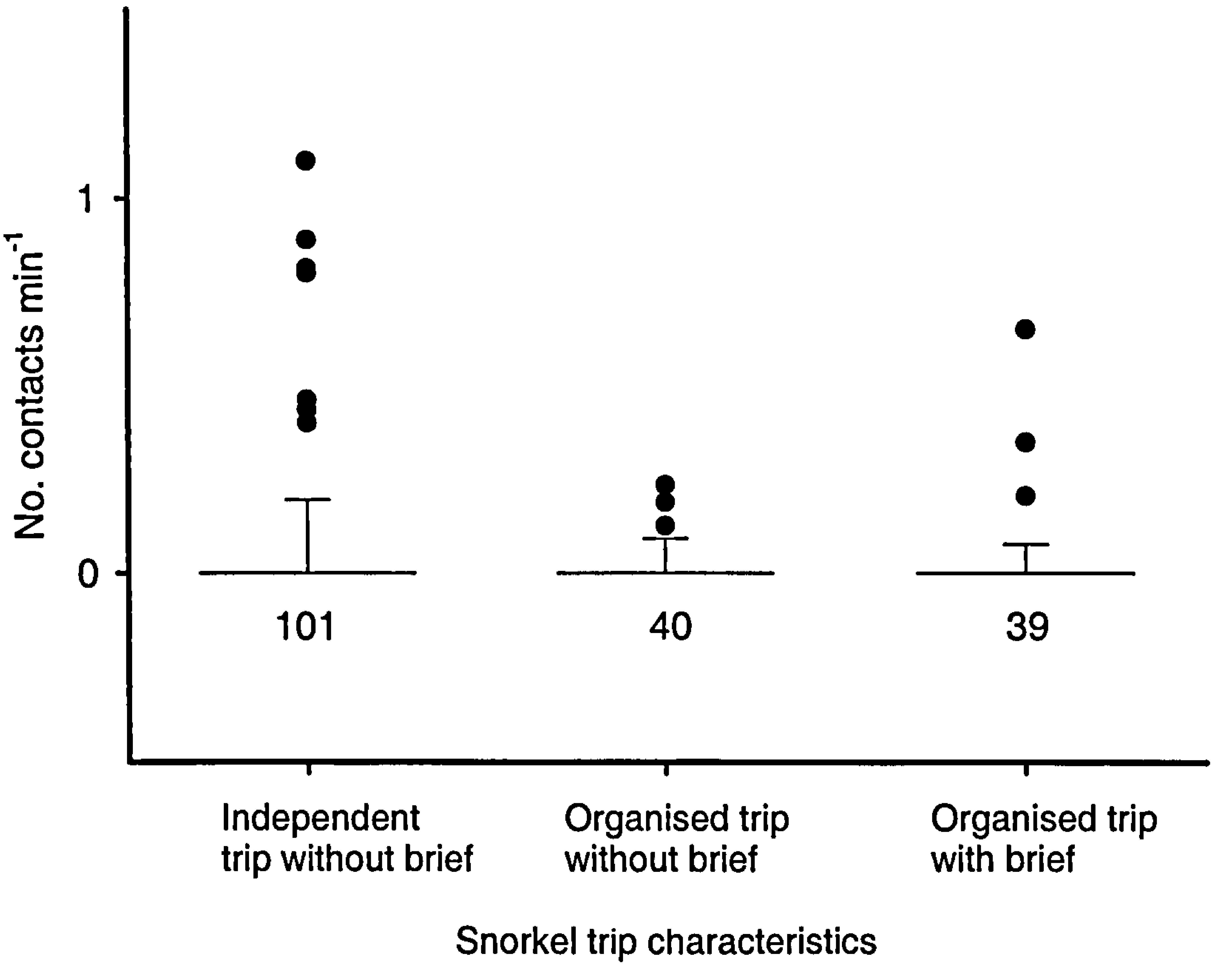

Fig. 3.4 Snorkeler contact rate according to snorkel trip type and whether or not they were given a briefing before the snorkel. See legend to Figure 2.3 for explanation of box plot. Numbers directly under the boxes represent sample size.

Experience, measured as whether or not this was their first time snorkeling and environmental awareness, measured as whether they were a member of an environmental organisation or read articles on marine life had no influence on contact rate (Mann-Whitney U test, $p=0.805$ and $p=0.789$ respectively).

I found camera use to be the only variable that increased the likelihood of a snorkeler contacting the reef whilst snorkeling. A second variable, whether snorkelers wore a life vest or not, narrowly missed statistical significance as a predictor variable (Table 3.3), but indicated that snorkelers wearing a life vest did have a reduced likelihood of contacting the reef. However, this model only correctly explains less than 10% (r^2= 0.098) of the variance in the likelihood of snorkeler contact.

TABLE. 3.3 RESULTS OF A LOGISTIC REGRESSION OF INFLUENCES ON THE PROBABILITY OF A SNORKELER CAUSING A CONTACT WITH THE REEF DURING THEIR SNORKEL (N=180)

	Mean	Variance	B	S.E.	Wald	df	*P*
Variable							
Camera user	0.16	0.136	0.996	0.445	4.998	1	0.025
Life vest worn	0.14	0.124	-1.933	1.039	3.464	1	0.063
Constant			-1.397	0.222	39.670	1	<0.001

Overall model classification accuracy, 79.4%. –2 Log likelihood = 171.208, Chi-square=11.675, df=2, *p*=0.003.

There were no interactions between the main factors.

Equation 1

Estimated logistic

= 0.996 (camera user) –1.933 (life vest worn) – 1.397

$$\textit{Predicted probability (P)} = \frac{\exp(\text{estimated logistic})}{1+\exp(\text{estimated logistic})}$$

Predicted probability of a contact occurring on any given snorkel for:

Non-camera user with a life vest	0.03
Non-camera user without a life vest	0.20
Camera user with a life vest	0.28
Camera user without a life vest	0.40

3.5 Discussion

My observations of snorkelers in St. Lucia showed them to be less damaging to the reef compared to divers, however the higher number of snorkelers compared to divers means that their cumulative impacts may still be significant.

Fewer than a quarter of snorkelers (21%) compared to 74% of divers (Chapter 2), contacted the reef during their excursion. In common with studies on divers (Chapter 2; Roberts & Harriott, 1994; Prior et al., 1995; Harriott et al., 1997; Rouphael & Inglis, 2001; Zakai & Chadwick-Furman, 2002), increased damage was positively related to the beginning of the excursion and use of a camera.

Snorkelers kicked the reef and raised sediment with their fins, mostly when adjusting their equipment or when they stopped swimming and were vertical in the water. Their mean contact rate with the reef was, however, a fifth of the rate I found for divers (0.05 versus 0.25 contacts per minute), but similar to divers in that most contacts (81%) appeared to be unintentional. The ratio of snorkeler contacts with inert versus live substrate (3:1) was different to that of divers (1:2). This is probably due to sites having less coral at the depths in which snorkelers swam (1-5m) compared to the average depths that divers used (1-25m), rather than because snorkelers were more conscious than divers of whether their fins were touching the reef. Divers and snorkelers have degraded reefs in the Red Sea and the Indo-Pacific, where shallow reef flats reach the surface at low tide (Spalding et al., 2001), breaking in particular, branching coral species (Hawkins & Roberts, 1992; Allison, 1996; Rouphael & Inglis, 1997, 2001). In contrast, coral reefs in the Caribbean tend to be non-emergent and therefore deeper. A widespread outbreak of white band disease in the mid-1980s in the Caribbean (Bythell & Sheppard, 1993) also resulted in the virtual elimination of branching corals, many of which were in shallower depths.

Wearing a life vest significantly reduced snorkeler contact rate with the reef when tested as a bivariate comparison with a Mann-Whitney U test, and narrowly missed being a significant variable in the likelihood of a snorkeler contacting the reef. Although life vests kept snorkelers at the surface, it did not prevent snorkelers from contacting marine life if it was within reach of their fins. As I found with divers, camera use significantly increased the probability of a contact with the reef and giving a briefing had no influence on reducing contacts. The logistic regression only correctly explained 10% of the variance in the likelihood of snorkeler contact though, so other factors not measured, such as depth or species composition, have had an influence.

Although only a small proportion of snorkelers came into contact with the reef, their total impacts were comparable to those of divers because at some sites there were many more snorkelers than divers (Table 3.4). If I compare estimates of snorkeler and diver numbers at these sites and calculate the total number of contacts likely to occur from each snorkeler or diver per excursion, we can see that snorkeler impacts are significant. Heavy use by divers at Anse Chastanet means that despite over a hundred contacts being inflicted by snorkelers every day, diver contacts far exceed these at over 600.

Some operators expressed concern over the degradation at Anse Cochon and Anse Chastanet, and suggested that dive and snorkel activities were in part to blame. In 1997, Anse Chastanet was the focal point of a disease outbreak called plague that killed 7% of the reef's coral (Nugues, 2002). Research in Bonaire also suggests that sites exposed to divers are more susceptible to disease (Hawkins et al., 1999). It is interesting therefore that the popular site Anse Chastanet, which is one of the most heavily dived and snorkeled sites in St. Lucia, was also the site of a disease outbreak.

Despite education in the form of briefings supplemented with visual materials, and information on marine biology being reported as one of the most effective ways to reduce diver impacts (Medio et al., 1997; Townsend, 2000), I have found that a short briefing given by local staff had no such effect. With divers I found that leaders had to intervene when they saw a diver damaging the reef, and snorkelers may need the same kind of supervision.

TABLE 3.4 COMPARISON OF CONTACTS MADE BY DIVERS AND SNORKELERS AT THREE SITES

SNORKELERS Mean snorkeler contact rate = 0.05 contacts min^{-1} Mean time spent in water by independent (I) snorkelers = 27 mins Mean time spent in water by snorkelers on organised trips (O) = 36 mins **DIVERS** Mean diver contact rate = 0.25 contacts min^{-1} Mean time spent in water = 42 mins
ANSE CHASTANET 130 snorkelers (60 cruiseship passengers (I) +40 Anse Chastanet guests (I) +20 Others (I) +10 from other resorts (O)) No. contacts resulting from independent (I) snorkelers = (0.05 x 27) x 120 = 162 No. contacts resulting from snorkelers on organised trips (O) = (0.05 x 36) x 10 = 18 Total no. contacts resulting from snorkelers = **180** 60 divers (20 cruiseship passengers +20 Anse Chastanet guests +20 divers from other resorts) No. contacts resulting from divers = (0.25 x 42) x 60 = **630**
ANSE COCHON 140 snorkelers (Two catamaran boats of 70 people each (O) + 60 Others (O)) Total no. contacts = (0.05 x 36) x 200 = **360** No. contacts resulting from divers = **0** because this site is rarely dived.
JALOUSIE-HILTON 70 snorkelers (50 resort guests (I) +10 other guests (I) +10 other guests (O)) Total no. contacts resulting from snorkelers = (0.05 x 27 x 60) + (0.05 x 36 x 10)=**99** 10 divers (resort guests) No. contacts resulting from divers = (0.25 x 42) x 10 = **105**

Snorkel leaders could prevent snorkelers damaging the reef by telling them of the impact that their behaviour can have on marine life and reduce snorkeler damage by informing and assisting snorkelers throughout their excursions. Contacts could also be avoided by ensuring that sites used for snorkeling are deep enough so that corals are out of reach of snorkelers' fins, i.e. approximately 2.5 to 3m minimum. Where tides affect depth, restrictions on when snorkelers could use the reef may be needed. For sites that are used by independent snorkelers and where enforcement of regulations may be impractical or impossible, buoys could be used to mark areas to be used.

It was evident from my interviews with visitors that they were eager to learn more about the marine environment and many asked for the provision of information on marine life (Chapter 5). They also asked for floating platforms. These would enable swimmers to rest without having to stand on the reef. Providing walkways and floating pontoons localises coral damage due to trampling and has been adopted by certain hotels in the Ras Mohammed National Park, Egypt (Ormond et al., 1997). The walkways have proved effective in decreasing coral damage although large constructions, such as the 40x40m pontoon reported in Ormond et al., (1997), resulted in bleaching of the coral beneath, most likely due to shading.

What is clear is that increasing numbers of snorkelers worldwide will be visiting coral reefs and unless their behaviour is modified, whether by education, restrictions, supervision or some combination of these, their impacts will add to other stresses on the reefs, and lead to their decline.

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Chapter 4: Economic benefits of coral reef tourism and maximising the potential for tourists to fund management of marine protected areas

4.1 ABSTRACT

Cheaper travel and increased interest in nature is making marine environments, particularly coral reefs, more accessible and popular with holidaymakers. The financial and employment gains are significant. In the present study on St. Lucia, the nine existing dive companies in 2001 employed over a hundred people, with St. Lucians taking up 71% of managerial and 97% of water sports staff positions. Dive companies collectively spent US$1.4million on salaries that year. I estimated revenues by questioning 786 scuba divers and snorkelers. Tourists in 2000 spent approximately US$7.3million on diving and snorkeling tours, nearly half of which (US$3.5m) was attributable to tours taken within its marine protected area (MPA). Forty four percent of my sample said they visited St. Lucia because of the existence of the MPA and over 90% were willing to pay more than the stated fees of US$4 for a diver's daily fee, US$12 for a diver's annual fee and US$1 for a snorkeler's daily fee. Using the maximum amount that 75% or 50% of visitors were willing to pay would increase annual revenue by 128% or 62% respectively. This would bring park revenue from fees to US$41,550 and US$58,475 respectively, representing 52% and 73% of the total management budget. Such increases in revenue could pay for higher management standards and support the park's conservation efforts. MPAs help manage and protect reefs, and attract tourists, but need financial support. This study shows that MPAs could harness more of the potential income that tourists are prepared to pay, thereby paying for a greater proportion of management costs, and revenues from fees could help MPAs categorised as 'paper-parks' to become fully functioning MPAs.

4.2 INTRODUCTION

Many developing countries rely on their natural resources to support a tourism industry for economic gain (Pearce, 1989). Tourism ranks among the most important industries globally, with international tourist arrivals numbering 693 million in 2001 (WTO, 2002). According to the World Travel and Tourism Council (WTTC, 2002), travel and tourism is forecast to contribute 3.6% in 2002 to global Gross Domestic Product (GDP) equivalent to US$1,195 billion, rising in nominal terms to US$ 2,271 billion (3.8% of total) by 2012. The travel and tourism industry is estimated to provide 198 million jobs worldwide or 7.8% of total employment and by 2012 is expected to rise to 8.5% (WTTC, 2002).

Nature tourism is a sub-sector of the tourism industry which uses natural areas, landscapes, wildlife and flora and has existed in practice if not in name for decades (Fennell, 1999). Both nature tourism and its low impact form 'eco-tourism', which aims to contribute to the maintenance of species and habitats (Goodwin, 1996), have grown over the past decade. This has in part been due to increased and affordable jet travel, greater accessibility to remote places, nature and travel documentaries, and the rising interest in conservation and environmental matters (Ceballos-Lascuráin, 1993). The fastest growth within tourism has been marine and coastal tourism (Hall, 2001) with coral reef recreation in the tropics increasing due to technical advances in equipment and boats, in addition to reasons given above (Orams, 1999).

Coastal tourism is a mainstay of the Sri Lankan economy, and contributes about US$ 200 million per year to it. Sri Lanka's reefs are worth an estimated net annual tourist-value of US$214,000 per km^2 (Berg et al., 1998). In the Caribbean, the island of Bonaire generated an estimated total gross revenue of US$ 23.2 million in 1991 through dive-based tourism (Dixon et al. 1993), while another island in the Caribbean, Saba ($11km^2$ and population 1,200), was estimated to generate US$2 million per year (Fernandes, 1995). Riopelle (1995) studied reef-related tourism on West Lombok and found a total net present value of benefit from divers and snorkelers of US$ 23.5 million. In Australia, tourism in the Great Barrier Reef area generated an estimated US$ 682 million for the year 1991-2 (Driml, 1994).

However, along with money, social opportunities and new infrastructure, tourism often brings social disorganisation (Britton, 1977; Rodenburg, 1980), congestion and environmental degradation (Miller & Auyong, 1991; Lindberg & Hawkins, 1993). Maximising revenue without threatening the integrity of the natural resources is a complicated challenge, particularly so when considering implications of an expanding coastal tourism industry. Infrastructure supporting such activities is often detrimental to the surrounding environment, and this is particularly pertinent to coral reefs which are often in close proximity to the coast where development is concentrated. An eleven-fold expansion in Egypt's coastal tourism was predicted to exacerbate problems associated with in-filling of shore habitat to create land, sedimentation and over-fishing for marine curios (Hawkins & Roberts, 1994). Similarly developments in Eilat, Israel and Jordan were concentrated in coastal areas alongside reefs. Such developments often result in additional problems of chemical pollution, waste water and sewage, all of which are known to damage reef habitat (Walker & Ormond, 1982; Koop et al., 2001; Nemeth & Nowlis, 2001; Negri et al., 2002).

With the expansion of coastal tourism comes the inevitable increase in diver and snorkeler numbers, whose activities can be damaging to corals as reported in Chapters 2 and 3.

The need for reef management is evident. Some of this management has been through the establishment of marine protected areas (MPAs). Although not widely established until the 1970s and 1980s, MPAs have been useful in helping to conserve reef resources including fish stocks since the early 20th century (Badalamenti et al., 2000). Globally, some 660 MPAs exist that incorporate reefs (Spalding et al., 2001). Despite this, in many MPAs, protection has not been realised due to lack of finance and/or management (Kelleher et al., 1995). They are known as 'paper parks', because they have legal status but are not enforced (Spalding et al., 2001).

In recent years, some protected areas have successfully covered part of their costs by charging user fees (Dixon et al., 1993) although for most, financial support from tourists is not enough (Balmford et al., in prep; Lee & Han, 2002). Saba and Bonaire marine parks in the Caribbean are among the few which, through user fees, have become self-financing with tourists paying for management of park resources (Dixon et al., 1993; D. Kooistra, pers comm.). For many others this is not the case. In Costa Rica for example, less than one percent of the national parks' 1992 budget came from entrance fees (Dixon & van't Hof, 1997). What is questionable is whether MPAs are capturing the full potential for tourist funding (Green & Donnelly, 2003). Studies addressing the amounts visitors are willing to pay for their experience of a protected area suggest that many would be willing to pay more (Dixon & van't Hof, 1994; Walpole et al., 2001; Lee & Han, 2002). A 1992 visitor survey in Bonaire showed that 80% would be willing to pay at least US$20 for access to the marine park, double the amount that was being charged at the time (Dixon et al., 1994). Similarly, recreational use values of five National Parks in South Korea showed that visitors were willing to pay between six and seventeen times the current fee of US 83 cents (Lee & Han, 2002).

Despite providing financial gain, tourism can be a volatile industry exposed to external forces, both natural, such as hurricanes and earthquakes, and man-made such as wars and terrorist attacks. Recurrent wars have inhibited tourist development in Sudan, Yemen and Ethiopia/Eritrea (Hawkins & Roberts, 1994). The kidnapping of 21 divers from the island of Sipadan by terrorists in 2000 caused tourist numbers to the island to drop 60-100 percent in the subsequent six months (Musa, 2002). The 2002 bomb attack in Bali will also inevitably have repercussions on tourist activity. Protected areas dependent on tourism revenue need to build resources to survive periods of financial difficulty. Part of this includes correctly pricing entrance fees so that maximum gain from tourists is achieved.

I explore the issues of financial gain from tourism and the potential for tourists to pay for management of a protected area in the Caribbean Island of St.

Lucia. Tourism represents an important economic contributor to St. Lucia, accounting in 2001 for an estimated 53% of the island's GDP (WTTC, 2002). Annual visitor arrivals have doubled over the last decade and in 2000 numbered more than 700,000 with 64% arriving by cruiseship (St. Lucia government statistics, 2002). Part of St. Lucia's priorities in tourism development is to target niche markets and diversify the tourist product (Ministry of Tourism and Civil Aviation, St. Lucia 2002). One such niche considered ready for expansion is marine-based tourism directly linked to the coral reefs that fringe the island, in particular diving and snorkeling. The growth of these activities in St. Lucia is reflected in marketing by the island's hotels and resorts, many of which offer diving and snorkelling packages through their own water-sports section or through a local dive company.

Management of the island's coral reefs began in 1995 with the establishment of the Soufrière Marine Management Area (SMMA) covering 11km of the western coast. By 2001, the SMMA was estimated to be financed 33% by diver fees, 3% by snorkeler fees, 62% by yacht fees and 2% from donations (SMMA data, 2001). However, to finance the desired level of management additional economic support is necessary (Kai Wulf, pers. comm.). Anecdotal evidence suggests that the most popular and certainly the most advertised dive sites are within the SMMA. Determining whether user fees to these sites could be increased, and if so by how much, is an obvious first step towards solving the present problem.

Financial and economic values of a resource highlighting the costs and benefits of uses have been used successfully in various protected areas in the world. These include, among others, the Great Barrier Reef Marine Park, the Tasmanian Wilderness World Heritage Area, the Wet Tropics World Heritage Area and Kakadu National Park in Australia (Driml, 1994), Bonaire Marine Park in the Netherlands Antilles, Buckoo Reef in Tobago, Key Largo National Marine Sanctuary in Florida (Dixon & Sherman, 1990) and the Marine Reserve of Apo Island in the Philippines (Vogt, 1997). In St. Lucia, no information has so far been gathered on the financial and economic values of the island's marine managed area, in terms of diving and snorkeling, even though the coral reefs are part of its natural capital used for economic development and hence they are vital to the country's dive and snorkel tourism industry. Through this case study, I illuminate some of the economic benefits of reef-based tourism for a developing country, and evaluate the potential of that tourism to support adequate resource protection. Using information from visitors and dive companies, I investigate benefits in terms of revenue directly attributed to diving and snorkeling activities, and in terms of number of people employed. Contingent Valuation Method (CVM) surveys have been used in coastal protected area studies to obtain information on people's maximum willingness to pay for stated preferences (Dixon et al., 1994; Kontogianni et al., 2001; Walpole et al., 2001; Arin & Kramer, 2002; Mathieu et al., 2002; Park et al., 2002). Although contingent valuation methods have in the past been seen as inferior to behavioural methods, the methods have now proved to be no less reliable (Haab & McConnell, 2002). Unless the values of St. Lucia's reefs are properly appreciated it is likely that predicted increases in pressures associated with visitor use, development and the plethora of stresses resulting from a growing population and economy may result in their gradual deterioration potentially culminating with their eventual loss.

4.3 METHODS

I contacted all nine dive companies in St. Lucia and surveyed a sample of divers and snorkelers over two sampling periods. Period 1 was from December 2000 to March 2001 and Period 2 from July to October 2001. I conducted a CVM survey of divers and snorkelers to examine their maximum willingness to pay for marine park fees and the effect this would have on revenue generation. I used open-ended questions to ask them whether they would pay more than the current fee of US$4 or US$12 per day or per year respectively, or the snorkeler fee of US$1 per day, and if so, by how much. Surveys were carried out using three questionnaires, one (Questionnaire 2, Appendix B) for divers during Period 1 and two during Period 2 (one with divers and snorkelers, Questionnaire 3, Appendix C and one with dive companies, Questionnaire 4, Appendix D). Both divers and snorkelers were interviewed at Anse Chastanet Resort and an additional sample of snorkelers was interviewed at Jalousie-Hilton Resort (Fig. 3.1, Chapter 3). After a dive I interviewed the same divers that I had previously chosen by stratified selection for my underwater observation studies (Chapter 2). Similarly, I interviewed the same snorkelers that I had already observed (Chapter 3).

During Period 1, I investigated visitors' holiday choices and expenditure patterns. I interviewed 459 visitors (Questionnaire 2, Appendix B) asking them questions about reasons for their visit, prior visitation, length and place of stay. I sought information on their diving and snorkelling activities on the island including whether they required rental equipment and noted their previous coral reef experiences. I also asked questions on their spending including total holiday cost, amount spent on travel, diving, tours and meals as well as country of residence and age. To determine their exposure to environmental issues, particularly with regard to marine life, I asked whether or not they belonged to an environmental group or read articles on marine life.

In Period 2, I interviewed 327 visitors (Questionnaire 3, Appendix C) and asked them to give a score for fish life, coral life, underwater visibility and their overall satisfaction with the site they had just dived or snorkeled at (scores were: 5 = very good, 4 = good, 3 = average, 2 = poor, 1 = very poor and 0 = no opinion). I also asked how the existence of the marine park had influenced their decision to visit the island. I then gave respondents details on existing and planned programs of the SMMA before asking them what was the maximum amount they would be willing to pay for access to marine park sites, explaining that revenues would go to support improved management. To explore their attitudes regarding spending of revenues from fees towards SMMA programs, I asked them to give a score to six proposed programs according to their view of importance. As in Period 1, I assessed respondents' exposure to environmental issues. Lastly, I asked them to state their household income level.

During Period 2 I also questioned (Questionnaire 4, Appendix D) either the owner or manager of nine of the ten dive companies (one was closed for refurbishment) on the island about their business and clientele. Questions included number of years they had been in business, whether they were affiliated to a hotel and how much of the business was St. Lucian owned. I also asked whether they had a retail store, what percentage of their sales were derived from diving and snorkelling (versus equipment rental and retail sales) and whether they sold packages offshore and through whom. I asked how many full and part-time employees they had and where they were from, how much was spent on salaries and overall dive shop annual income and profit. I also enquired as to how many divers and snorkelers they sold trips to per year, the mean number of trips taken per visitor per trip to St. Lucia, average package value per customer and what sites they used for these activities.

The overall refusal rate for both sampling periods was less than 3% for visitors and 0% for dive companies.

4.4 Results

4.4.1 Visitor characteristics

Respondents' country of residence was similarly distributed over both study periods with most respondents residing in America (61%), followed by the UK (23%), Germany (4%) and twelve other countries each with less than 1%. Roughly equal numbers of men and women were interviewed (53% and 47% respectively) and the mean and median age group was 40-49yrs.

Most respondents (95.6%) were visiting St. Lucia for a holiday, with a minority (4.4%) visiting for work purposes. Over a third (34.4%) stated their main reason for visiting St. Lucia was to dive or snorkel on the reef. The remainder

(65.6%) who gave other reasons still partook in either one or both as a holiday activity. It should be remembered that interviews were conducted at beach resorts and this pattern is unlikely to fully represent visitors to St. Lucia in general. More than half of respondents had experienced diving or snorkeling on coral reefs elsewhere in the world (64.0%). Repeat visitors made up 13.1% of the sample, 41 respondents were visiting for the second time, and 17 for their third or more time. Most respondents (72.0%) were exposed to environmental issues either by being members of an environmental organisation, reading articles on marine life or by watching environmental programmes on television (see Appendix G for complete list of names and titles.)

Length of stay ranged from a few hours (day-trippers) to permanent residence with the most common duration of stayovers of more than 24 hours being 7 days (40.0%), followed by 14 days (29.5%) (Fig. 4.1). 106 respondents (23.1%) were day-trippers of which 95.3% arrived by cruise boat and 4.7% by yacht. 353 respondents (76.9%) were stayovers of which 71.9% were accommodated in hotels, 3.1% were lodged privately by friends or family, and a small proportion (0.7%) used self-catering accommodation.

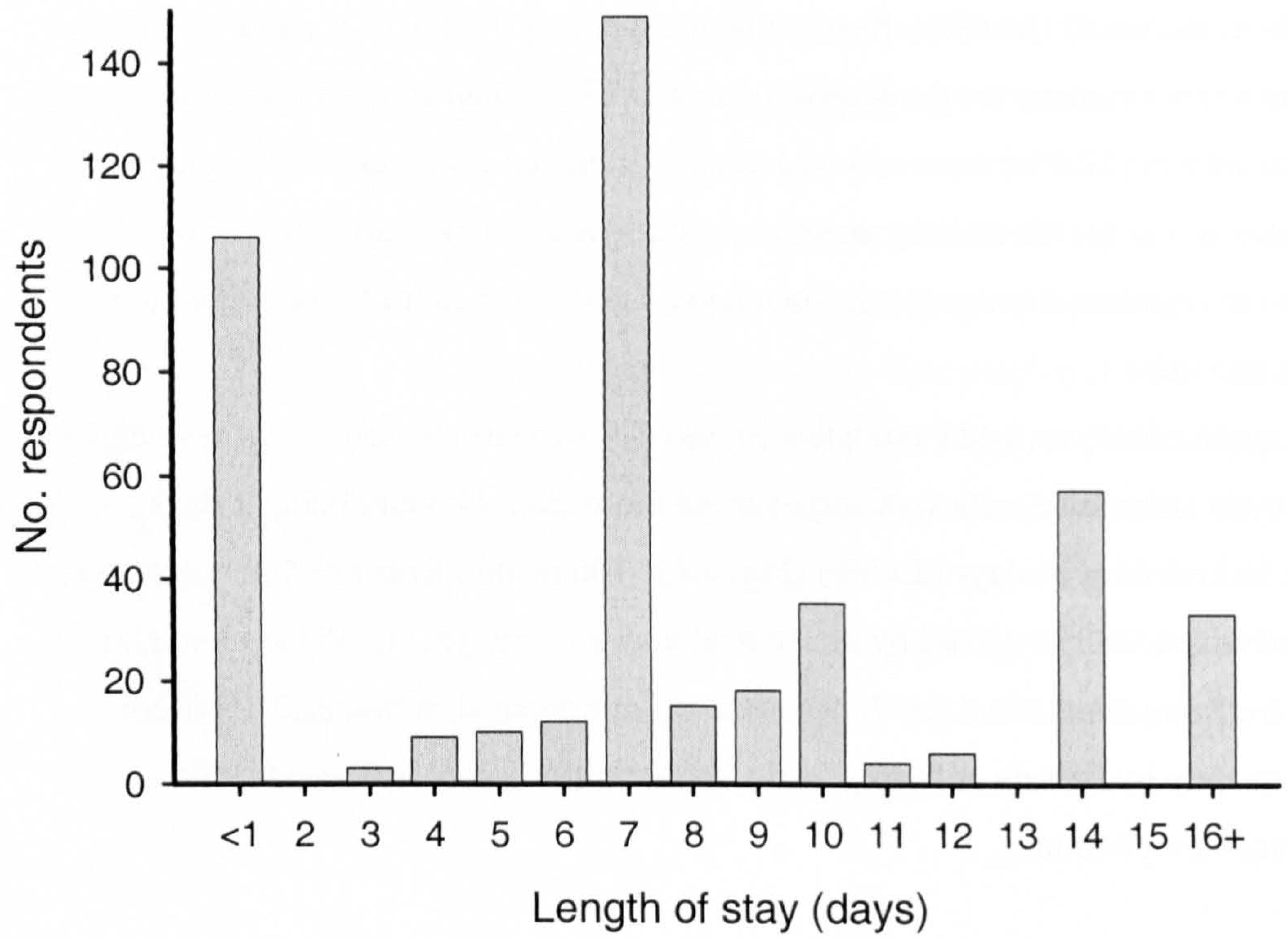

Fig. 4.1 Number of days spent by respondents in St. Lucia.

Divers among the respondents planned on completing between one and twenty day dives and 27.4% of divers planned one to two night-dives (Fig. 4.2). The mean number of day dives planned was 6 and the median 5. The mean and median number of night dives planned was 1.

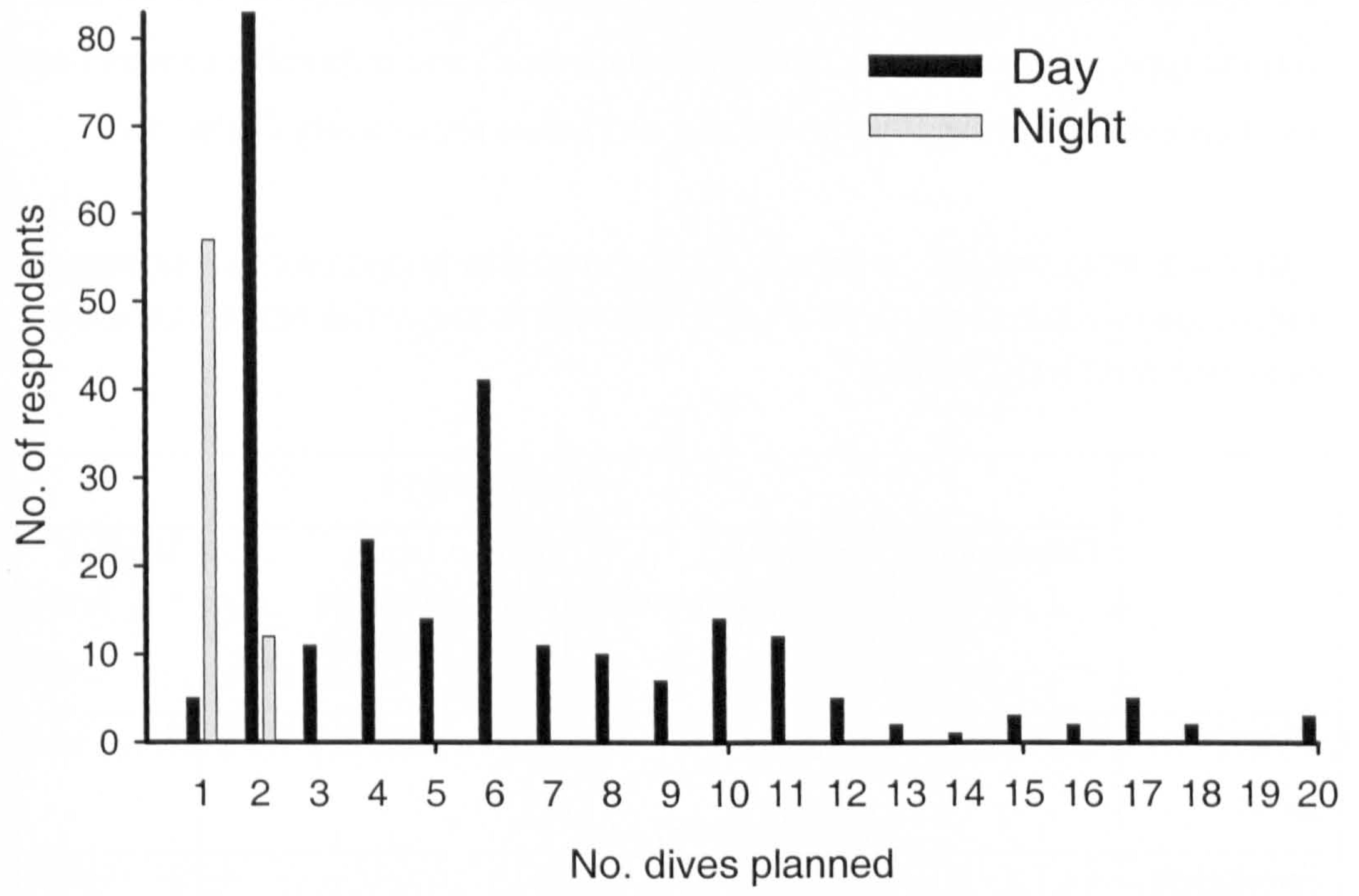

Fig. 4.2 Number of dives planned by respondents that were diving in St. Lucia.

More than half of divers (59.4%) and a quarter of snorkelers (25.4%) rented equipment, ranging from mask and snorkel to buoyancy compensating devices (BCDs) and cameras (Table 4.1).

TABLE 4.1 PERCENTAGE OF DIVERS AND SNORKELERS THAT RENTED VARIOUS PIECES OF EQUIPMENT

	Mask	Snorkel	Fins	Wetsuit	BCD	Regulator	Torchlight	Camera
Divers (n=254)	13.8	13.8	18.1	40.6	57.5	56.3	0.8	3.1
Snorkelers (n=205)	20.0	20.0	25.4	-	-	-	-	-

22.8% of divers and 8.3% of snorkelers took underwater photographs. Few visitors rented cameras (3.1% of divers only). Of the camera users, most divers and all of the snorkelers owned their own photographic equipment. When broken down into camera type, automatic focus point-and-shoot styles and disposable cameras were the most commonly used among divers and snorkelers respectively (Table 4.2).

TABLE 4.2 PERCENTAGE OF DIVERS AND SNORKELERS TAKING PART IN UNDERWATER PHOTOGRAPHY AND CAMERA TYPE USED. BRACKETS SHOW THE PERCENTAGE OF CAMERAS THAT WERE RENTED

	Camera type				
	Disposable	Automatic focus/point-and-shoot	Manual focus, interchangeable lenses, external strobes	Digital	Video
Divers n=58	3.4	48.3 (10.7)	37.9 (22.7)	3.4	6.9
Snorkelers n=17	64.7	35.3	-	-	-

4.4.2 Expenditure patterns

Analysis of total cost of trip including travel, accommodation and spending money per person, whether stayover or day-tripper revealed a range from US$480 to US$10,000, with a mean of US$2,276 ± 121 (95% CI). Table 4.3 shows the difference in total cost of trip between types of accommodation used in St. Lucia.

TABLE 4.3 TOTAL COST OF TRIP ACCORDING TO TYPE OF ACCOMMODATION USED IN ST. LUCIA

	Accommodation type			
	Cruiseship	Hotel/guest house	Yacht	Private/friends /relatives
US$				
Minimum	500	480	876	500
Maximum	7300	10000	3000	3800
Mean	2006	2373	2290	1839
Median	1750	2000	2920	1500
N	86	308	9	13

Taking into account the length of stay in St. Lucia for each respondent, a daily mean expenditure was calculated at US$264 ± 17 (95% CI). Subtracting air travel cost from total cost of trip, daily mean expenditure for stayovers was US$183 ± 19 (95% CI).

Day-trippers' spending varied widely between the islands they visited making calculations of mean daily expenditure throughout their trip problematic. I therefore calculated a daily spending value according to their visit to St. Lucia, excluding spending at other islands. Using number and cost of dive and snorkel trips, I calculated daily mean expenditure to be US$89 ± 4 (95% CI). This was based on a mean snorkel excursion cost of US$69 and a two-tank dive excursion cost of US$110 calculated from dive company rates for 2001.

Data on expenditure per person per trip by main purpose of visit shows that people visiting St. Lucia primarily to dive spent the most per trip (Table 4.4). The median expenditure values of US$69 and US$110 in Table 4.5 are due to these being the only values used for snorkel and dive excursions (in this instance the means and medians for excursions and expenditures respectively are identical).

TABLE 4.4 TOTAL COST OF TRIP PER PERSON CLASSIFIED BY MAIN PURPOSE OF VISIT

	Stayovers		*Day trippers*	
	Number of respondents	Median cost US$	Number of respondents	Median cost US$
Main purpose of visit:				
To dive	63	2528	7	2000
To snorkel	5	1825	3	1600
To dive or snorkel among other reasons	63	2044	10	1600
For a general holiday	185	1896	71	1896
For work or business	12	1625	nil	

TABLE 4.5 SPENDING PER PERSON PER DAY BY MAIN PURPOSE OF VISIT

	Stayovers		*Day trippers*	
	Number of respondents	Median expenditure US$	Number of respondents	Median expenditure US$
Main purpose of visit:				
To dive	7	56	7	110
To snorkel	3	73	3	69
To dive or snorkel among other reasons	14	46	10	110
For a general holiday	37	50	77	110
For work or business	7	63	4	110

Two thirds of respondents (68%) were on a package holiday. These varied between those including only accommodation and airfare to those including meals, diving and snorkelling trips in addition to other watersport activities offered by their resorts. The mean total cost of a trip, whether as part of a package or not was similar at US$ 2310 and US$ 2246 respectively. Of the stayovers, 23.2% bought their dives as part of their holiday package prior to arrival in St. Lucia. 13.8% bought their dive package on arrival directly from the diving company. The remainder bought individual dive trips, usually on a daily basis. All cruiseship visitors arranged dive and snorkel trips through their ship's on-board excursion office.

4.4.3 The SMMA and visitor's willingness to pay fees

139 (43.7%) respondents said they visited St. Lucia because of the existence of the marine park with proportionally more divers (50.3%) than snorkelers (37.9%) doing so. A small proportion of divers (11.4%) and snorkelers (16.6%) did not know of the existence of the marine park prior to their visit.

At the time of the research, marine park fees were US$4 and US$12 per diver (daily and annual fee respectively) and US$1 per snorkeler (daily fee available only). Over 90% of divers and snorkelers were willing to pay more than the stated daily and annual fees (Fig.4.3). Seventy five percent of divers were willing to pay at least US$6 for a daily fee, and 50% US$7. Seventy five percent of divers were willing to pay at least US$20 for an annual fee and 50% US$30. Seventy five percent of snorkelers (and up to 91.5%) were willing to pay at least US$2 per day, double the current fee and 50% US$4. Although an annual fee is currently not available to snorkelers due to a perceived lack of demand and uneconomical returns (Kai Wulf, pers. comm.), 40.5% of respondents said they would like such an option. Seventy five percent were willing to pay at least US$10 for it, and 50% US$20.

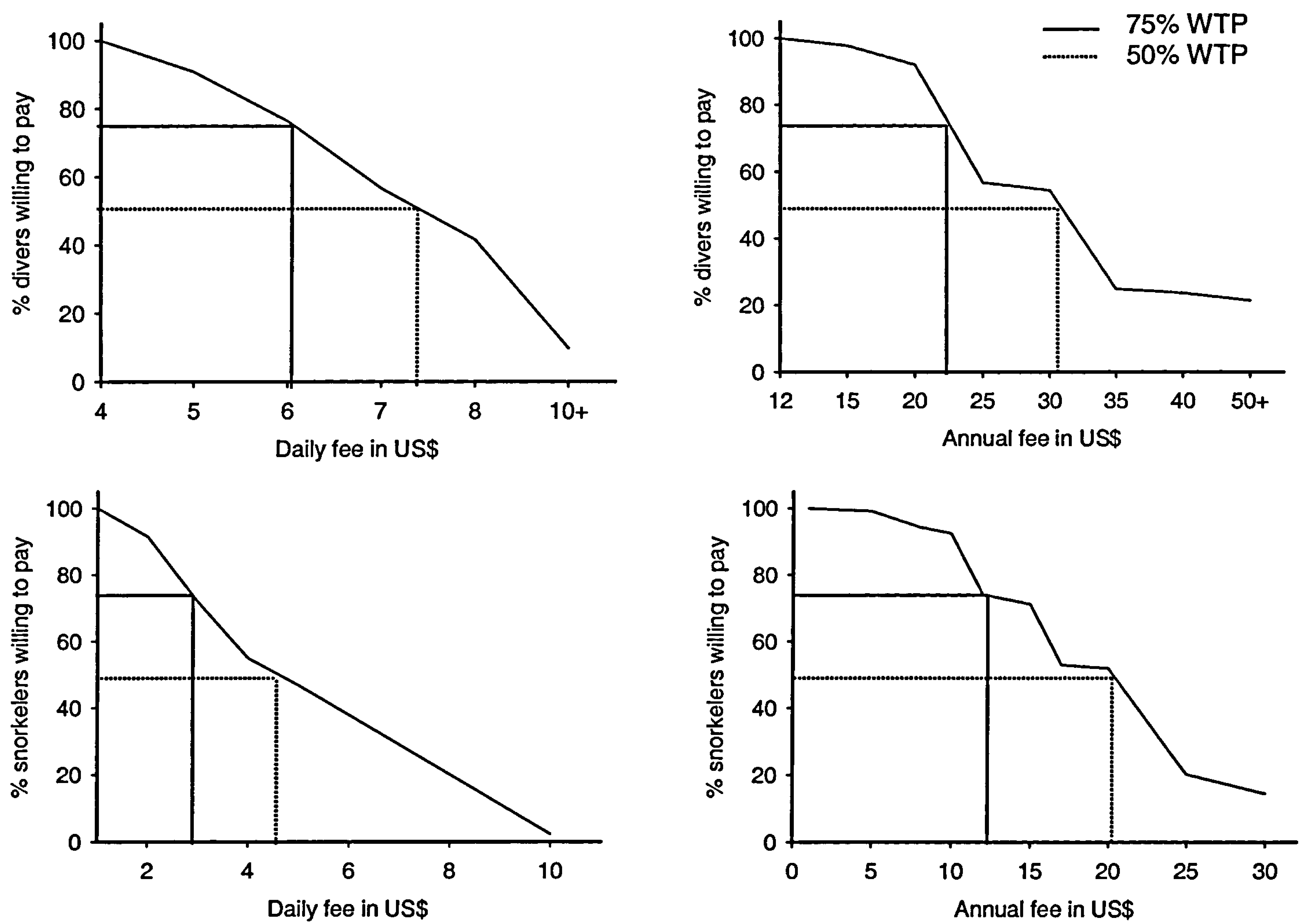

Fig. 4.3 Maximum amount visitors surveyed were willing to pay for use of reefs in the Soufrière Marine Management Area in St. Lucia

Respondent's income ranged from level 1 (up to US$20,000) to 5 (US$80,001 and above) with most earning the latter amount (Table 4.6).

TABLE 4.6 INCOME DISTRIBUTION OF RESPONDENTS

	Income level	No. respondents
Income in US$		
up to 20,000	1	4
20,001 to 40,000	2	9
40,001 to 60,000	3	40
60,001 to 80,000	4	45
80,001 +	5	220
Mean income level	4	
Median income level	5	
Modal income level	5	

The null hypothesis that maximum willingness to pay is similar across all income ranges was accepted for divers but not for snorkelers (Kruskal-Wallis test, p=0.039, Fig. 4.4).

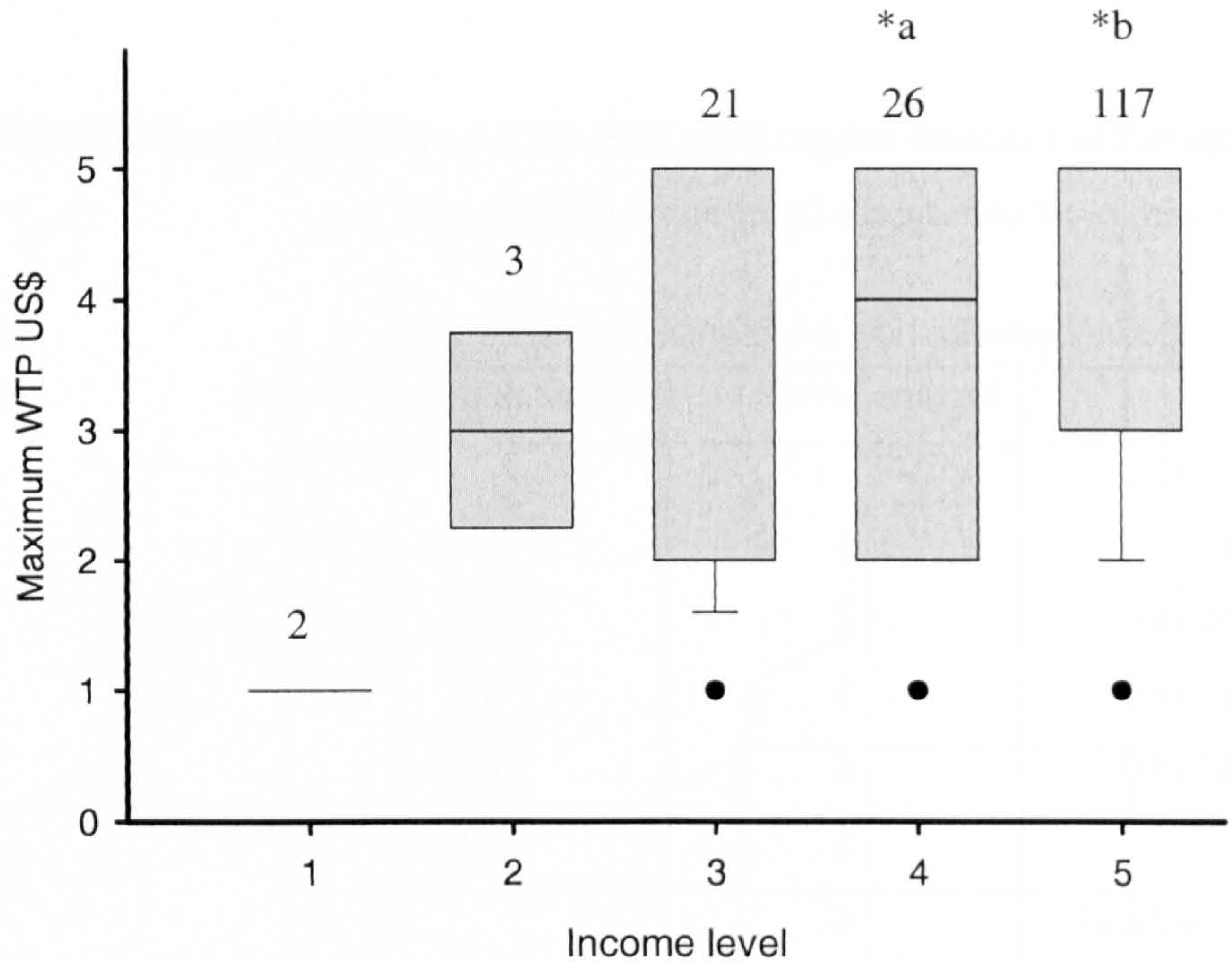

Fig. 4.4 Maximum daily snorkeling fee respondents were willing to pay according to income level (1= up to US$20,000, 2=US$20,001-40,000, 3= US$40,001-60,000, 4=US$ 60,001-80,000, 5=US$80,001 and over). See legend to Figure 2.3 for explanation of box plot. Numbers directly above the boxes represent sample size. *a and *b denote n=1 and n=4 outliers respectively, each with WTP values of US$10.

Most respondents noted that their marine park experience, ranked from 1-4 (1= not satisfied your expectations, 2 = made no difference, 3 = satisfied your expectations, 4 = exceeded your expectation) had satisfied their expectations resulting in a median score of 3 ± 0.09 (95% CI) and a mean of 3.08. No relationship was found between visitors' willingness to pay and their level of satisfaction with the marine park (Kruskal-Wallis test, p=0.33 for divers and p=0.84 for snorkelers). Exposure to environmental issues by belonging to an environmental group or organisation, reading articles on marine life or watching environmental programmes on television also had no effect on willingness to pay (Mann-Whitney U tests were all non-significant).

Multiple regression analyses did not find any of eleven measured independent variables (sex; rating for fish, coral, visibility and overall satisfaction; total dives done in whole dive history; dive qualification; experience of St. Lucia's marine park; exposure to environmental issues; income; weather, measured on a gradient from sun to rain) to significantly influence divers' willingness to pay. However, when snorkeler daily willingness to pay was used as the dependent variable with the same independent variables plus one other, whether the snorkeler was on an organised trip or not, the regression was significant (Multiple regression, Table 4.7, F=6.648, $P<0.001$, $R^2=0.140$).

TABLE 4.7 VARIABLES WITH SIGNIFICANT INFLUENCE ON SNORKELERS' WILLINGNESS TO PAY

	Unstandardised coefficients		Standardised coefficients	t	Sig
	B	S.E.	Beta		
Fish score	0.510	0.158	0.242	3.227	0.002
Knowledge of MPA	-0.646	0.265	-0.180	-2.438	0.016
Income score	0.490	0.150	0.243	3.276	0.001
Organised trip	0.596	0.271	0.168	2.195	0.030
Constant	-0.157	1.012			0.877

Scores on fish and income and snorkelers on an organised trip were positively correlated with increased willingness to pay. Knowledge of the marine protected area (MPA) was negatively correlated. Taking the fish score for example, this therefore meant that for every increase in fish score by one unit, willingness to pay increased by 0.51 units.

Spearman's rank-order correlation tests also indicated a significant positive association between snorkelers' willingness to pay and both underwater visibility (r=0.147, d.f. =169, p=0.028) and overall satisfaction (r=0.148, d.f. = 169, p=0.027). Both these correlations support the prediction that higher ratings for underwater visibility and overall satisfaction would correlate with higher willingness to pay values, but they account for only 2% (r^2=0.02 for each) of the variability in maximum willingness to pay. This leaves 98% of the variability still to be accounted for by other variables.

Divers' and snorkelers' willingness to pay daily fees were also positively correlated with their willingness to pay their respective annual fees (Spearman's rank-order correlation, r=0.527, d.f.=172, p<0.001 and r=0.568, d.f.=104, p<0.001 respectively). Thus, those divers and snorkelers willing to pay more for daily fees were also willing to pay more for annual fees.

When respondents were asked to give proposed SMMA programs a score according to whether they thought it important (1= not important, 10= very important), high scores with a median of 8 were recorded for all but two programs. Sharing information and experiences with other marine parks got a slightly lower score (median 7.5) and increasing facilities for users of the marine park such as developing snorkel trails received the lowest score (median 5). These differences were significant (Fig. 4.5, Kruskal-Wallis Test, p<0.001) meaning that I could reject the null hypothesis of identical medians for each of the marine park programs.

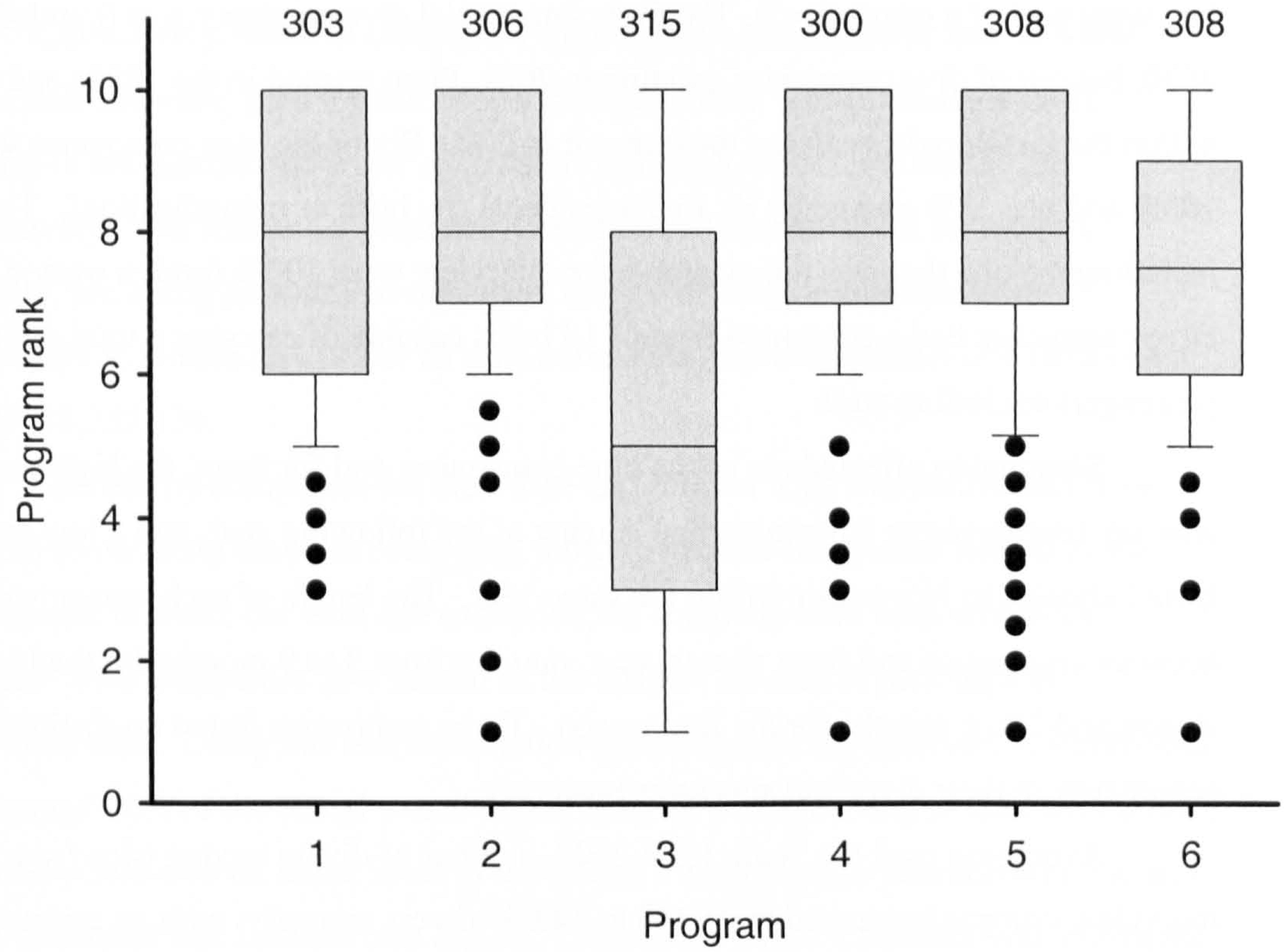

Fig. 4.5 Program rank distribution. See legend to Figure 2.3 for explanation of box plot. Numbers directly above the boxes represent sample size. Programs: (1) increase implementation and enforcement of existing policies e.g. increase patrols carried out by the rangers, so improving the effectiveness of protection; (2) develop alternative employment programs for fishermen who are displaced by no-fishing zones; (3) increase facilities for users of the marine park such as developing snorkel trails; (4) train fishermen in deep sea fishing techniques to divert pressure from the near-shore resources; (5) establish a trust fund to acquire critical land and beach area for conservation purposes and (6) develop programs to share information and experiences with other marine parks e.g. the ranger exchange program.

4.4.4 Dive companies

Companies were almost evenly split between independent businesses (n=4) and those that were part of a resort (n=5). The first commercial dive company was founded in 1970, but out of dive companies existing in 2001, three opened in the 1980s and six within the last decade, with the most recent in 2000. Six of the nine companies were 100% and one 51% owned by St. Lucia residents (by birth or naturalisation). Three, including the one that was not available for interview were 100% foreign owned. Dive companies had a combined fleet of 18 boats capable of carrying a total of 357 passengers excluding staff.

Seasonality affected six of the nine companies, and for them, the high season was any time between November and August of the following year, and a low season from February to November within the same year. The length of each season varied between companies and from year to year, ranging from 3 to 9 months for the high season and 2 to 6 months for the low season. Three companies found no distinct seasonality in their diver and snorkeler business.

Averaging over the years 1999-2000, number of divers buying trips from individual companies ranged from 450 to 14,000 divers annually, with an estimated total of 34,500 divers for the year 2000. The annual number of snorkelers who bought snorkel trips through dive companies ranged from 50 to 28,000, and for the year 2000 totalled 32,900 (all companies collectively). The median number of dive and snorkel trips taken per customer was 4 and 1 respectively.

Annual gross revenue between dive companies ranged from US$3,500 to US$700,000 and collectively was US$1,597,413. Six companies revealed that dive and snorkel trips and courses made up 80% or more of sales. Equipment rental contributed between 3 and 20%, and retail (applicable to only two companies) between 2 and 8% of sales. Two companies revealed annual net profits of between 29 and 31% and three reported a profit of 0%. The remaining companies were unwilling or unable to provide this information, particularly the all-inclusive resorts whose dive and snorkel activities formed part of a pre-paid package.

Seven companies sold packages offshore either through their own hotel or marketing office, tour companies, travel agents or web pages, and three reported that these sales accounted for between 0 and 25% of gross revenue.

Collectively, the dive companies employed 14 management and 96 water sports staff full-time, plus 9 water sports staff part-time. The percentage of St. Lucians in managerial and water sports staff positions was 71.4% and 97.1% respectively. The remainder were non-Caribbean. Amounts spent on salaries annually, including all staff and managers ranged between companies from US$16,095 to US$551,811. For all nine companies, the total annual cost in salaries was US$1,357,136.

Site use by companies for their dive and snorkel trips was distributed from north to south along the west coast (Fig. 4.6). In general companies tended to use sites closest to them, but with one exception, all routinely used sites within the SMMA. Dive companies also submit to the SMMA records of dive trips to individual sites. Using this and information gathered from my interviews, I estimated that around 60% of the island's total diving activity was occurring at sites within the SMMA, which also included some of the island's most popular snorkel sites, namely Anse Chastanet and Jalousie (see Fig 3.1, Chapter 3). Anse Chastanet was estimated to receive 20% of the island's diving activity and is one of the most advertised and used snorkel sites. Anse Cochon, 6km north of the SMMA (Fig 3.1, Chapter 3) is another locally renowned snorkeling area.

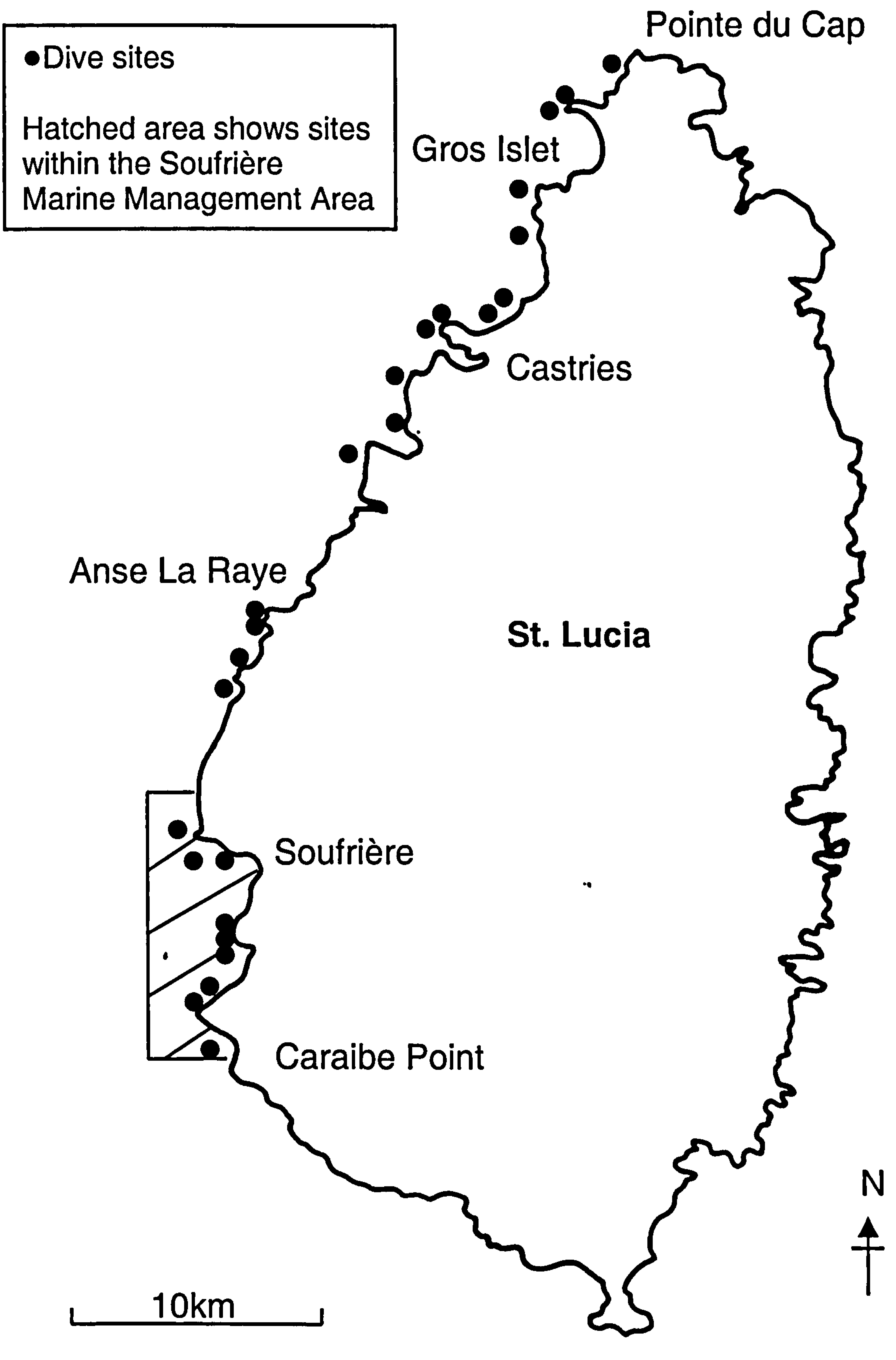

Fig. 4.6 Location of sites used by dive businesses in 2001.

Anecdotal evidence and personal observations indicated times when several boats, including those with a capacity of over seventy people, were using this site simultaneously resulting in over a hundred snorkelers in the water. During interviews, some operators voiced their concerns regarding the high use of Anse Chastanet and Anse Cochon sites reporting that the reefs in these areas were being degraded and over used. Comments from visitors diving and snorkeling on Anse Chastanet reef varied. Some described it as amazing, and others, particularly those returning to the same site after between one and twenty two years, noted that the corals appeared fewer and looked dead. One visitor noted the loss of branching corals of the species *Madracis mirabilis*, commonly known as the yellow pencil coral, which they said had ten years previously occurred in patches of several square meters.

4.5 Discussion

Reef tourism is a valuable business. Tourists spend significant amounts in order to dive and snorkel on St. Lucia's coral reefs and for many, these activities are their prime motivation for choosing to holiday there. The marine park was also significant in visitors' decisions to visit St. Lucia but it is clear that the park is not maximising the financial benefits that visitors could bring to it. This study shows that in St. Lucia, park user fees could be increased and in so doing pay for improved management. By calculating the financial gain derived from visitors and dive companies we can put a value on coral reefs directly attributable to reef tourism and thus highlight the value of conserving and managing the resources on which that tourism industry depends.

Although St. Lucia has no statistics on numbers of people taking part in reef-based activities, its financial significance is clear from diver and snorkeler expenditures. I estimate that reef tours and marine park fees alone contributed some US$7.3 million in 2000. Using the information on site use by dive companies, I estimate that roughly half of this revenue (US$3.5 million) comes from dive and snorkel trips done within the marine park. Dive and snorkel businesses also benefit. In St. Lucia, most of these businesses are St. Lucian owned and collectively employ a workforce of over a hundred people. In addition the hotel and restaurant industry that caters to visitors, employs some 17,382 people or 11% of the total population (St. Lucia government statistics, 2001). Central government also derives revenues from hotel occupancy (US$8.5 million) and travel taxes (US$936,000) as well as reporting an annual visitor expenditure of US$108 million.

The median cost of trip per person to St. Lucia in 2000 was US$2000. This compares with other visitor expenditures on marine related holidays. Visitors that participated in whale shark tours in Belize spent a median of US$1,500 in total on their trip and 15% of these visitors spent more than US$3,000 (Graham, 2002). A survey of readers of Skin Diver Magazine in 1991 reported that divers spent an average of US$3,150 per dive trip (Skin Diver, 1991 Subscriber Survey).

Stayovers in St. Lucia spent more than day-trippers, spending a median of US$172 per day compared to US$69 spent by cruiseship passengers. This backs up research in Dominica, an island 150km north of St. Lucia, which found the median expenditure per person per day for stayovers was US$65 compared to cruise passengers US$ 36 (Westbrook et al., 1997). In the Philippines, overnight visitors to coral reefs at Apo Island spent US$20 per person per night compared to visitors coming for a few hours who spent US$5 per person per day (White, Vogt & Arin, 2000). Despite the lower expenditure of day-trippers arriving by cruiseship, this type of holiday has significantly increased since the early 1980s and is set to continue growing (CLIA, 2002).

Cruise Lines International Association (CLIA) who represent 23 cruiselines and the majority of whose customers originate from the United States and Canada reported an increase in beds from 41,073 in 1981 to over 170,000 in 2001. They also plan to add 42 new ships to their fleet by 2006 (CLIA, 2002). The dominant world destination is the Caribbean region which accounted for 47% of total world capacity placement in 2002 (CLIA, 2002). Cruiseship passenger arrivals to St. Lucia have more than doubled since the early 1990s to almost 500,000 in 2000 (St. Lucia government statistics, 2002).

Similarly, package holidays have, over the years increased and are now the major form of vacation, (Wood & House, 1991 cited in Gössling, 1999). More than half (68%) of respondents interviewed in the present study bought their holiday as a package. Although the total holiday cost, whether package or not, was the same for respondents, it is likely that non-package holidays resulted in greater financial benefits to the St. Lucian economy. Package holidays are renowned for problems associated with 'leakage'. Significant proportions, sometimes up to 80%, of revenue is repatriated due to expenditures on tourism-related imports and services, foreign ownership of businesses, or overseas credit loans (Gössling, 1999). In Bonaire, visitors who purchased packages typically made few additional expenditures during their stay (Scura & van't Hof, 1993; Westbrook et al., 1997). Expenditure by visitors to Bonaire over and above packages, was as low as US$275 per person per average 6-day stay (Dixon, Scura & van't Hof, 1993).

Estimates of the leakage rate in St. Lucia range from 45% in 1978, to 61% for 1986 (Wilkinson, 1997 cited in UK CEED, 1998). The increase in cruiseship activity and development of all-inclusive resorts, where all or most guest services are included in one pre-paid holiday package price may aggravate the problem of leakage, both in St. Lucia (UK CEED, 1998) and the Caribbean in general (Miller & Auyong, 1991). In addition, there may be an increase in conflict between visitors and local communities, who often perceive that all-inclusive resorts exclude them from tourism benefits.

The environment plays an important role in attracting tourists. Coral reefs and marine parks are particularly valuable resources and attractions. Many visitors to St. Lucia showed an interest in environmental issues, with almost three-quarters surveyed either belonging to an environmental organisation or reading articles on marine life and many (possibly up to 86%) knowing that St. Lucia had a marine park.

Nearly half (44%) of those interviewed said they visited St. Lucia because of its marine park, demonstrating the value of marketing protected areas for economic gain.

For the marine park in St. Lucia, part of the economic gain from visitors comes in the form of user fees but these appeared to be lower than what most visitors were willing to pay. More than 90% of divers and snorkelers interviewed were willing to pay above the current daily and annual fees for the SMMA.

Revenue from diver fees in 2001 was US$71,675 and from snorkeling was US$5,400. Adding the revenue from yacht mooring fees and donations brings total revenue for 2001 to US$80,139. This is below the US$98,016 which, according to the MPA manager, is required to cover minimum park management standards (Kai Wulf, pers. comm.). An additional US$17,877 is therefore needed. This could come from increasing user fees to levels that 75% of visitors interviewed in this study were willing to pay. A daily diver fee of US$6, an annual diver fee of US$20 and a daily snorkeler fee of US$2 would increase revenue by approximately US$15,900. The diver willingness to pay levels are similar to those found by Dixon, Scura and van't Hof (1994) who note that 80% of divers were willing to pay at least US$20/diver/year and 48% would be willing to pay at least US$30/diver/year. If levels in St. Lucia's marine park were set at what 50% of visitors were willing to pay, US$7/diver/day, US$30/diver/year and US$4/snorkeler/day, the increase would be in the region of US$32,800 per year. This would bring the total park revenue close to the US$140,000 estimated by Wulf that would pay for ideal management standards (Kai Wulf, pers. comm.). These calculations do not include the potential revenue that could be gained from an annual snorkeling fee, which as my results show, was an option 41% of visitors to the park would have liked and for which a third were willing to pay US$20.

Anecdotal evidence from this work in St. Lucia, and work by others elsewhere, suggests that visitors would be willing to pay higher fees so long as they could see where the money was going (Davis & Tisdell, 1998; Spash, 2000; Lindberg, 2001). In this study many visitors wanted information on the biological aspects of the reef and marine park projects. Willingness to pay was not correlated with respondents' satisfaction with marine-park experience, probably because the majority were satisfied by what they saw. Nor were the two factors used to measure exposure to environmental issues, belonging to an environmental group or organisation and reading or watching programs on marine life related to willingness to pay, probably because most visitors showed an interest in the environment. Income level also had no influence on willingness to pay except in the instance of snorkelers, where those in the lowest income bracket were willing to pay the least. However, most visitors were in the highest income bracket, which may have masked underlying trends.

Results from the multiple regression reinforced the indication that snorkelers' willingness to pay was positively influenced by their income as well as another influencing variable, fish life. The higher the scores given for fish life, the higher the willingness to pay. Other research has found divers to particularly appreciate abundant and diverse fish (Williams & Polunin, 2000; Rudd & Tupper, 2002). Snorkelers' willingness to pay was also positively correlated with better scores for underwater visibility and overall satisfaction. Research has also found that divers expect, value and place importance on clear water (reviewed in Tabata, 1992). Both fish life and water quality are amenable to improvement by park management (Kelleher & Kenchington, 1992), suggesting again that parks add value to reef assets.

Snorkelers on organised trips were also willing to pay more than those snorkeling independently. It is likely that people willing to pay for a snorkel trip will have an increased tendency to pay towards other things associated with this activity which in this case, consisted of marine park fees. The regression model only explained 14% of the variance however, and this means that other variables not measured are probably having a greater influence. Further research looking for those likely influencing variables would be useful to try and explain more of visitors' willingness to pay fees.

What many visitors did express, was their objection to paying for an 'annual' fee when they were only staying a few weeks and were unlikely to be revisiting the island within the next 12 months. However, this is more of a marketing problem than a cost problem since my data show most visitors are willing to pay above the current fees. Replacing 'annual' with 'multiple day, valid for 12 months' for example, may resolve this issue.

Implementing and increasing fees could decrease visitation. A study of visitors to Komodo National Park in Indonesia suggested that a five-fold increase in fees from US$0.87 to US$4 would result in only a 20% decline in visitation (Walpole et al., 2001). Research by Walpole et al. (2001) and others indicated that demand was relatively insensitive to price (Mundet & Ribera, 2001), although their studies had low starting fees of between US$0.87 and US$2.2. In Costa Rica, an increase in tourist fees from US$1.25 to US$15.00 in 1994 for visiting National parks may have contributed to the 47% decrease in visitation by non-residents (Laarman & Gregersen, 1996) but resulted in a five-fold increase in revenues (Dixon & van't Hof, 1997). Both those studies highlighted the importance of disseminating information and preparing the tourism sector, tourists and residents for fee systems and any potential increases in fees. Asking tourists their attitudes and preferences with regards to marine-park issues also helps reveal where improvements to a marine park could be made.

CVM has been widely criticised because of the hypothetical questions that are used to elicit answers (hypothetical questions yield hypothetical answers) and biases linked to survey design and cognition (Hoehn & Randall, 1987; Schkade & Payne, 1994; Sagoff, 1998). However, in my survey I carried out all the interviews personally, giving people the same information on the current management of the marine park and what their fees paid for. I also told people what their additional money would pay for and, as they had already paid a fee and experienced the reefs, the scenario that I presented them with was more realistic than some other CVM studies. The people I interviewed had a good idea of where their money would be going and had a first-hand experience of what it would be paying for. There has also been debate on the elicitation process, with dichotomous choice being preferred and endorsed by science compared to the open-ended question method (Boyle & Bishop, 1988; Ready et al., 1996). However, recent literature suggests that both methods are truth revealing (Haab & McConnell, 2002).

When I asked visitors to score the various proposed SMMA programs according to importance, only two received median scores of less than 8. One was sharing information and experiences with other marine parks, which got a median score of 7.5, and the other was increasing facilities for users of the marine park such as developing snorkel trails which received a median score of 5. The SMMA proposed to share information and experiences by running a ranger exchange program involving parks throughout the Caribbean. Some visitors thought that using the worldwideweb would be a cheaper means of sharing information that did not require rangers to incur travel and living costs elsewhere. However, this is unlikely to be as effective as hands-on experience. Rangers accompanying each other on patrols and looking at each other's working methods are able to experience and see at first hand which methods are most effective and how to achieve the best results.

Increasing facilities for users received the lowest score. This is interesting because it is one of the only things directly targeted toward tourists. Many visitors disliked the idea of snorkel trails suggesting that it would lead to overcrowding and spoil the naturalness of the area. Certainly research in the Great Barrier Reef has shown that snorkel trails localise damage to that area and immediate surrounds, particularly near interpretative signs (Plathong et al., 2000). Concentrating damage to certain areas may be helpful though, if it means other areas are left intact.

Despite the obvious financial benefits from reef tourism, there remains a long-standing problem of distribution i.e. the rich get richer and the poor can't get a share (Cater & Goodall, 1992). Not everyone benefits from tourism and the losers are capable of undermining tourism and conservation efforts including management plans such as MPAs. One of the most significant barriers to community involvement in tourism is the lack of financing which limits communities' opportunities to participate in tourism ventures (Wells, 1997). Communication between protected area management and the local population and involving local populations in conservation efforts is also of paramount importance (Wells, 1997; Nepal, 2002). Community involvement could be improved with ventures through park management authorities for example. Fee systems can be used to gather revenue from users but prices need to be set so that optimum financial gain is achieved. If set too low, administrative costs may exceed fee receipts; if set too high, visitor numbers may drop. Community trust funds are another tool that could spread some of the benefits from tourism more equitably. In the case of marine parks, such funds could compensate fishers after hurricanes, pay for repairs and maintenance of fishing equipment, pay for re-training programs and offer low cost loans. Benefits could even be linked to compliance with regulations such as no-fishing areas. Marine parks also need to acknowledge that tourism is a fickle source of income that can evaporate at the hint of trouble. They therefore need a buffer. If one assumes that the demand for tourism is cyclical it will follow the country's economy and in the case of St. Lucia, will follow the economy of the United States and Europe where most of St. Lucia's tourists come from. In years when tourist numbers and revenues are high, then a portion of MPA revenues could be set aside to compensate for potentially lower visitation in the future. In years when demand for tourism is low, this investment could be drawn from to cover running costs.

At present there does not seem to be enough slack in tourist willingness to pay for such funds or investments. However, there may be a case for being able to charge a premium for high quality sites. A study of two Red Sea diving resort areas by Medio (1996) found that limiting and regulating access and development reduced damage to, and maintained quality of, coral reefs. Consequently, tourist businesses in one area were able to charge almost double what they charged in the other area, which allowed unlimited reef use for tourism and fishing as well as unrestricted coastline development. This illustrates the necessity of applying other tools such as access restrictions in addition to user fees. In the Medes Islands protected area, Mallorca, over-use and impoverishment of their marine ecosystem led to the decrease in its value as a tourist attraction and the introduction of a US$2.2 dive permit in 1990 to reduce visitor demand (Mundet & Ribera, 2001). However, this was not enough to conserve their marine ecosystem and in 1995, the number of dives allowed in the protected area was set at 450 per day. In response to this, dive clubs diversified site use by taking beginners and advanced courses to sites outside the protected area. This approach could be used in St. Lucia to alleviate diving and snorkeling pressure from some of its most popular sites.

For countries whose economies rely on coral reef tourism such as St. Lucia, Saba, Bonaire, the Maldives and the Seychelles, continued existence and growth of their industries requires a high quality underwater environment. This only comes from management, control of development and controlled use of the resources. The establishment of MPAs and the charging of fees to use protected areas for recreation and commercial purposes can go a long way to providing the funds necessary to finance such protection. As this study shows, the vast majority of reef users are willing to pay such fees and in many cases are willing to pay much more than is currently being asked. If MPAs were to harness more of the potential income from visitors, a greater proportion of management costs could be met and for some, moving from 'paper-parks' to becoming fully functioning MPAs would be realised.

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Chapter 5: Relationships between tourist perceptions and measured attributes of coral reefs

5.1 Abstract

Coral reef tourism relies on the health of reefs and the marine life that they support. The relationships between visitor attitudes and environmental quality are complex and variable and little is known of the reliability of visitor perceptions of environmental attributes. 789 tourists were interviewed over two sample periods and asked about their motivations for visiting St. Lucia's reefs, their perceptions of reef attributes including fish and coral life, underwater visibility, garbage and crowding, their best and worst experiences on their reef trip and what would have improved their reef visit. Measurements were made of fish life, coral life, underwater visibility and garbage at the different sites to compare with visitor perceptions. 85.0% of visitors rated viewing marine life as their number one motivation for diving or snorkeling in St. Lucia. 88% of divers in sample Period 1 cited marine life as providing the highlight of their trip and 52.4% of divers and snorkelers interviewed in Period 2 said that marine life had given them the most enjoyment. Tourists were discerning of relative abundance of small (<25cm) and large fish (25+cm) and levels of underwater visibility and garbage but not skilled enough to differentiate marine life abundance between the different sites. Negative experiences in St. Lucia related to equipment problems or personal difficulties (33%), poor underwater visibility (14%) and seeing damaged coral (14%). Remaining factors included poor weather or water conditions and seeing other divers damaging the reef. Similarly negative factors most cited in Period 2 were dead or damaged coral (15.4%), garbage (13.3%), boat traffic noise and pollution (11.2%). Remaining factors, each representing less than 9% of answers, included a lack of fish and diversity of fish, poor underwater visibility and

crowding. In general, tourists wanted more information on the marine life of the area (51.9%), better infrastructure (30.4%), better service (15.2%) and removal of garbage (2.5%). These results highlight the importance of reef quality to tourists, and the need for monitoring and regulating the use of reef resources for the benefit and long-term sustainability of reef-dependent industries.

5.2 INTRODUCTION

Environmental quality is important for tourism. Relationships between the two are complex but certain levels of quality are necessary for tourism to thrive (Ayala, 1996; Gregory, 1999; Bhat, 2003; CAST, 2003). The degradation of marine ecosystems can result in economic loss that in turn could cause the eventual collapse of those industries dependent on marine resources. Coral reef tourism obviously relies on reefs and the life that they support. Various reef attributes can directly enhance or detract from visitors' enjoyment. It is in the interest of countries and businesses that generate economic gains from reef tourism to manage and monitor activities and development, at sea and on land, that may negatively impact upon reefs.

Reef attributes and conditions play an important role in visitor perception in the Caribbean (Williams & Polunin, 2000), South East Asia (Musa, 2002) and Australia (Vanclay, 1988; Inglis et al., 1999; Kim & Lee, 2000). Sediment pollution is a problem detrimental to both the environment and tourist activities. It reduces fish abundance and diversity (Richardson & Jowett, 2001). It reduces the light available for corals to use for photosynthesis and coral must expend energy to remove it (Rogers, 1990), energy which could otherwise be used for growth and reproduction and other functions. Sediment thus decreases the growth, abundance and species diversity of corals (Acevedo & Morelock, 1988) and in some instances, sediment kills corals (Sladek Nowlis et al., 1997; Nemeth, 2001). Reduced light also means poor visibility and good visibility is among the most important underwater attributes for tourists (Tabata, 1992). Most often, logging, agriculture, dredging, construction and other human activities that expose soils are the cause of excessive sediment in waterways and eventually the marine environment (reviewed in Marsh, 1992). In Bacuit Bay, Philippines, logging was predicted to cause sediment pollution that would severely limit the viability of the local fisheries and dive tourism businesses (Hodgson & Dixon, 2000). Over 10 years, the predicted gross revenues from logging were US$8.6 million, compared to US$6.2 million from fishing and US$13.9 million from tourism, industries incompatible with logging. By 1996, after a ban on logging, a survey of the area showed that corals and much of the forest had recovered and that tourism had flourished. However, over-fishing decreased the size and number of the most highly valued fish.

Size, abundance and diversity of fish are other attributes that divers particularly appreciate (Williams & Polunin, 2000) and divers that have seen higher quality coral receive greater satisfaction than those who have seen poorer examples (Vanclay, 1988). Estimates of economic losses at diving destinations due to the 1997-98 mass bleaching event range from US$2-19 million in regions of the Indian Ocean (Westmacott et al., 2000) and US$1.5 million in El Nido, the Philippines (Cesar, 2000).

Tourists are also concerned about crowding, over-development, noise and litter (Musa, 2002). For some, experiencing nature in a natural, unstructured way, is the most important motivational factor for their trip (Kim & Lee, 2000). Experience seems to influence whether visitors find crowding an issue (Inglis, 1999) with more experienced divers for example preferring fewer people and less infrastructure. Investigations on diver preferences for various environmental attributes began in the late seventies (see Tabata, 1989) but none have compared perceived attributes with objective measures of them on reefs. Here, I use quantitative data on fish and corals, underwater visibility, sediment load and garbage and compare them with tourists' perceptions of them. Revealing the relationship between tourist perceptions and actual measurements of those attributes will help managers understand the motivations and sensitivities of tourists. It may also shed light on the importance of visitor education and the relevance of monitoring and managing reef resources for their many benefits.

5.3 METHODS

Over two sampling periods, the first from December 2000 to mid March 2001 and the second from July to October 2001, I embedded questions pertaining to tourists' perceptions of St. Lucia's reefs within three questionnaires that I used to interview divers and snorkelers (Chapters 2, 3 and 4). I used a mixture of open-ended and closed questions. For closed questions I used Likert Scales and each scale had an option of 'no opinion/don't know'. Less than 2% of questionnaires were incomplete or refused. In Period 1 I interviewed 214 divers using Questionnaire 1 (Appendix A), beginning by asking visitors to state the highlight and low-point of their dive. I asked them to rate 'numbers of fish', 'small fish', 'big fish', 'different types of fish', 'amount of living coral' and 'underwater visibility' (*1= very poor* to *5= very good*). I then asked how their ratings of those factors compared to their expectations (*1= a lot less than expected* to *5= a lot more than expected*). I asked visitors whether they had noticed damaged coral, and if so, what kind as well as how much sediment and litter they saw (*1=none* to *4= a lot*), then whether that damaged coral, sediment, litter and number of divers in their dive group had affected their enjoyment of the dive (*1= decreased enjoyment a lot* to *5= increased enjoyment a lot*). Visitors stated their overall satisfaction with their dive (*1= very dissatisfied* to *4= very satisfied*) and I used this as the dependent variable in a multiple regression to test whether measured factors, including underwater visibility, number of divers in group, weather, current, fish abundance, fish diversity and hard coral cover had any significant influence on divers' satisfaction. I also used an open-ended question to ask them whether anything particular to the marine environment would have improved their dive experience.

I completed questionnaire 2 (Appendix B) during Period 1 with 206 of the same divers that I had observed (Chapter 2) and with whom I had completed questionnaire 1 (Appendix A), and randomly approached another 245 visitors at Anse Chastanet resort. I began by asking what their main reason for visiting St. Lucia was and to rate their three main motivations for diving or snorkeling on the island (*1=most important* to *3= least important*) from a list of options. Those included: 'to view marine life in its natural environment', 'for the enjoyment of diving or snorkeling itself', 'to be with friends or relatives', 'for the adventure / fun', 'for photography', 'for being active out-of-doors', and 'other'. Visitors then rated the importance of 'lots of fish', 'big fish', 'different types of fish', 'lots of living coral', 'different types of coral', 'particular species' and if so, what kind, 'clear water' and 'trash free sites' to their dive or snorkel (*1= not important at all* to *5= very important*). I asked snorkelers how many people were in their immediate vicinity during their time in the water, whether this was too many or about right, and asked divers and snorkelers about their overall satisfaction with their diving or snorkeling in St. Lucia (*1=very dissatisfied* to *5= very satisfied*). Then using open-ended questions, I asked them to state what they had enjoyed most and least about St. Lucia's marine environment and what would improve their experience. Lastly I asked whether they had visited any other coral reefs in the world and to state which, according to them, were the best and worst and why.

To compare diver and snorkeler perceptions of reef attributes, I completed Questionnaire 3 (Appendix C) with 150 divers and 180 snorkelers immediately after their dive or snorkel trip during Period 2. They were asked to rate 'fish life', 'coral life', 'underwater visibility' and 'overall satisfaction' for the site they had just visited (*1=very poor* to *5=very good*). I asked whether the marine park had influenced them to visit St. Lucia and how the experience of the park measured up to their expectation.

To compare visitor perceptions of fish and coral attributes with scientifically measured data on fish and coral I used fish counts and coral cover measurements collected by J.P. Hawkins and C.M. Roberts. They counted fish using an adaptation of the stationary point visual census technique (Bohnsack and Bannerot, 1986) at 5 and 10m depths. During 15-minute intervals, they estimated size (total length to nearest cm) and number of non-cryptic reef species (Table 5.1) within or passing through an imaginary 10m-diameter vertical cylinder 5 or 10m high depending on what depth they were at. The location of each cylinder for fish counts was separated by the next by at least 10m. Five to six counts were made at nine of the dived sites (Site nos.1, 3, 4, 6, 7, 8, 9, 11 and 12) and two of the snorkeled sites (Site nos. 13 and 14) (see Table 5.2 for complete list of sites). Within the same cylinders J.P. Hawkins and C.M. Roberts also measured percentage cover of hard corals and live substrate (this included hard and soft corals, fans, sponges, gorgonians, octocorals, zoanthids, tunicates, algae, anemones and hydroids). To compare visitors' perceptions of underwater visibility with measured data, I took daily secchi disc readings at sites where I was observing tourists (for method see Chapter 2). Sediment trap data collected by C.K. Schelten at five sites (Site nos. 6, 8, 9, 11 and 12) were used to compare visitors' perception of sediment pollution with measured data. Spearman's Rank Order Correlation coefficients were used because my data were non-normally distributed.

Dive and snorkel trips were distributed between fourteen sites (Table 5.2).

TABLE 5.1 FISH SPECIES IDENTIFIED DURING COUNTS

	Latin name	Common name
A.	*Abudefduf saxatilis*	Sergeant major
	Chromis multilineata	Brown chromis
	Chromis cyanea	Blue chromis
	Stegastes partitus	Bicolor damselfish
	Thalassoma bifasciatum	Bluehead wrasse
	Myripristis jacobus	Blackbar soldierfish
	Clepticus parrae	Creole wrasse
B.	*Lactophrys polygonia*	Honeycomb cowfish
	Gymnothorax miliaris	Goldentail moray
	Gymnothorax funebris	Green moray
	Gymnothorax moringa	Spotted moray
	Echidna catenata	Chain moray
	Enchelycore nigricans	Viper moray
	Myrichthys breviceps	Sharptail eel
	Myrichthys ocellatus	Goldspotted eel
	Synodus intermedius	Sand diver (lizardfish)
	Bothus ocellatus	Eyed flounder
	Bothus lunatus	Peacock flounder
	Equetus punctatus	Spotted drum
	Narcine brasiliensis	Lesser electric ray
	Diodon holacanthus	Balloonfish (puffer)
	Diodon hystrix	Porcupinefish
	Malacanthus plumieri	Sand tilefish
	Scorpaena plumieri	Spotted scorpionfish
	Rypticus saponaceus	Greater soapfish
	Sphoeroides spengleri	Bandtail puffer
	Aluterus scriptus	Scrawled filefish
	Gerres cinereus	Yellowfin mojarra
	Calamus calamus	Saucereye porgy
	Chaetodipterus faber	Atlantic spadefish
	Aulostomus maculatus	Trumpetfish
	Halichoeres radiatus	Puddingwife
	Balistes vetula	Queen triggerfish
	Bodianus rufus	Spanish hogfish
	Kyphosus sectatrix	Chub
	Pomacanthus paru	French angelfish
	Holocanthus ciliaris	Queen angelfish
	Cantherhines macrocerus	Whitespotted filefish

A= species identified in the 'small fish' (<25cm long) category, B= species identified in the 'big fish' (≥25cm long) category.

TABLE 5.2 SITES USED BY THE COMPANY FOR THEIR DIVE AND SNORKEL TRIPS

Site No.	Site Name	Site No.	Site Name
1	Anse la raye wall (D)	8	Pinnacles (D)
2	Lesleen M (D)	9	Superman's Flight (D)
3	Turtle reef (D)	10	Piton wall (D)
4	Anse Chastanet reef (D, S)	11	Jalousie (D, S)
5	Fairyland (D)	12	Coral Gardens (D, S)
6	Grand Caille (D, S)	13	Anse Cochon (S)
7	Trou Diable (D, S)	14	Jalousie-Hilton reserve (S)

D= sites used for dive trips, S= sites used for snorkel trips.

5.4 RESULTS

5.4.1 Questionnaire 1, Period 1

Highlights and low points

During Period 1, 153 out of 208 interviewed divers reported a highlight during their dive. 88% said that marine life was the highlight including coral, fish and other reef animals. Individual fish, such as angelfish, puffers, eels and rays made up 57% of divers' answers and corals 23%. Turtles accounted for 9% and good visibility, large barrel sponges, the shipwreck and various aspects of the dive and dive staff accounted collectively for 13%. This comes to over 100% because some divers reported more than one factor among their highlights.

93 of 208 divers reported a low point during their dive. The largest proportion (33%) of answers related to equipment or personal difficulties including ear and sinus problems, 14% were related to bad underwater visibility, another 14% to seeing damaged coral, and 10% to too strong a current or surge. 9% of divers noted trash; 3% noted other divers damaging the reef; and values of 2% or less were

noted each for excessive algae smothering corals and rocks, lack of colour and other factors.

Diver ratings for fish attributes

Divers rated total numbers of fish for eleven out of the twelve dive sites as good (median score of 4) (Fig. 5.1). Divers' perceptions of fish abundance did not differ substantially among sites despite that measured abundance varied from less than 500 to more than 2000 individual fish (Fig. 5.4 a & b).

In general, divers gave higher scores for small fish, with median scores ranging from 'good' (score of 4) to 'very good' (score of 5) (Fig. 5.3 a), than for big fish which received median scores that ranged from 1.5 to 3.5 (Fig. 5.3 b). No significant correlation was found between divers' perceived abundance scores for small or big fish and measured data (Fig. 5.4, b & c).

Divers' ratings for fish diversity were mostly 'good' (median of 4 for 10 sites) and between 'average' and 'good' for two sites, sites 1 and 10 (Anse la Raye Wall and Piton wall) (Fig. 5.2). Again, no correlation was found between divers' perceptions of fish diversity and measured diversity.

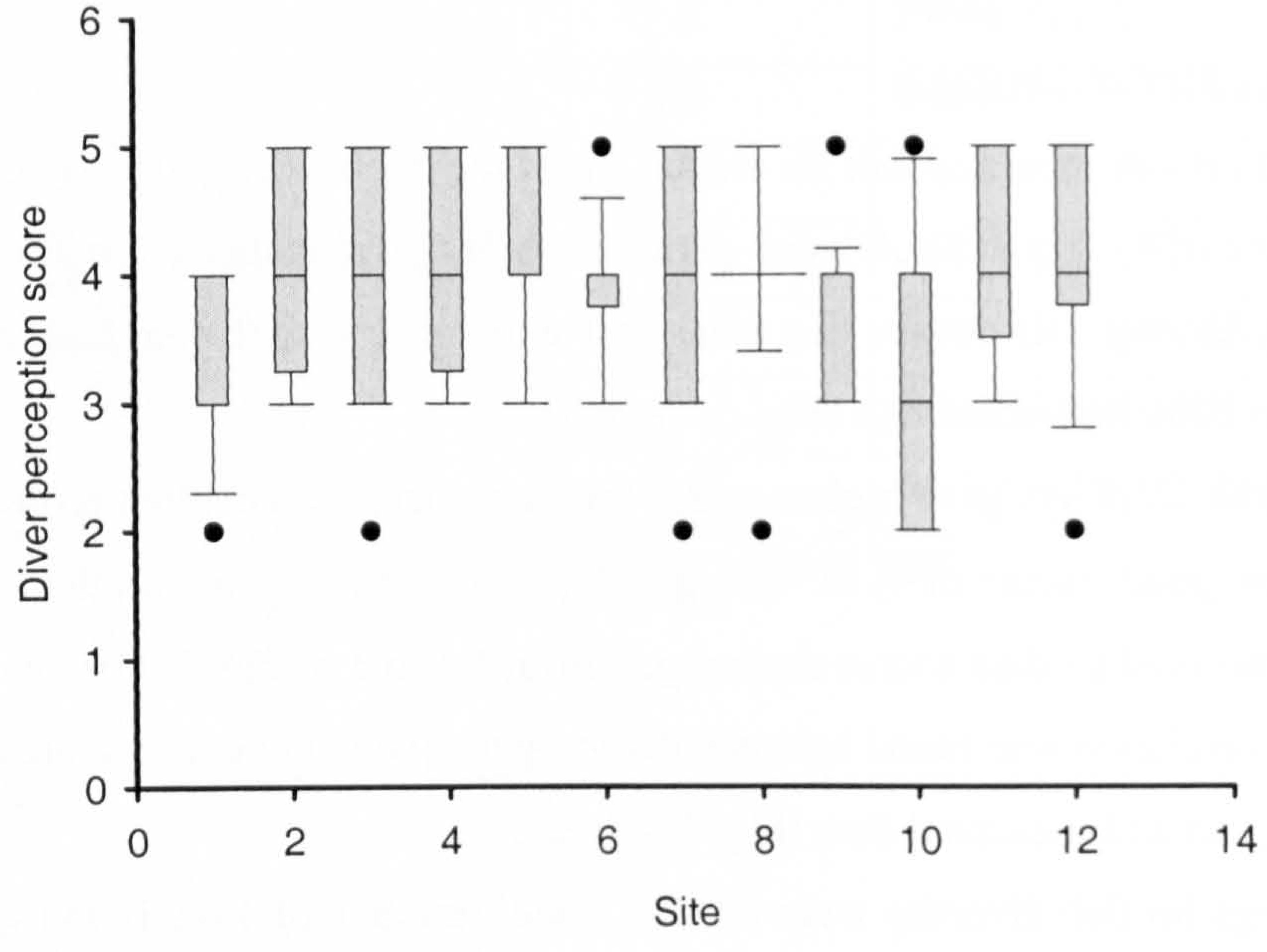


Fig. 5.1 Diver perception of fish abundance at dive sites. See legend to Figure 2.3 for explanation of box plot.

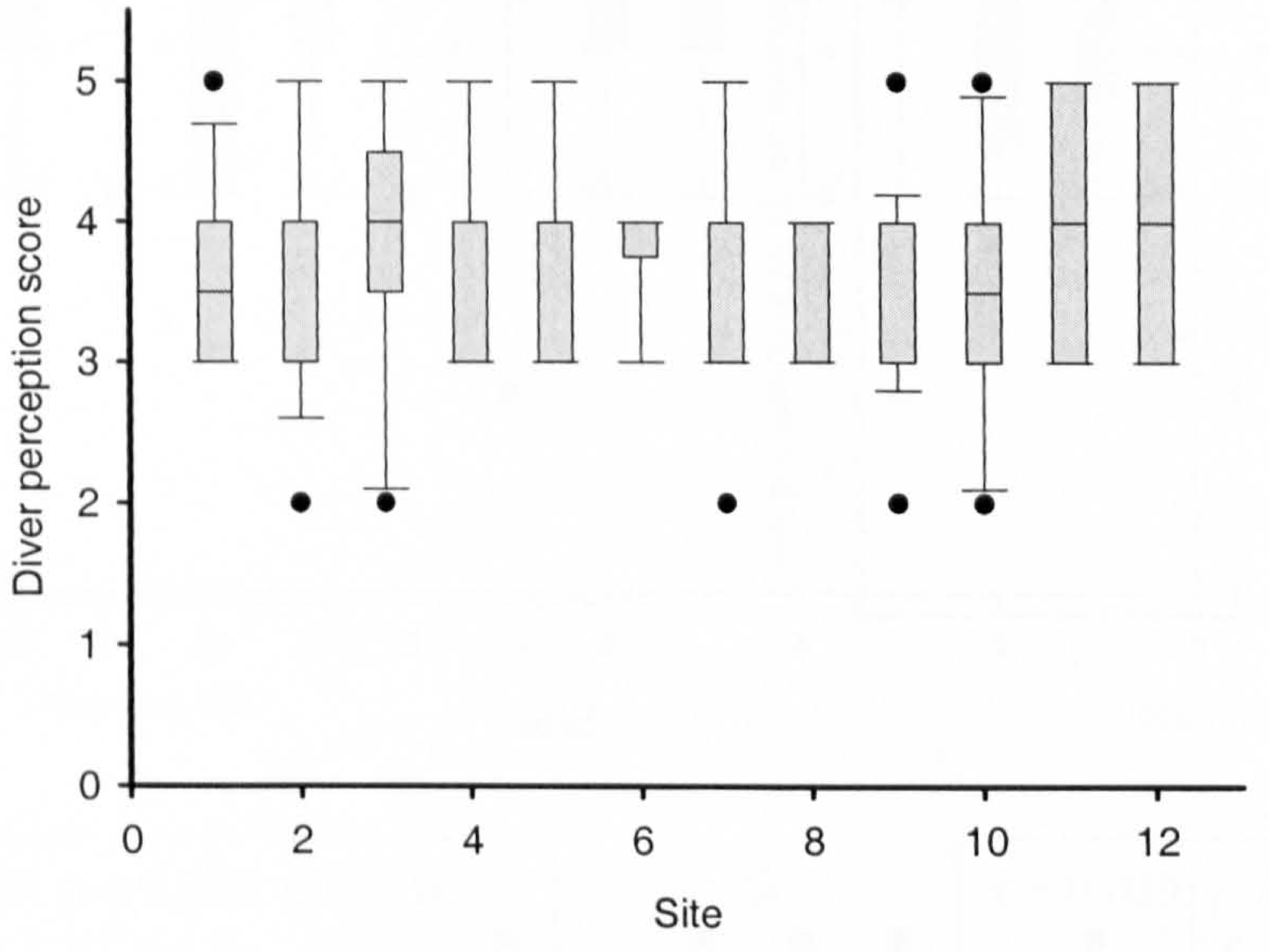
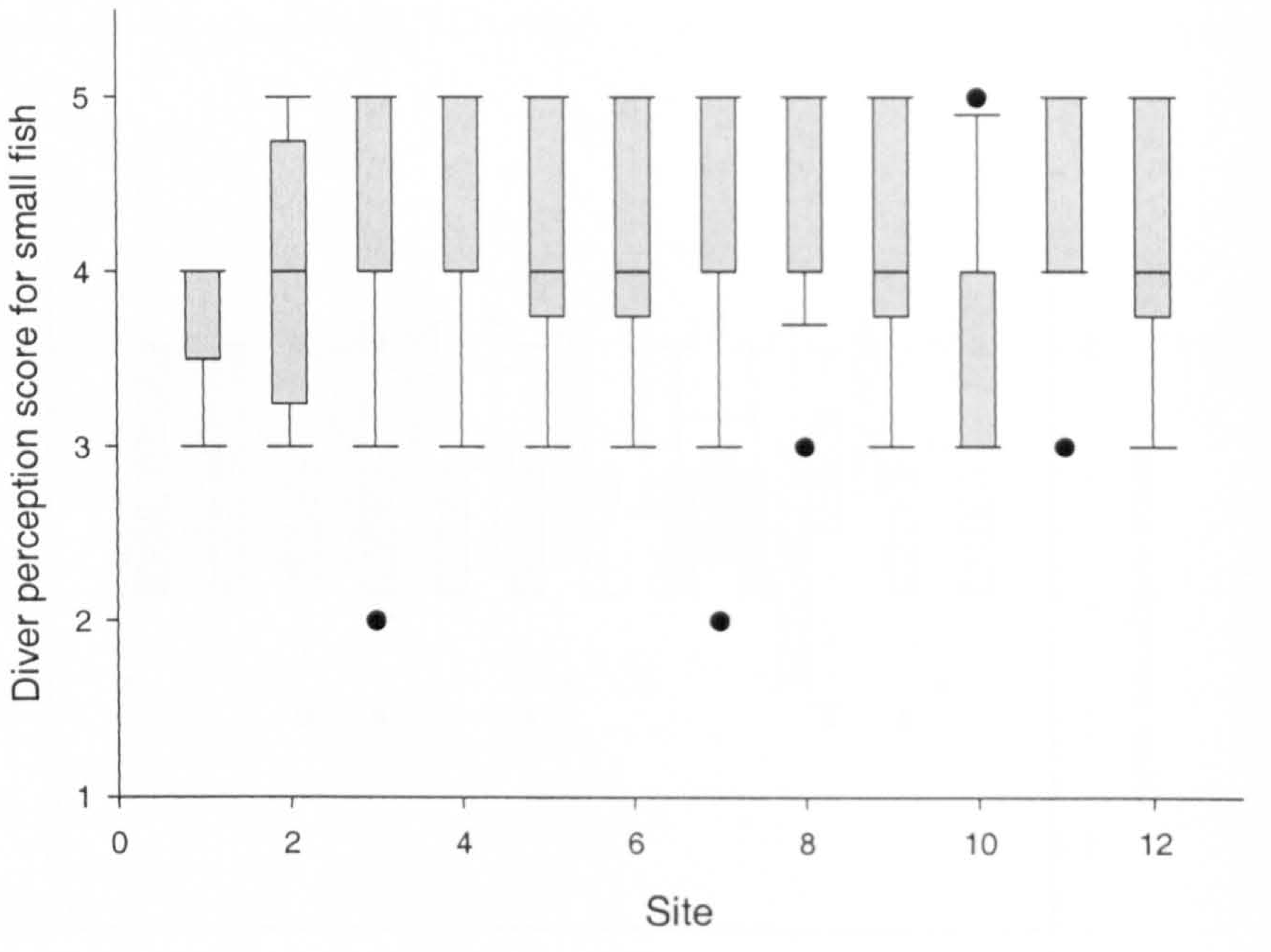


Fig. 5.2 Diver perception of fish diversity. See legend to Figure 2.3 for explanation of box plot.

a.



b.

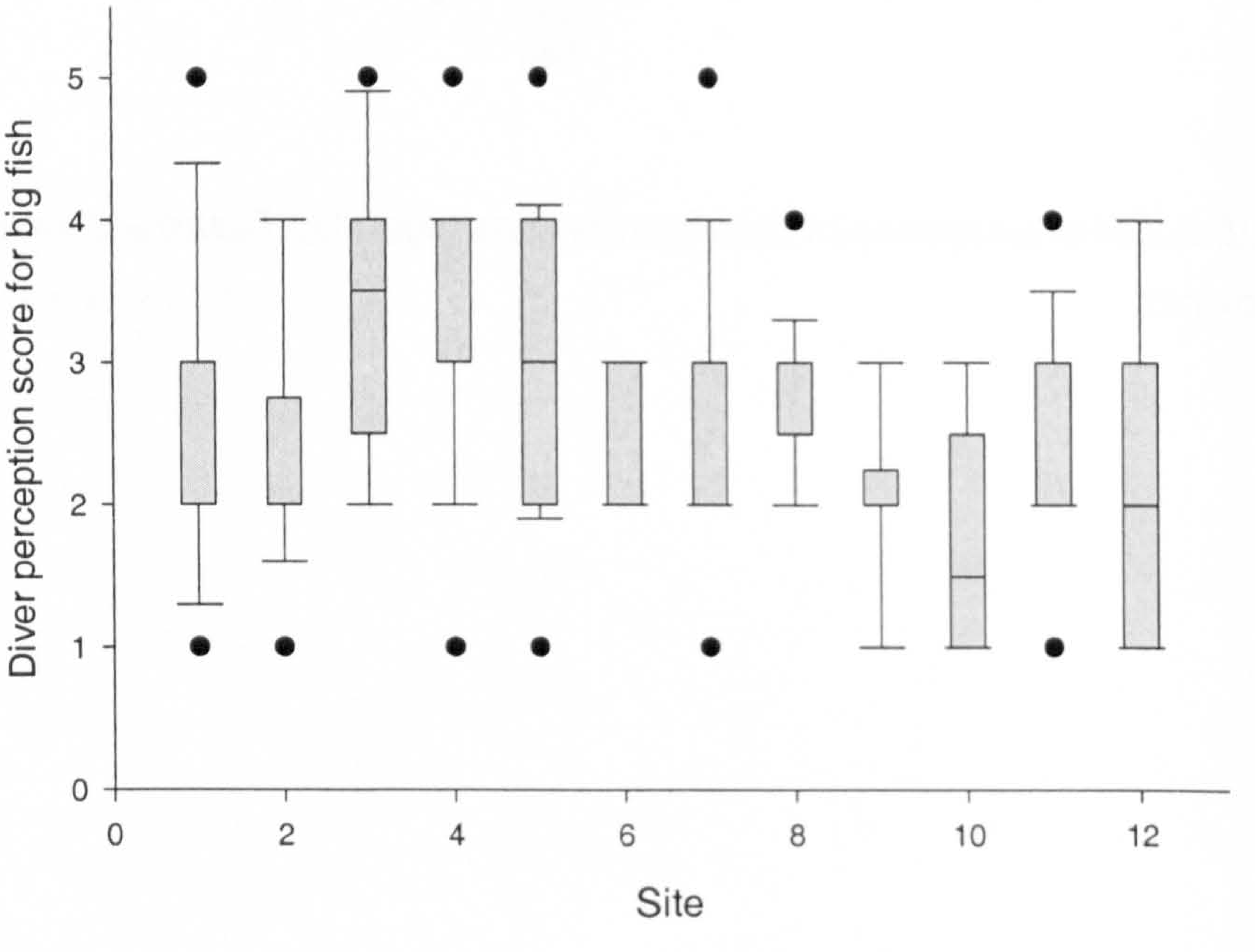


Fig. 5.3 Diver perceptions of small (< 25cm long) and big (≥ 25cm long) fish abundance. See legend to Figure 2.3 for explanation of box plot.

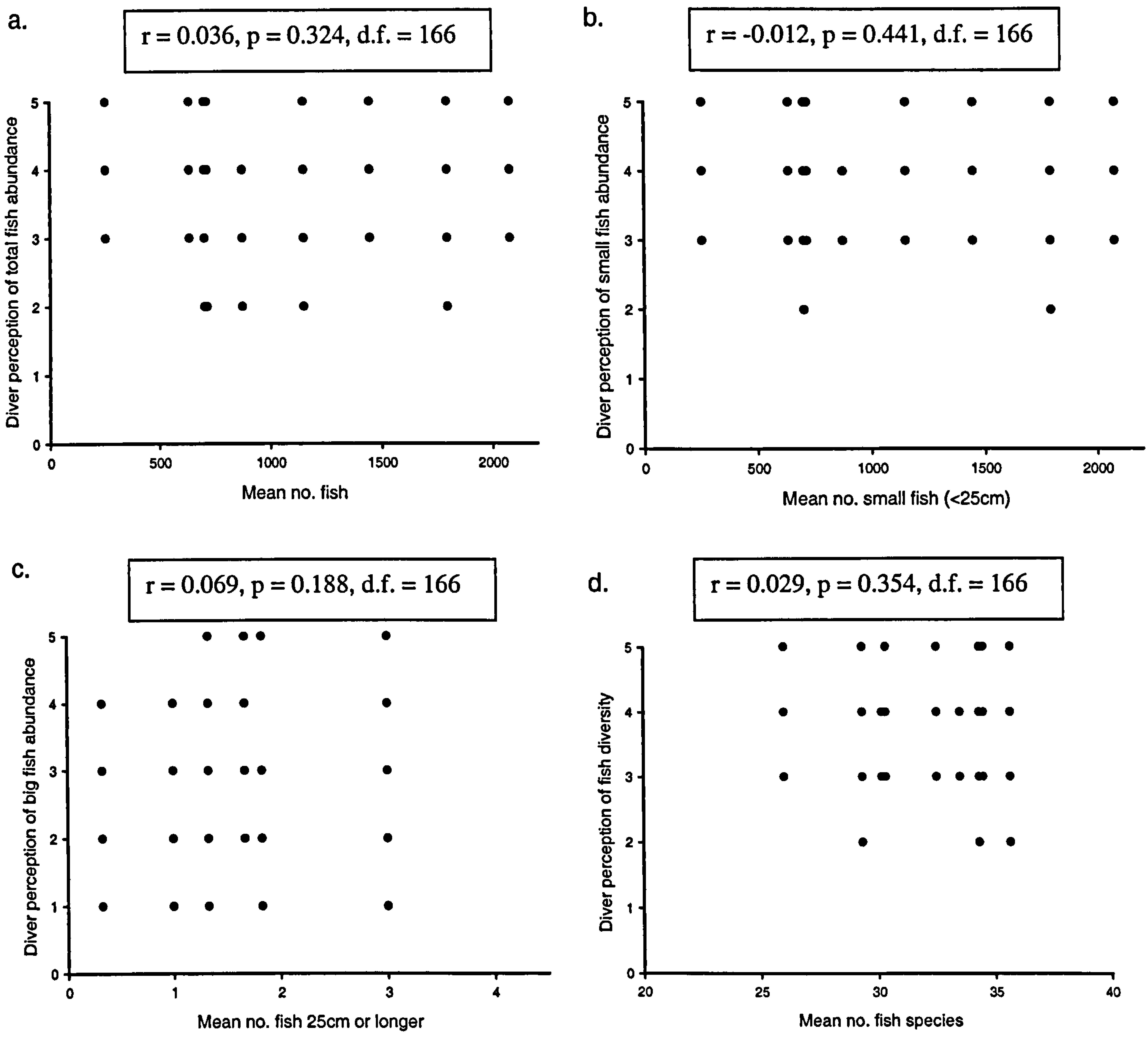


Fig. 5.4 Diver perceptions of fish attributes versus measured fish attributes. Spearman's rank order correlation tests results shown in boxes. n = d.f. + 1.

Coral attributes

Median scores from divers showed that they perceived amount of living coral at the sites to be between 'good' (score 4) and 'very good' (score 5), however some divers did express that at six of the sites, amount of living coral was 'poor' (score of 2) (Fig. 5.5). Divers perceived coral diversity at most sites to be 'average – good' to 'good-very good' (Fig. 5.6), but again, certain individuals noted that at four sites, coral diversity was poor.

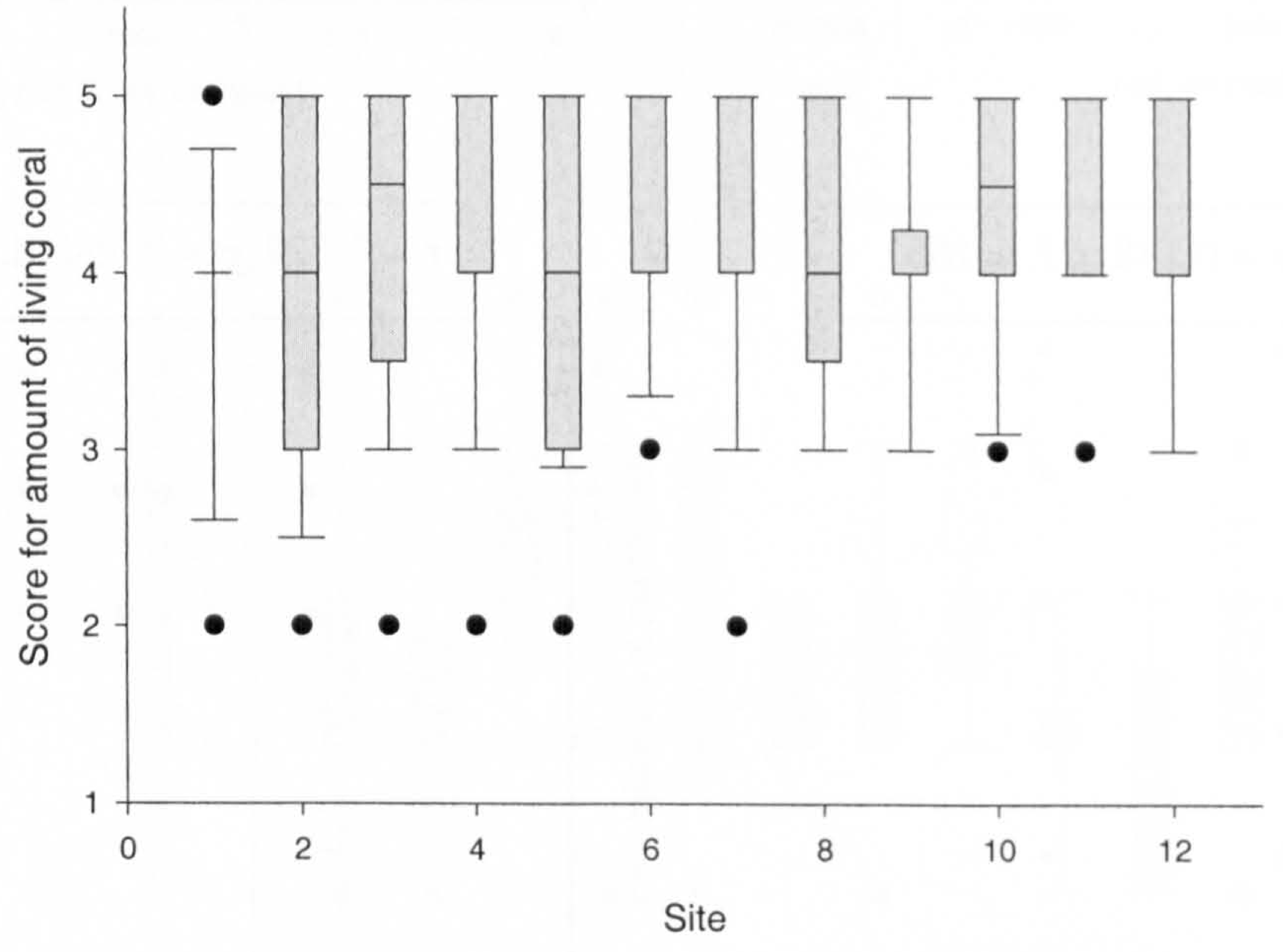


Fig. 5.5 Diver perception of amount of living coral. See legend to Figure 2.3 for explanation of box plot.

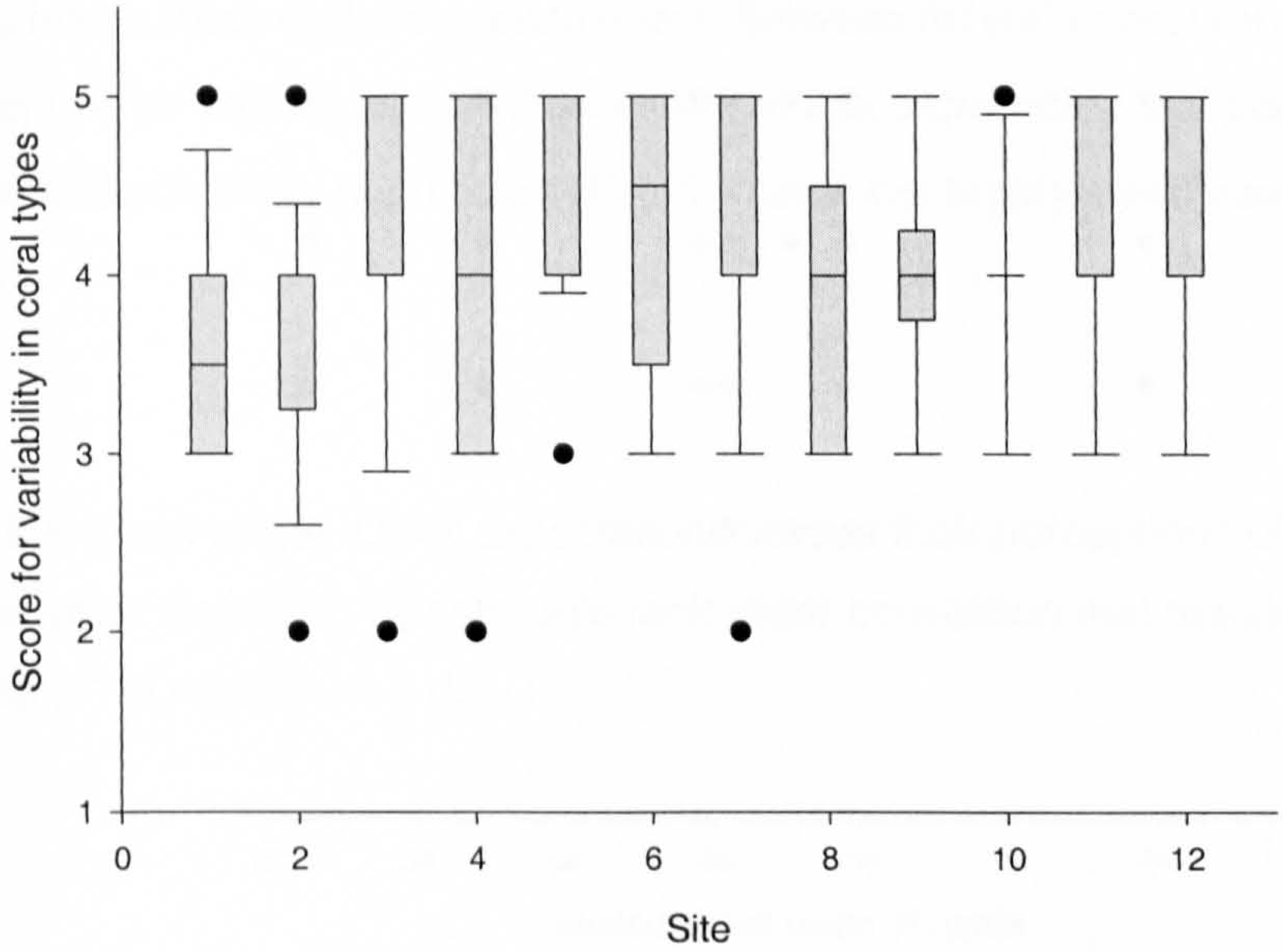
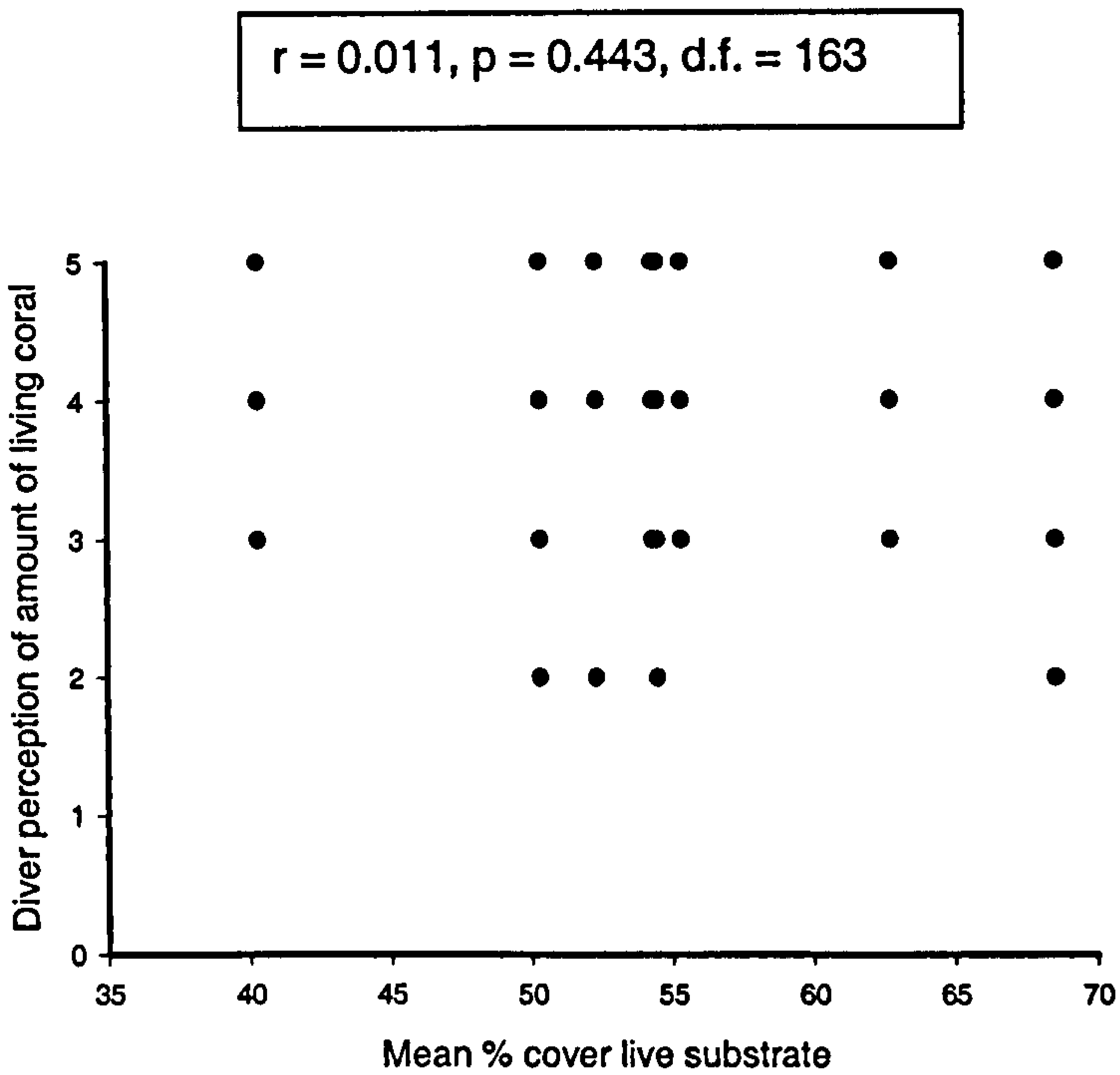


Fig. 5.6 Diver perception of coral diversity. See legend to Figure 2.3 for explanation of box plot.

When diver perception scores for living coral were correlated against measured percentage cover of live substrate (this included hard and soft corals, fans, sponges, gorgonians, octocorals, zoanthids, tunicates, algae, anemones and hydroids) and percentage cover of hard coral only, no trends were observed (Fig. 5.7).



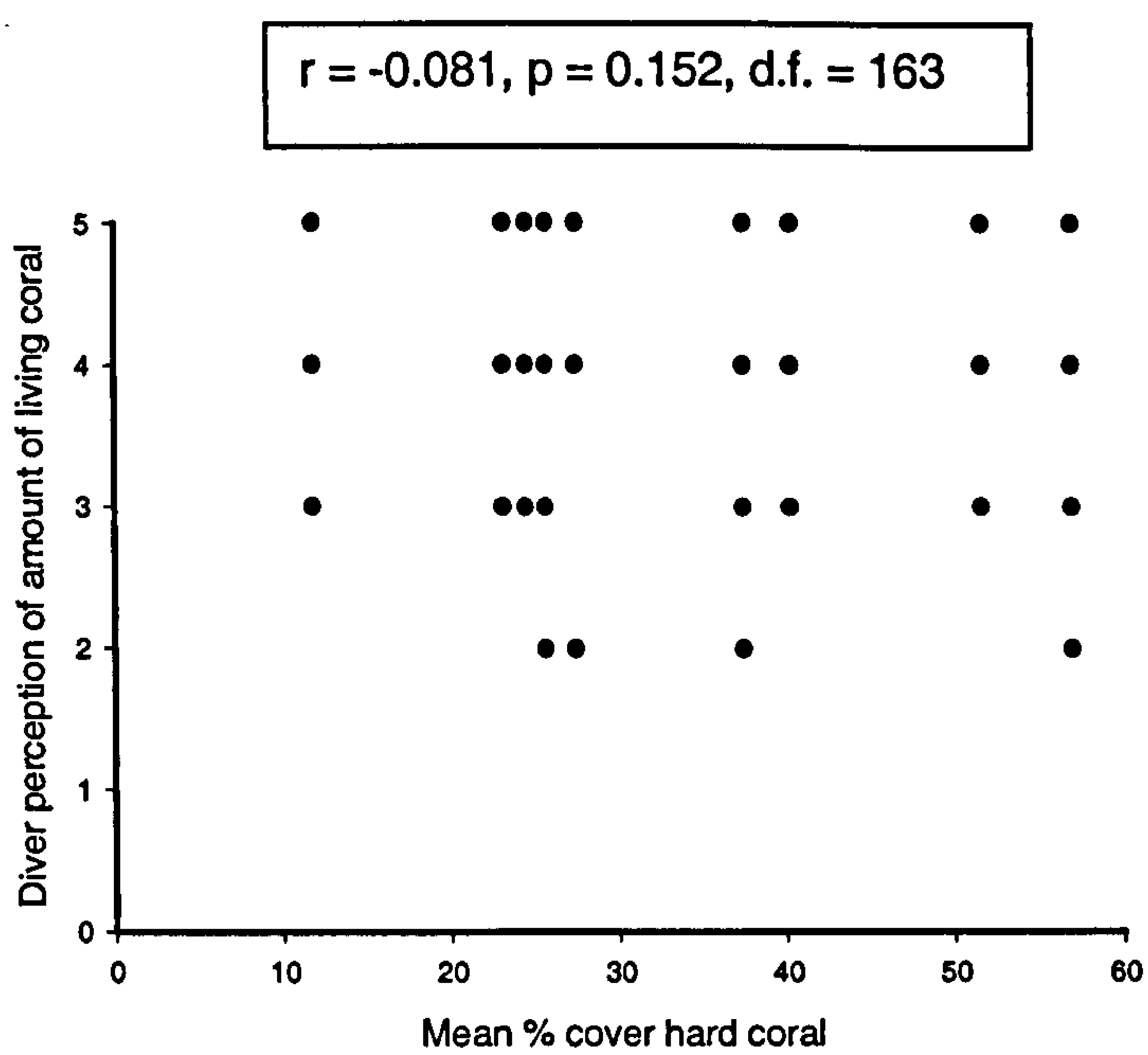
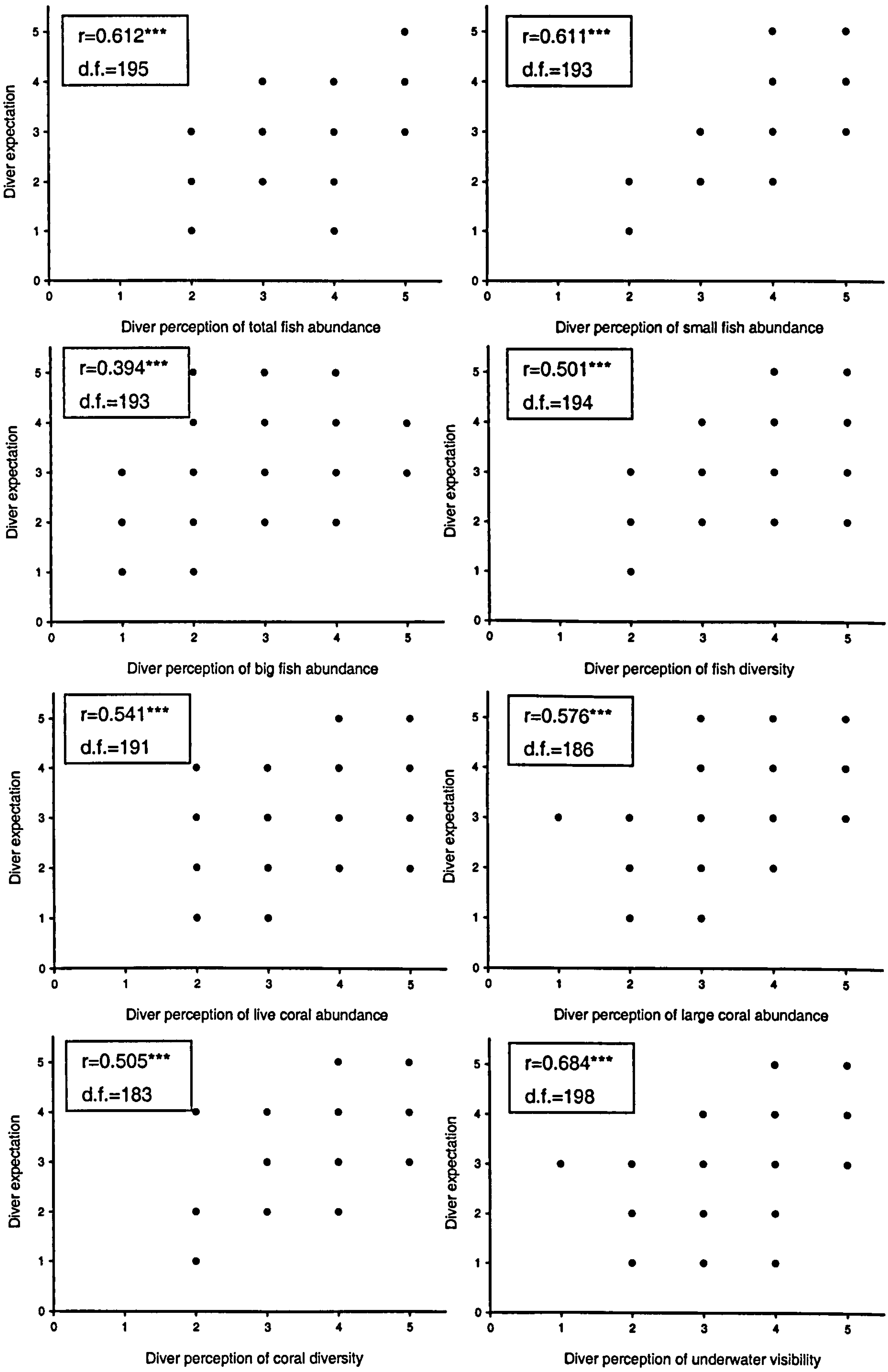


Fig. 5.7 Diver perceptions of living coral versus measured coral attributes. Spearman's rank order correlation tests are shown in boxes. n = d.f. +1.

Spearman's Rank Order correlation tests between divers' expectations and their perception of various reef attributes showed that expectation and perception correlated positively in all cases (Fig. 5.8) and was highly significant.

Fig. 5.8 (next page) Diver expectations versus their perceptions of fish, coral and underwater visibility. Spearman's rank order correlation test results are shown in boxes, *** $p < 0.001$. $n = d.f.+1$.



r=0.612***
d.f.=195
Diver expectation
Diver perception of total fish abundance
r=0.611***
d.f.=193
Diver perception of small fish abundance
r=0.394***
d.f.=193
Diver expectation
Diver perception of big fish abundance
r=0.501***
d.f.=194
Diver expectation
Diver perception of fish diversity
r=0.541***
d.f.=191
Diver expectation
Diver perception of live coral abundance
r=0.576***
d.f.=186
Diver expectation
Diver perception of large coral abundance
r=0.505***
d.f.=183
Diver expectation
Diver perception of coral diversity
r=0.684***
d.f.=198
Diver expectation
Diver perception of underwater visibility

Diver perception of reef damage, sediment & trash

134 out of 208 divers had an opinion on damaged coral. Of those, 63% noted that they had seen breakage and 45% said they saw marks on the coral including discoloration, white patches and 'dead-looking' areas. 3% reported seeing 'slime' or 'algae'. 1% said they saw sediment on the corals. 4% admitted that they did not know what coral damage looked like.

Using median scores, divers perceived one of the sites to have '*no damage*' (score of 1), seven to have '*a little*' damage (score of 2) and four to have '*some*' damage (Fig. 5.9).

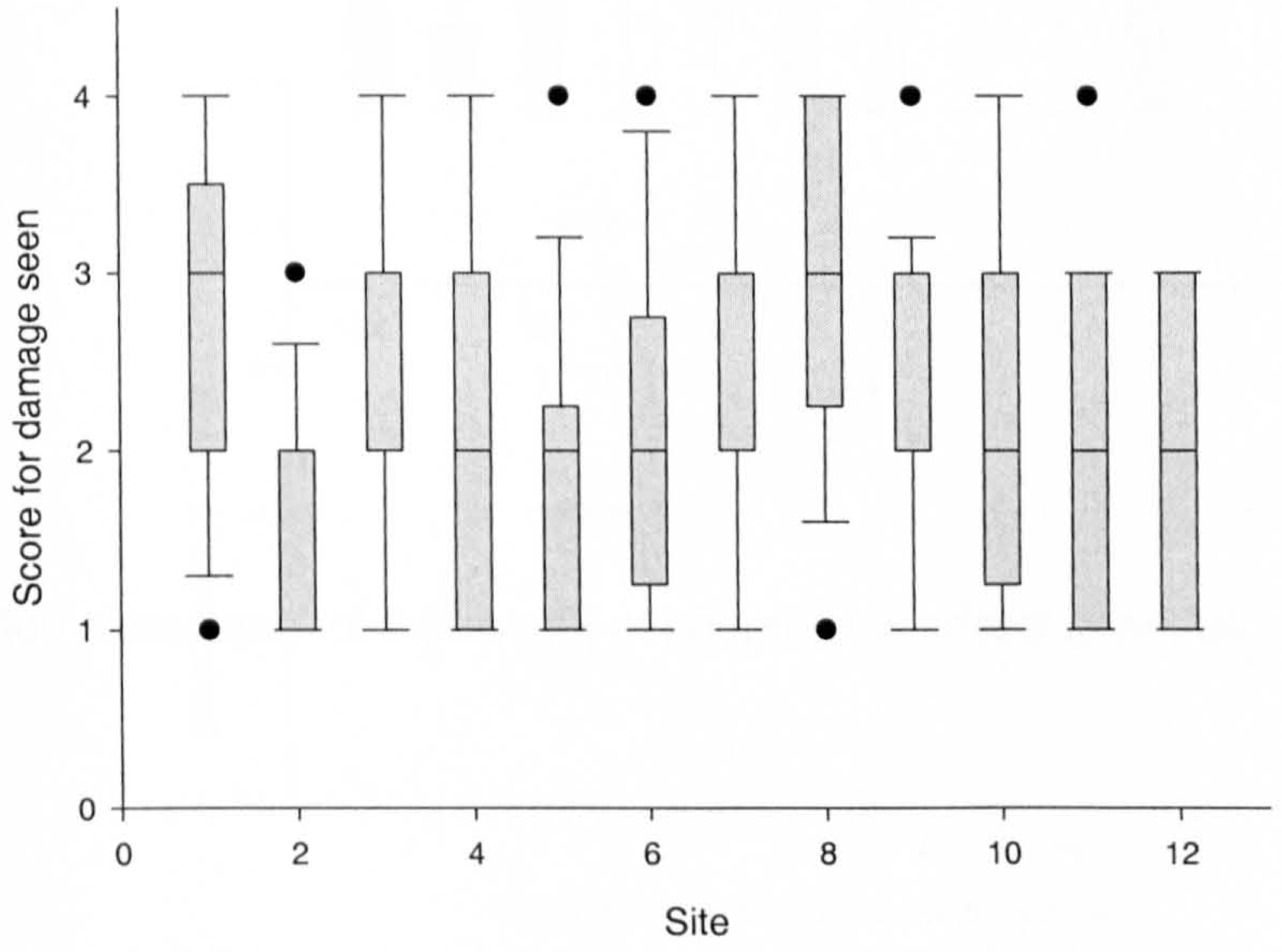


Fig. 5.9 Diver perceptions of damage seen on reef. Scores:1= none, 2= a little, 3= some, 4= a lot. See legend to Figure 2.3 for explanation of box plot.

Divers perceived the amount of sediment in general to be low, giving nine of the sites a median score of 1 for 'none' and three sites a median score of 2 for 'a little'. Trash was also perceived to be absent or 'a little' except at site 8, Pinnacles, which received a median score of 3 (Fig. 5.10). After interviewing divers, it became apparent that some were mistaking the common spaghetti worm *Eupolymnia crassicornis* for discarded fishing line.

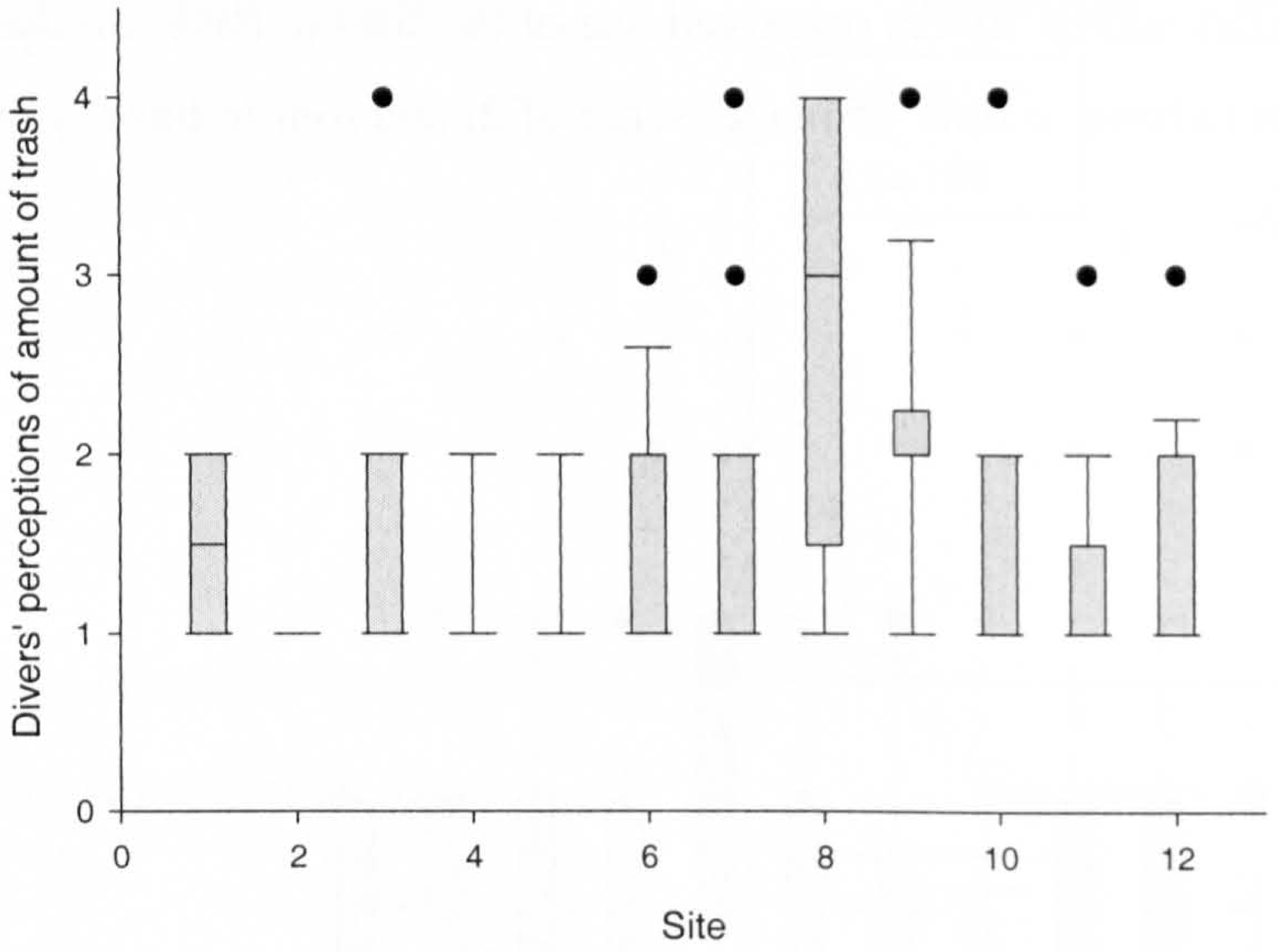
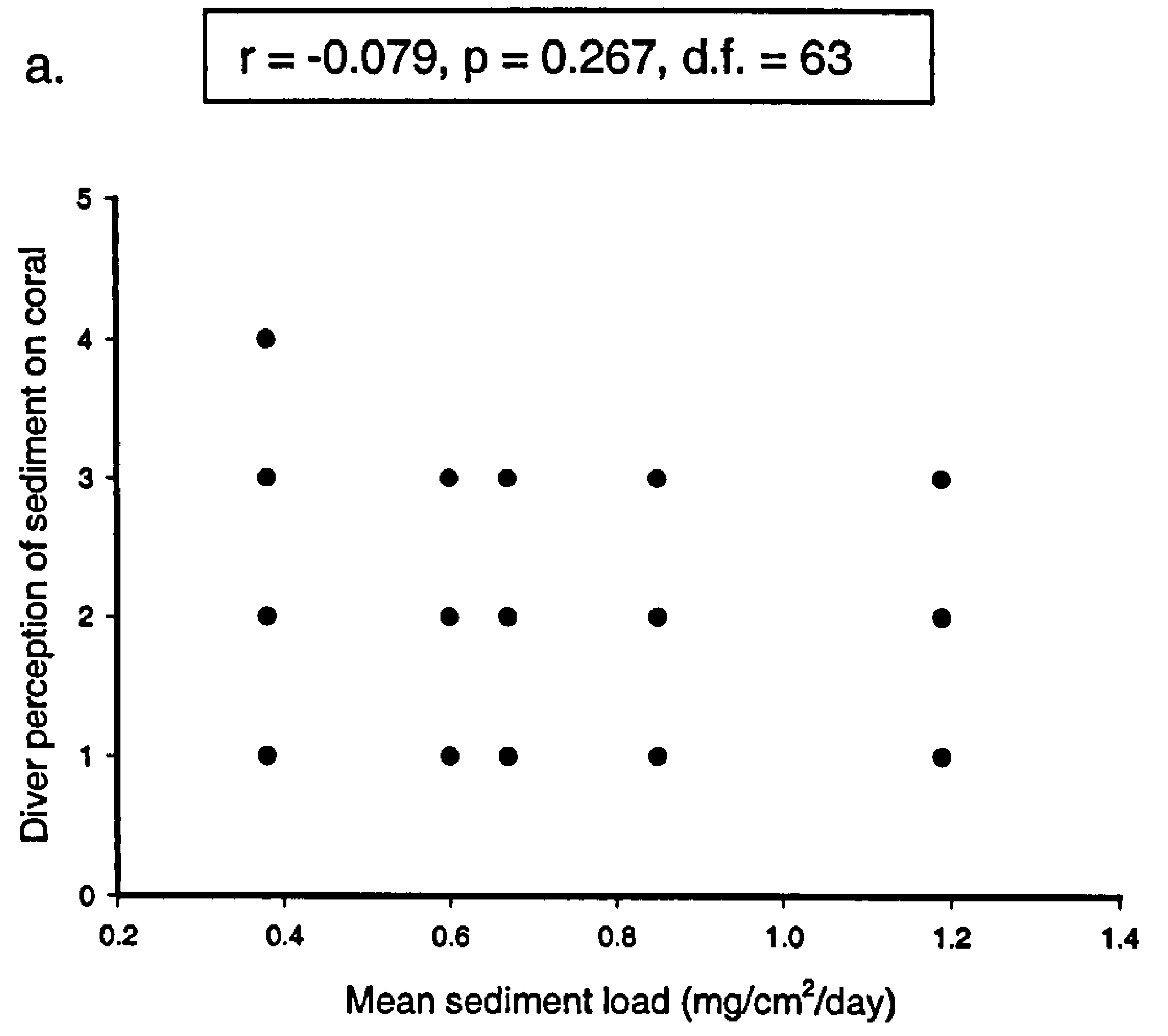


Fig. 5.10 Divers' perception of trash. See legend to Figure 2.3 for explanation of box plot.

Although divers' perception of sediment was not correlated to measured data (Fig. 5.11, a), their perception of trash was (Fig. 5.11, b).



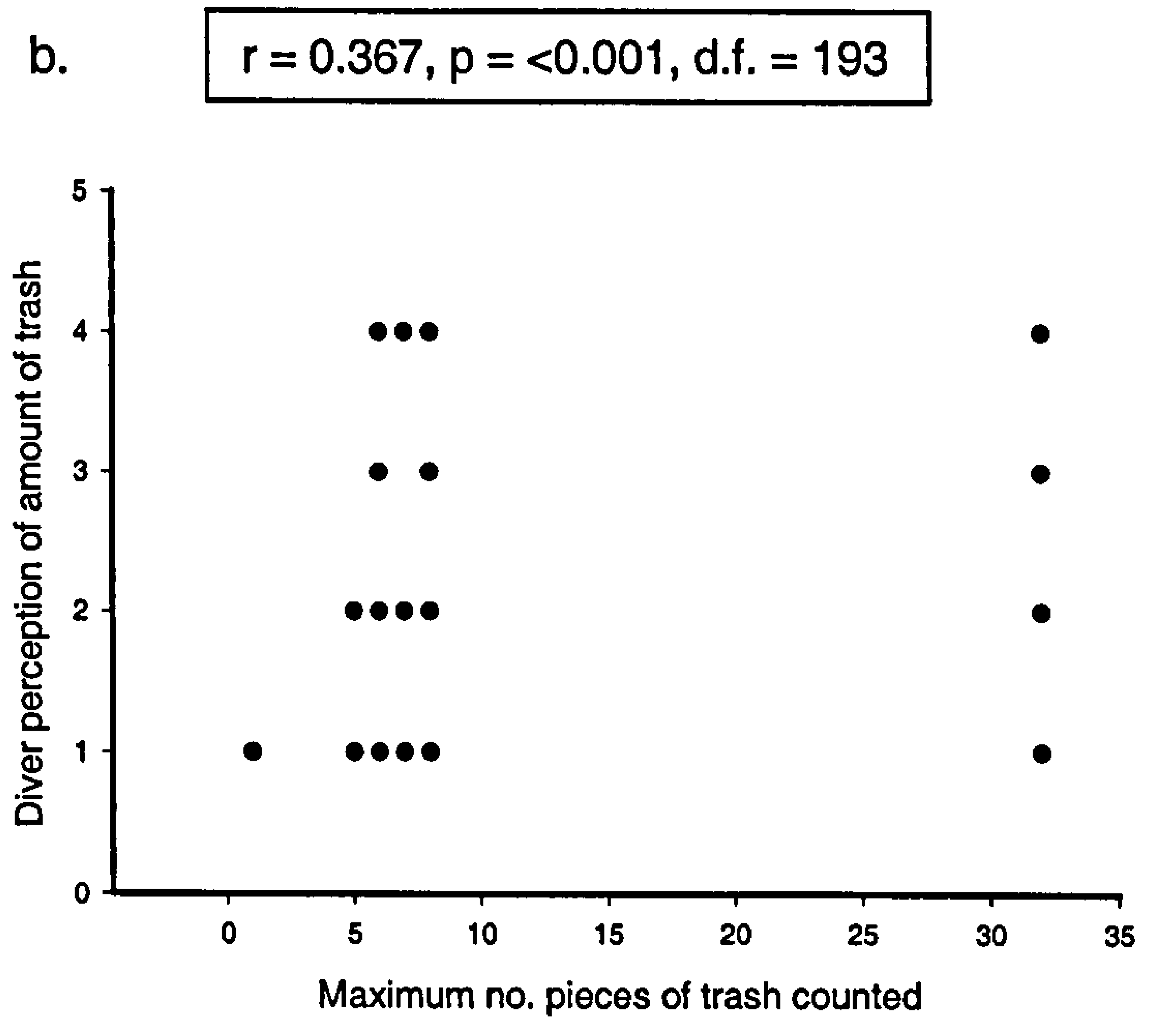


Fig. 5.11 Diver perception of sediment and trash versus measured sediment and trash. Spearman's rank order correlation test results are shown in the boxes. n = d.f. +1.

Effect of damaged coral, sediment, trash and size of dive group on divers' enjoyment

Divers' enjoyment was negatively correlated to their perception of damage when measured for coral damage, sediment and trash (Fig. 5.12).

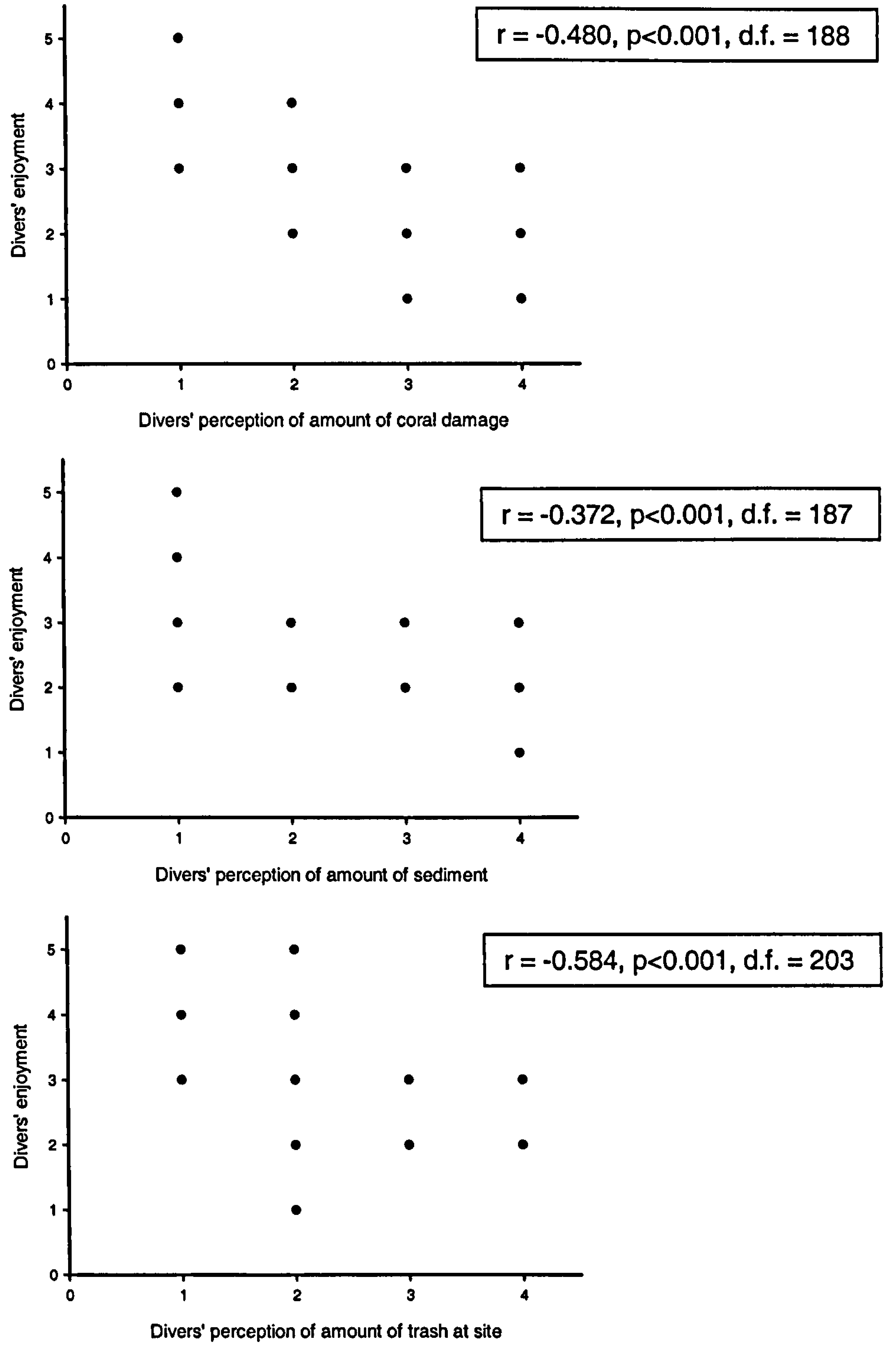


Fig. 5.12 Divers' enjoyment score versus their perception of coral damage, sediment and trash. Spearman's rank order correlation test results are shown in boxes, n=d.f.+1.

Divers' enjoyment was significantly negatively correlated with dive group size (Fig. 5.13, Spearman's rank correlation test, $r = -0.555$, $p<0.001$, d.f. = 207). For some divers however, groups of 6 still decreased their enjoyment a little and yet for others, a group of more than 15 divers made no difference to their enjoyment.

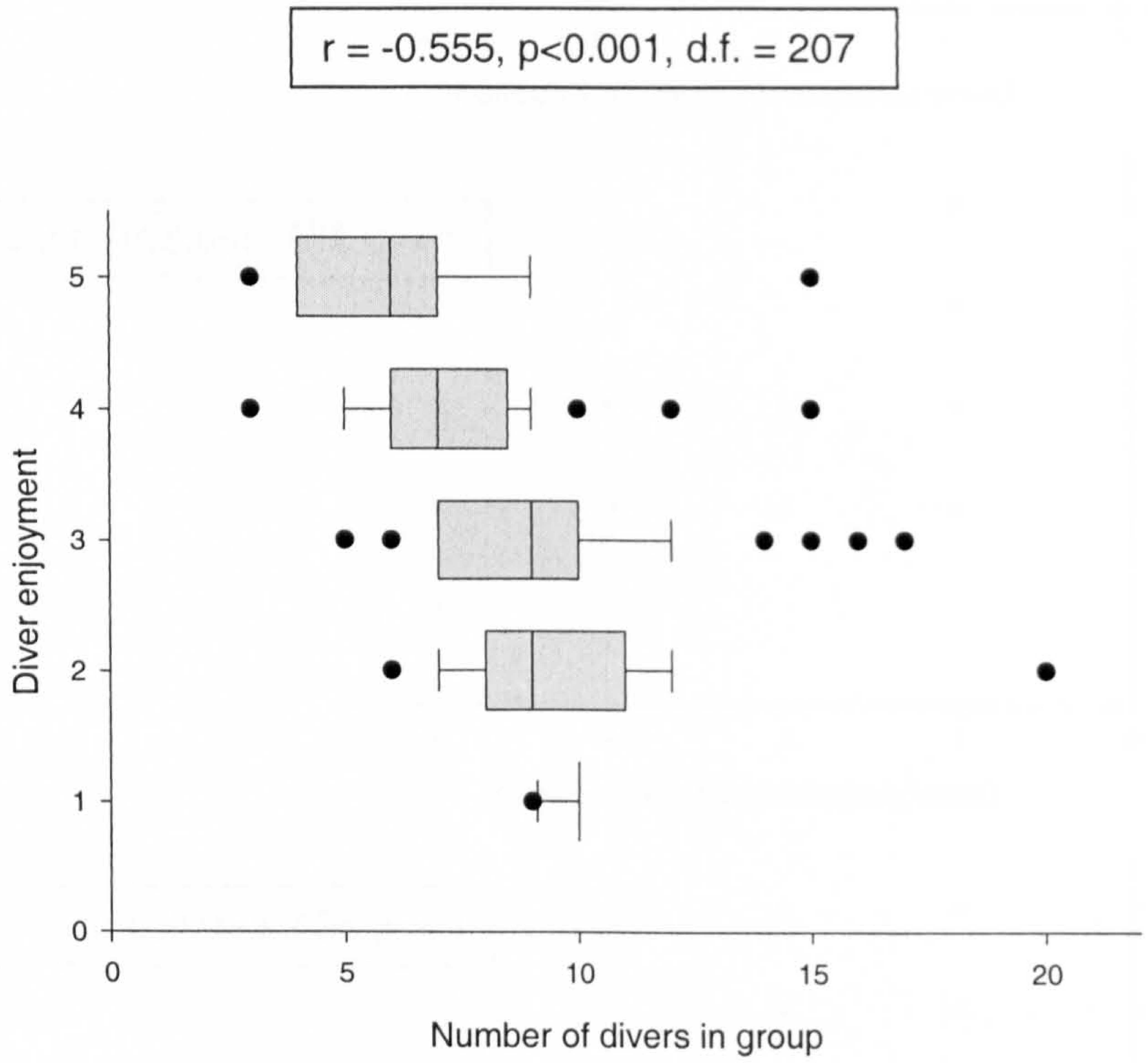


Fig. 5.13 Divers' enjoyment versus dive group size. See legend to Figure 2.3 for explanation of box plot.

Underwater visibility

Divers' scores for underwater visibility generally fell into the 'average' and 'good' categories with only sites 2, Lesleen M, the only wreck dive and 3, Turtle reef, receiving a substantial number of 'poor' scores (Fig. 5.14).

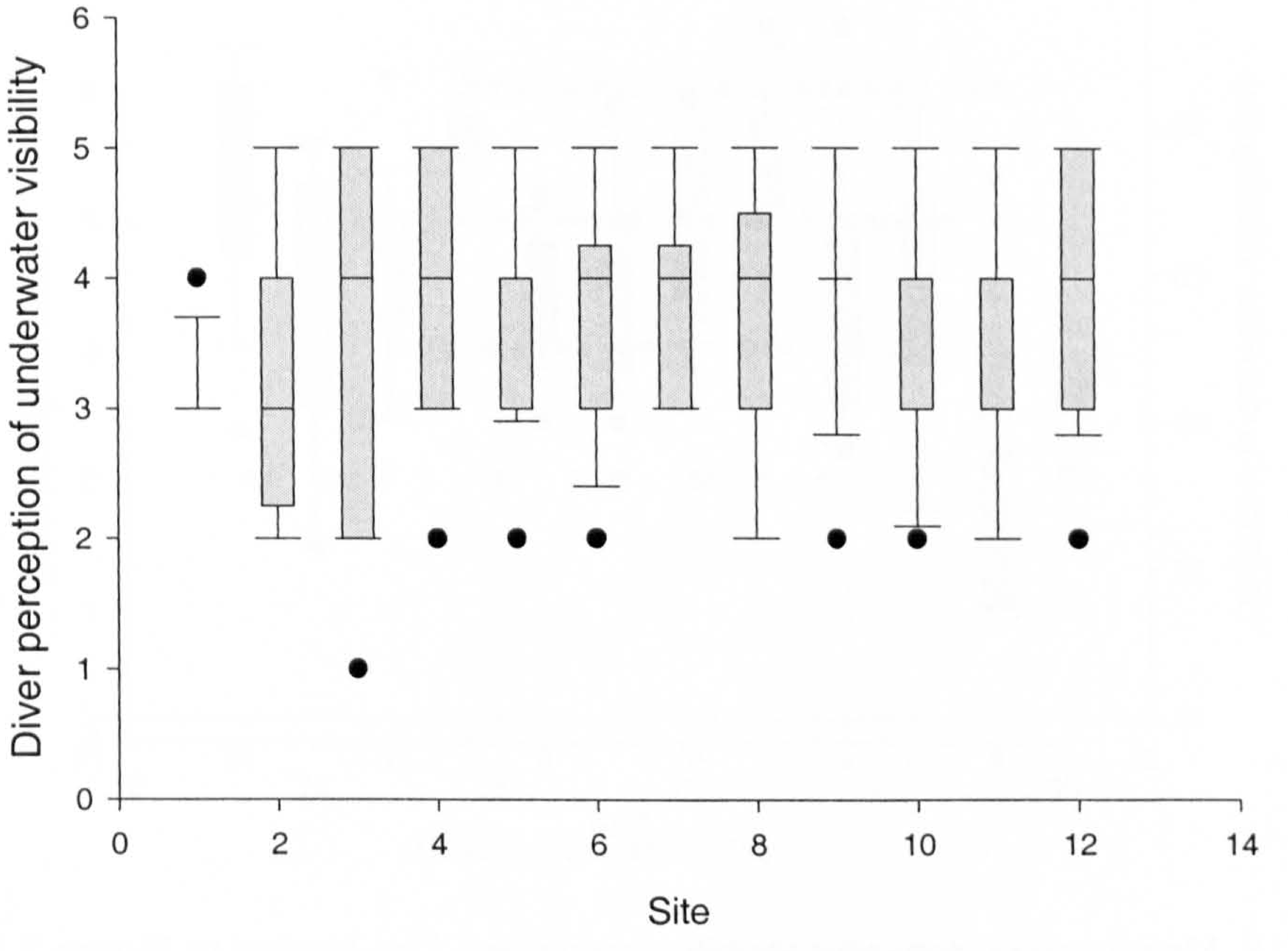


Fig. 5.14 Diver perception of underwater visibility. See legend to Figure 2.3 for explanation of box plot.

My underwater visibility readings at the dive sites ranged from 13.3 to 33.3m with some of the lowest values recorded at site 2, Lesleen M (Fig. 5.15). Sites 5, Fairyland and 9, Superman's flight, recorded some of the highest visibility readings (Fig. 5.15).

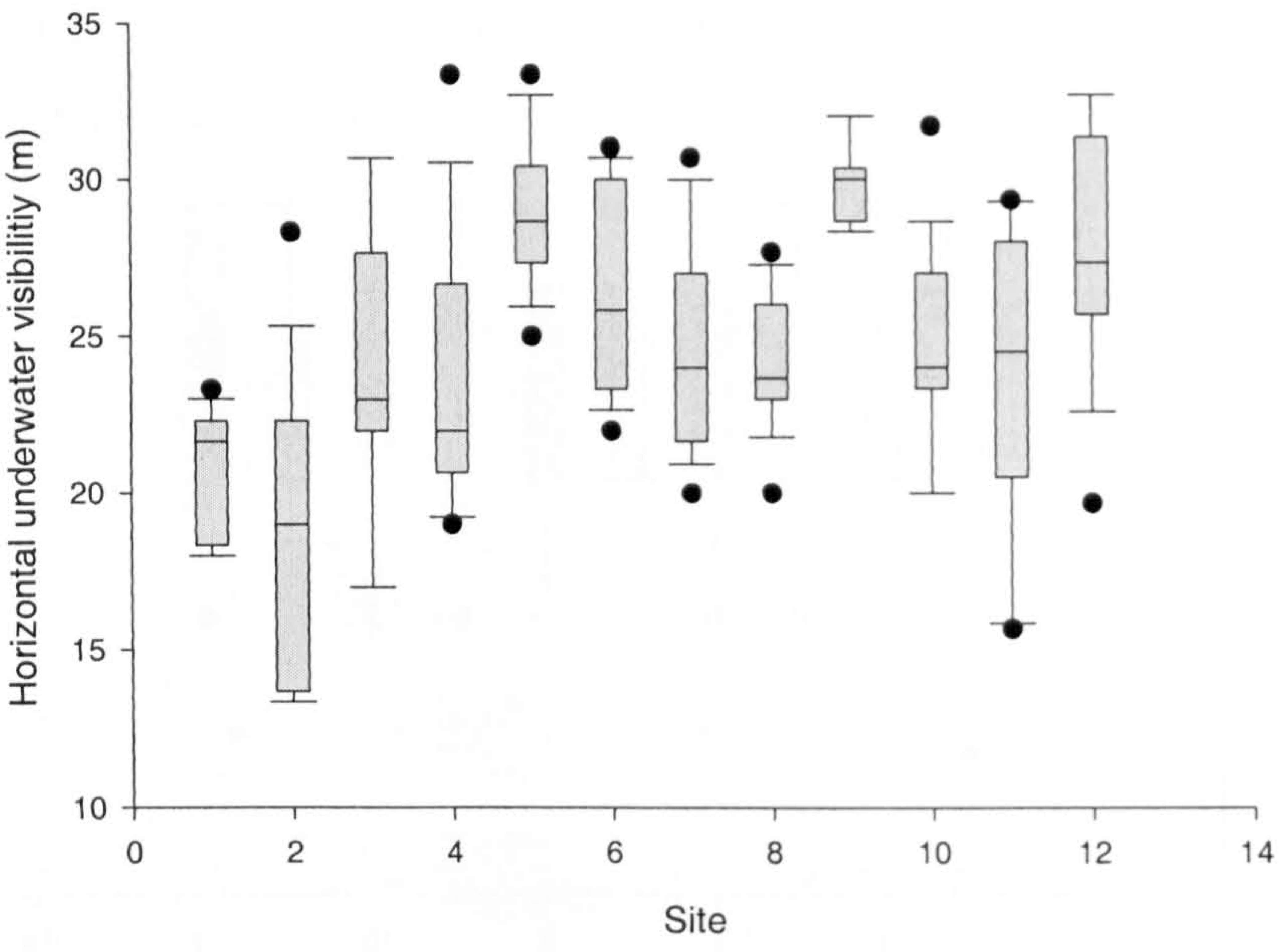


Fig. 5.15 Measured underwater visibility readings. See legend to Figure 2.3 for explanation of box plot.

When divers' perception scores were plotted against my visibility readings, a significant correlation resulted (Spearman's rank order correlation test, $r=0.292$, $p<0.001$, d.f. $=153$, Fig. 5.16).

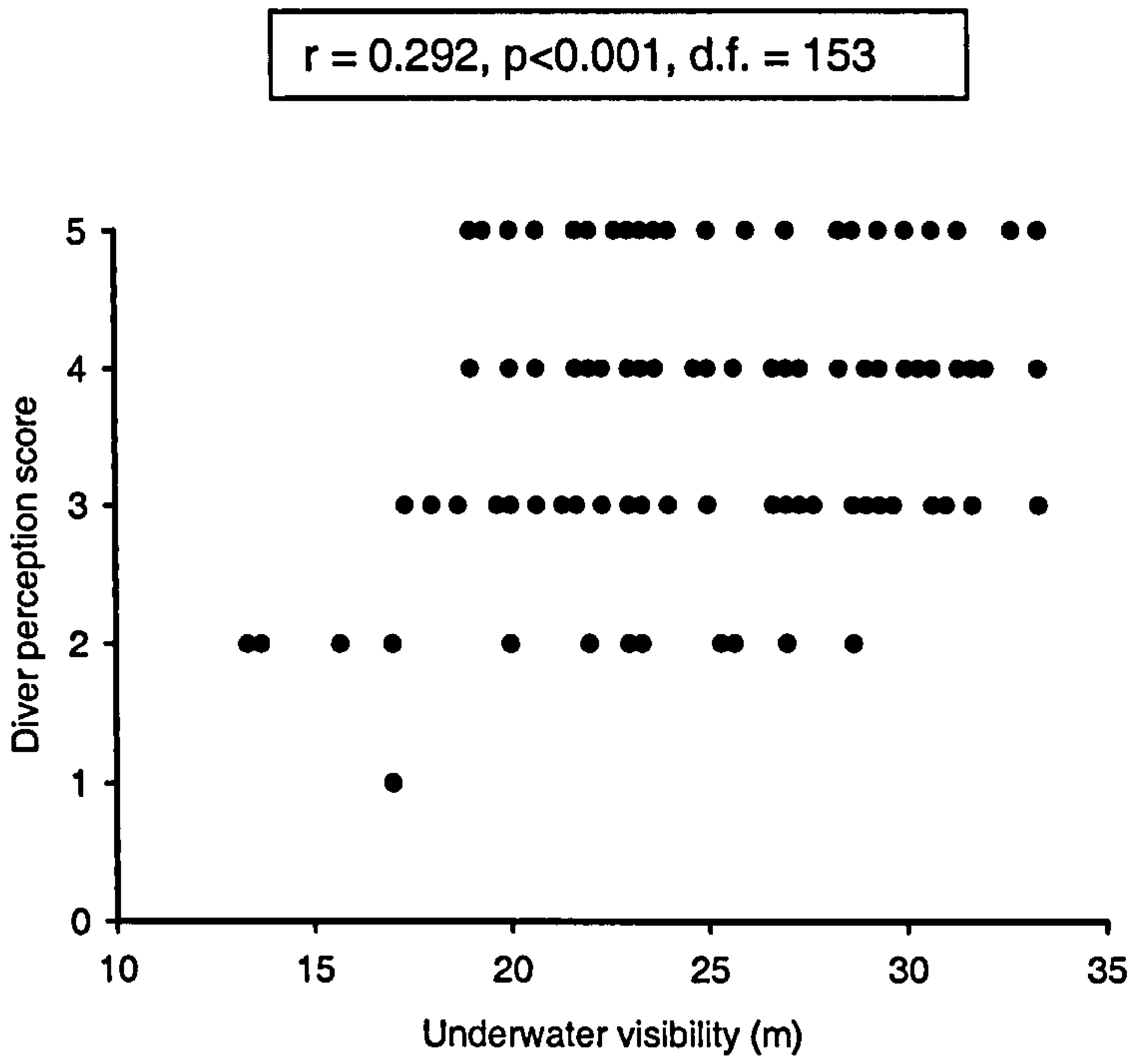


Fig. 5.16 Diver perception scores versus measured underwater visibility. Spearman's rank order correlation test results are shown in the box. n = d.f.+1.

Overall satisfaction

In general, divers appeared satisfied with their dive although some dissatisfaction (scores of 1 and 2) was reported by divers who had dived at Turtle Reef (site 3), Anse Chastanet (site 4) and Pinnacles (site 8) (Fig. 5.17).

The multiple regression using divers' overall satisfaction as the dependent variable was only weakly significant (r^2= 0.114, p=0.052, F=2.072) with two variables having significant, although minimal, influence on the dependent variable: number of divers in the group, B -0.067, p=0.017 and percentage cover of hard coral B 0.017, p=0.021.

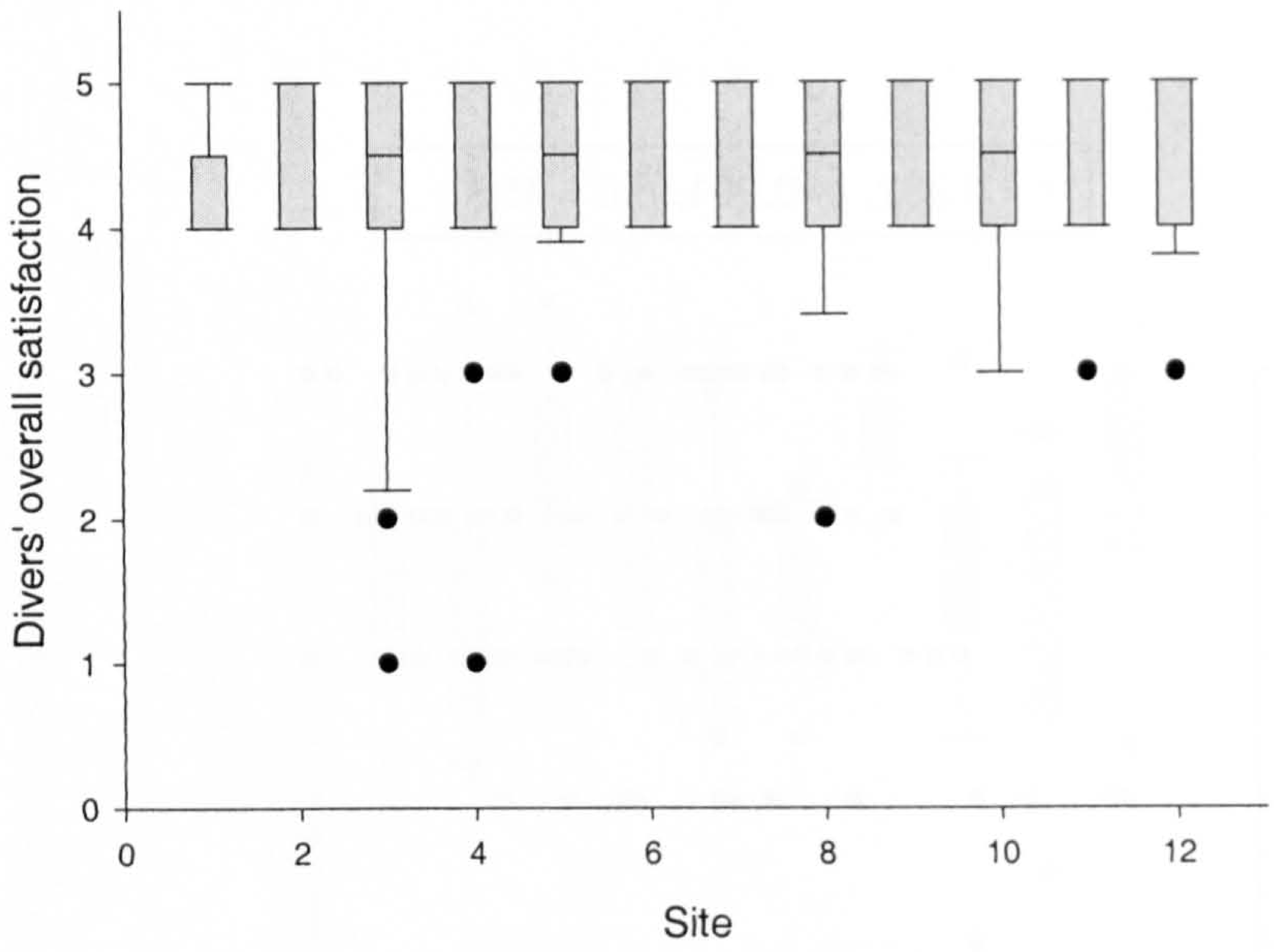


Fig. 5.17 Divers' overall satisfaction according to site. 1=very dissatisfied to 5= very satisfied. See legend to Figure 2.3 for explanation of box plot.

What would have improved visitors' diving experience?

127 out of 208 divers answered this question. Some divers expressed more than one attribute but considering all answers (n=152), the three highest proportions (26.3, 14.5 and 13.2%) were 'bigger' and 'more fish' and 'better underwater visibility' respectively (Table 5.3).

TABLE 5.3 PERCENTAGE OF ANSWERS GIVEN BY DIVERS TO VARIOUS ATTRIBUTES THAT WOULD HAVE IMPROVED THEIR DIVING IN ST. LUCIA

	Attribute	%
1	Bigger fish	26.3
2	More fish	14.5
3	Better underwater visibility	13.2
4	Better coral, healthier reef	9.9
5	Miscellaneous: ill-fitting equipment, water too cold, bad smell from boat fumes, too much boat traffic.	9.9
6	More diversity of marine life	7.9
7	Presence of particular species incl. rays, turtles, sharks	7.2
8	Smaller groups of people on dive	3.9
9	If garbage/trash were removed, or if bags were provided to collect the garbage in during dives	2.6
10	More information in briefings and during dive on marine life	2.6
11	Better control of divers' behaviour	0.7
12	Evidence of active policing of marine park	0.7
13	Less sediment	0.7

5.4.2 Questionnaire 2, Period 1

Main reason for visit

215 (46.8%) out of the 459 visitors interviewed said that their main reason for visiting St. Lucia was for a general holiday. 18.5% came primarily to dive or snorkel, 15.9% to dive or snorkel among other reasons, 10.2% as part of a cruise, 4.1% for work or business and the remainder included people visiting friends or relatives, getting married and those on honeymoon.

Top three motivations for diving and snorkeling

Viewing marine live in its natural environment was by far the most popular motive for diving and snorkeling irrespective of its position in the top three motivations (Table 5.4). Sample sizes were lower for motivations 2 and 3 as some visitors did not have a second or third motive.

TABLE 5.4 VISITORS' TOP THREE MOTIVATIONS FOR DIVING OR SNORKELING IN ST. LUCIA

	Motive		
	1	2	3
To view marine life in its natural environment	85.0	6.7	5.3
For the enjoyment of diving or snorkeling	6.9	42.9	15.9
To be with friends or relatives	0.8	8.4	10.6
For the adventure/fun	4.1	29.4	33.2
For photography	0.4	2.9	4.9
For being active out-of-doors	0.8	8.0	27.0
Other (new activity, peaceful/relaxing, to be in the water)	2.0	1.7	3.1
n	245	238	226

1=most important to 3= least important. Numbers are percentages of sample n.

Relative importance of reef attributes to divers and snorkelers

Divers and snorkelers gave most reef attributes (Table 5.5) scores of 4 (important) and 5 (very important) with snorkelers giving the lowest median value of 3 (average) to 'big fish'.

TABLE 5.5 THE IMPORTANCE OF CERTAIN SITE ATTRIBUTES TO VISITORS

	Lots of fish	Big fish	Different types of fish	Lots of living coral	Different types of coral	Clear water	Trash free sites
Divers n=244	4	4	4	5	4	5	5
Snorkelers n=207	4	3	5	4	4	5	5

Scores are median values. 1=not important at all, 2= not so important, 3=average, 4=important, 5=very important.

Divers were more particular than snorkelers about crowding. Most divers (n=198, 83.5%) thought that a mean group size of 7.6 and median of 7 divers ranging from 2 to 17 divers, was '*about right*'. 16.0% (n=38) of divers thought a mean of 9.9 and median of 9 was '*too many*' (range of 6 to 20). In comparison, 196 of 206 (95.0%) of snorkelers thought a group with a mean of 9 and median of 6 (range of 1 to 36) snorkelers was '*about right*'. A minority (n=10, 5.0%) of snorkelers said that a mean of 39 and median of 20 snorkelers (ranging from 3 to over 100 snorkelers) was '*too many*'.

What visitors enjoyed most and least about their visit and suggested improvements

210 visitors consisting of divers and snorkelers gave their views on what they had enjoyed most. Considering all the attributes that had given the most enjoyment, the largest proportion of answers (52.4%) referred to the marine life, particularly the variety and colours of the fish and corals (Table 5.6).

TABLE 5.6 PERCENTAGE OF ANSWERS GIVEN BY VISITORS ON ATTRIBUTES THAT THEY ENJOYED MOST (N=254)

	Attribute	**%**
1	The marine life: variety/diversity/colours of fish and corals	52.4
2	The clarity of the water	15.7
3	The environment: 'natural and unspoilt', beauty of the island	7.8
4	The easy access, proximity, sheltered environment	7.1
5	The secure buoyed off area that excluded boats	3.9
6	The warm sea water	3.5
7	The cleanliness	3.1
8	Miscellaneous: being outside, inexpensive, good staff, trying diving/snorkeling for the first time	3.1
9	That the reefs are preserved	1.7
10	That it was not crowded	1.7

Following a similar pattern with marine life at the top of the list, 89 visitors expressed that what had reduced their enjoyment was dead or damaged looking coral (15.4% of answers), seeing garbage/trash (13.3%) and too much boat traffic causing pollution and noise (11.2%) (Table 5.7).

TABLE 5.7 PERCENTAGE OF ANSWERS GIVEN BY VISITORS ON ATTRIBUTES THAT REDUCED THEIR ENJOYMENT OF THE MARINE ENVIRONMENT OF ST. LUCIA (N=98)

	Attribute	%
1	Poor weather: cloud, rain, current, waves	17.3
2	Dead looking and damaged coral, lack of colour	15.4
3	Seeing/smelling garbage/trash: sewage pipes, dumping of household waste in the ocean	13.3
4	The boat traffic: too many boats, smell of boat fumes, jet ski noise pollution	11.2
5	Not enough big fish or variety of fish, lack of fish in general	8.2
6	Poor underwater visibility: contributed in some cases by boats' propellors	8.2
7	Crowding: particularly on cruiseship days and at popular sites	6.1
8	Miscellaneous: didn't like wearing life-vest to snorkel, not enough beach chairs, staff incompetent	6.1
9	Beaches without buoyed off areas for snorkelers/ areas for snorkeling too small	5.1
10	Being scared or stung by a marine organism	4.1
11	Too far or too deep to snorkel	2.0
12	Too expensive (dive trips, food and beverage)	2.0
13	Forceful vendors	1.0

41 out of 79 visitors told me that aside from the marine environment, what would have improved their diving or snorkeling experience would have been more information on what they were likely to see in terms of corals and fish and where else they could snorkel. Other improvements were mostly linked to infrastructure such as better roads, mooring buoys, lavatories, moving boat traffic away from snorkeling

areas, better public transport links and removing or reducing waste and pollution (Table 5.8).

TABLE 5.8 PERCENTAGE OF ANSWERS GIVEN BY VISITORS ON WHAT WOULD HAVE IMPROVED THEIR DIVING OR SNORKELING EXPERIENCE (N=79)

	Attribute	%
1	More information on marine life they could expect to see, more maps of reef area, location of snorkel sites	51.9
2	Infrastructure developments including better roads, mooring buoys, beach space, chairs, lavatories, entry ladder and platform for snorkelers, removal of boat traffic, better public transport links	30.4
3	Dive/snorkel business changes: dive gear-handling service, protective waterproof gear on boats	15.2
4	Removal of garbage/trash at sites, along the coast, on beaches, removal of contaminants going into the ocean	2.5

Best and worst reefs in the world

For 58 out of the 245 interviewed visitors, this was their first experience of a coral reef. 187 visitors had been to reefs other than those in St. Lucia and of these, 164 told me what attributes made their 'best reef'. Among the most popular attributes were 'variety of fish and corals', followed by 'abundant fish', 'bigger corals and larger reef area' and 'good visibility' (Table 5.9).

TABLE 5.9 PERCENTAGE OF ANSWERS GIVEN BY VISITORS ON ATTRIBUTES THAT THEY ASSOCIATED WITH THE BEST REEF THAT THEY HAD EVER VISITED (N=323)

	Attribute	%
1	Variety of fish and corals	20.4
2	Abundant fish	13.3
3	Good visibility	11.8
4	Bigger corals, more reef area	11.8
5	Pretty/colourful	10.5
6	Bigger fish including barracuda, rays, turtles	6.5
7	More outstanding marine life	5.2
8	More accessibility to reefs, reefs closer to shore	3.7
9	Shallow reef	3.1
10	Reefs and surrounding environment protected, use of reefs regulated, patrolled, anchoring disallowed	2.8
11	No-one else/v. few people there, small groups (maximum of 4)	2.8
12	Spectacular topography e.g. walls, pinnacles, swim-throughs	2.8
13	Unspoilt, environment left natural, non-developed	1.9
14	Well-informed guides	1.9
15	Warm water, calm seas	0.9
16	Better equipment, reasonable prices	0.6

77 visitors gave their opinion on the worst reef they had visited and most (23.8%) of their answers related to seeing damaged or dead coral, followed by lack of fish (16.2% of answers) and lack of colour and life in general (14.5% or answers, Table 5.10).

TABLE 5.10 PERCENTAGE OF ANSWERS GIVEN BY VISITORS ON ATTRIBUTES THAT THEY ASSOCIATED WITH THE WORST REEF THAT THEY HAD EVER VISITED (N=118)

	Attribute	%
1	Seeing damaged and dead coral	23.8
2	Lack of fish	16.2
3	Lack of colour and lack of life in general	14.5
4	Poor visibility, presence of silt and/or sediment	11.0
5	Lack of coral	9.3
6	Polluted, dirty	5.9
7	Too many boats, overcrowded with people, over-used reefs	5.9
8	Poor weather, rough conditions, cold water	3.4
9	Lack of variety	2.5
10	Reef either too deep or too shallow	2.5
11	Difficult access to reef	2.5
12	Unnatural settings e.g. artifacts placed on reef, confined to snorkel trail	1.7
13	Presence of jelly fish	0.8

5.4.3 Questionnaire 3, Period 2

Diver and snorkeler perceptions of St. Lucian reefs

Divers and snorkelers (total n=320) gave median ratings for coral, fish and underwater visibility as average (score of 3) to very good (score of 5) and they all gave a score of at least good (score of 4) for their overall satisfaction (Table 5.11). Only one site, number 13 (Anse Cochon), received a lower median score of 2.5 which lay between poor and average (Table 5.11).

TABLE 5.11 VISITORS' MEDIAN PERCEPTION SCORES FOR REEF ATTRIBUTES AT DIFFERENT SITES

Site	D/fish	S/fish	D/coral	S/coral	D/vis	S/vis	D/overall	S/overall
1	5		5		4		5	
3	4		4		3		4	
4	4	4	4	4	4	4	4	4
5	5		5		4		5	
6	5	3.5	5	4	4.5	3.5	5	4
7	3	4	4	4	4	4	4	4
8	4		4		4		4	
9	4		4		3		4	
10	5		5		3.5		4	
11	3	4	4	3	4	4	4	4.5
12	4		5		3		4	
13		4		2.5		4		4
14		4		3		4		4

D = divers, S = snorkelers, fish = fish life, coral = coral life, vis = underwater visibility, overall = overall satisfaction. Score 1 = very poor, 2 = poor, 3 = average, 4 = good, 5 = very good.

Diver and snorkeler perceptions of, versus measured, reef attributes

The only two attributes that both divers and snorkelers' perceived correctly, shown by a significant positive correlation with measured data, were overall fish abundance and underwater visibility (Table 5.12). A significant positive correlation was also found between snorkelers' perceptions of, and measured abundance of, hard coral.

TABLE 5.12 SPEARMAN'S RANK ORDER CORRELATION TEST RESULTS OF VISITOR PERCEPTION SCORES OF REEF ATTRIBUTES VERSUS MEASURED DATA ON THE SAME ATTRIBUTES

		r	p	n
Divers	Abundance of fish	0.202	0.010	131
	Abundance of hard coral	-0.003	0.487	131
	Abundance of living substrate	0.085	0.166	131
	Underwater visibility	0.449	<0.001	150
Snorkelers	Abundance of fish	0.194	0.006	170
	Abundance of hard coral	0.239	0.001	170
	Abundance of living substrate	0.066	0.198	170
	Underwater visibility	0.393	<0.001	148

Diver and snorkeler overall satisfaction scores versus their perceptions and their overall satisfaction versus measured attributes

For both divers and snorkelers, overall satisfaction was significantly correlated with scores given to fish life, coral life and underwater visibility (Table 5.13). The higher the scores visitors gave for these attributes, the higher their overall satisfaction. When scientifically measured data were used however, only underwater visibility was significantly correlated with both divers and snorkelers' overall satisfaction. Divers' overall satisfaction was also significantly correlated with the weather. As the weather worsened, divers' overall satisfaction decreased.

TABLE 5.13 SPEARMAN'S RANK ORDER CORRELATION TEST RESULTS FOR DIVERS' AND SNORKELERS' OVERALL SATISFACTION SCORES VERSUS PERCEIVED AND MEASURED REEF ATTRIBUTES

	Divers			Snorkelers		
Attributes perceived by visitors*:	r	p	n	r	p	n
Fish life	0.545	<0.001	150	0.703	<0.001	170
Coral life	0.564	<0.001	150	0.535	<0.001	170
Underwater visibility	0.452	<0.001	150	0.546	<0.001	170
Measured attributes:						
Abundance of fish	0.112	0.101	131	0.030	0.349	170
Percentage cover of hard coral	0.077	0.192	131	-0.004	0.482	170
Percentage cover of living substrate	-0.009	0.459	131	0.034	0.329	170
Current	0.126	0.064	149	0.029	0.353	168
Underwater visibility	0.213	0.004	150	0.202	0.007	148
Group size	-0.062	0.224	150	-0.078	0.156	170
Weather	-0.246	0.001	150	0.038	0.311	170

*Perceptions scored as: 0=no opinion, 1=very poor, 2=poor, 3=average,4=good, 5=very good. Abundance of fish measured as number of fish per $79m^2$; current scored as 1=none, 2=low, 3=moderate, 4=strong; underwater visibility measured in m; weather scored as 1=sun, 2=sun +/-cloud +/-rain, 3=cloud + rain, 4=rain.

Multiple regression: The influence of reef attributes on divers' and snorkelers' overall satisfaction

The multiple regression using scientifically gathered data on abundance of small fish, percentage cover hard coral, percentage cover living substrate, current, visibility, group size and weather on the dependent variable, overall satisfaction was significant but weak (r^2= 0.142, p=0.008, F=2.886). Two variables had significant, although minimal, influence on divers' overall satisfaction: underwater visibility, B 0.026, p=0.050 and weather B -0.166, p=0.012. Running a separate multiple regression using the same independent variables against overall satisfaction was non-significant (r^2= 0.052, p=0.371, F=1.094).

MPA issues

When asked whether or not their decision to come to St. Lucia had been positively influenced by the existence of the marine park, 65 (38.2%) out of the 170 snorkelers said that it had. 28 out of the remaining 105 snorkelers that said that the marine park hadn't influenced their decision specified that they did not know the marine park existed prior to arriving on the island.

When divers were asked the same question, 75 (50.3%) out of 150 said that the marine park had influenced them, and 74 said not. One person did not answer. Of the 75 that answered yes, 7 said that the marine park was the main or only reason for their visit. 17 of the 74 that said they did not know the park existed.

5.5 Discussion

For most tourists, marine life and the quality of the environment are paramount to their coral reef experience. They were central to tourists' motivations for diving and snorkeling in St. Lucia, they directly affected their enjoyment of it and they contributed to their best and worst experiences of reefs elsewhere in the world.

Despite the quality of marine life being so important, tourists were not good at distinguishing differences in fish abundance and diversity or abundance of living coral among sites. What divers were able to correctly perceive was the lower abundance of large (≥25cm) versus small (<25cm) fish, measures of underwater visibility and levels of garbage.

Tourists consistently regarded fish and coral life as the most important site attributes and they dominated their answers about what had made a particular reef the best they had ever visited. Similar findings have been reported from elsewhere. A study in Malaysia found that 'marine life', 'easy access and unlimited dives' and 'marine environment' contributed to 68.1% of the best aspects of divers' experiences (Musa, 2002). Another study in Spain reported that over 90% of divers' responses included the 'rich marine life of area' among five principal reasons for choosing the Medes Islands as a diving place (Mundet & Ribera, 2001). In Australia, visitors to the Great Barrier Reef thought visual beauty (scenic beauty and variety of fish and coral) the most important element of their recreational experience (AGBMcNair, 1995). Similarly, Davis et al. (1997) reported on the Australian whale shark tourism industry and noted that the three most important factors that increased visitors' enjoyment were 'being close to nature', 'seeing large animals' and 'many different types of marine life'. In Jamaica, divers preferred to see fish and other large animal attributes rather than benthic life such as algae or coral (Williams & Polunin, 2000).

Despite the large emphasis that visitors put on the quality and quantity of marine life this study shows that their perceptions do not always reflect reality. In fact, visitors scored most sites highly for fish and coral attributes and their perceptions of them met their expectations. Their perceptions, however, did not correlate well with actual coral cover, live substrate cover, fish abundance and diversity and sediment load at the various sites. Fish abundance, for example, varied by an order of magnitude across some sites and yet divers' perceptions varied little. It may be that the scientifically gathered data differed from conditions present on the day visitors dived or snorkeled a particular site, but it is more likely that as long as a certain number of fish were present, visitors were satisfied.

Some visitors said that they were not aware of any sediment even though at some sites it was widespread. In those cases, it appeared that visitors did not notice or look for sediment because their attention was focused on the fish and invertebrates. Another point is that the tourists interviewed in this study were not exposed to the full range of sites in existence in St. Lucia. Certain sites were excluded from dive companies' itineraries because they were already heavily impacted by sediment, poor visibility or were less aesthetically pleasing. Had visitors gone to those sites with heavy sediment loads leading to poor visibility, reduced coral cover and marine life, the relationships between their perceptions and scientifically measured attributes may have been more pronounced.

Divers' perceptions of coral damage, sediment, trash and crowding in St. Lucia affected the quality of their experience. The more coral damage, sediment and trash they saw, the less they enjoyed their dive. A study of divers in Costa Rica showed that 24.8% considered the quality of the sites to be bad and noted 'broken coral colonies', 'strong currents and poor visibility' and the relatively 'low abundance of big fish' among their main reasons for their answer (Jiménez, 1997). In my study, visitors' enjoyment was significantly reduced the bigger the group of people participating in the activity and differed between divers and snorkelers. The number of participants which divers reported as being too many (median of 9) was much lower than that for snorkelers (median of 20). Crowding has been reported by many to be of concern to visitors interviewed, including resorts in Spain (Mundet & Ribera, 2001), Malaysia (Musa, 2002) and the Caribbean (Rudd & Tupper, 2002). The Caribbean study indicated that older divers (more than 30 years old) would be willing to pay US$10 more per dive than younger divers to dive in a small groups of 3-7 divers than in groups of 8-14 divers. In Australia, experienced scuba divers preferred fewer people and less infrastructure whilst novices with little experience of diving or snorkeling regarded the presence of other people and infrastructure as more acceptable (Inglis et al. 1999).

Many visitors in my first sample period (51.9%) wanted more information on the marine life they were likely to see and on sites to visit and this was the most popular request from visitors on what would have improved their diving or snorkeling experience. The request for additional tourist information and interpretative facilities has been reported by others in Spain and Malaysia (Mundet & Ribera, 2001; Musa, 2002). Businesses could disseminate more information on the local marine life, whether through their dive and snorkel briefings or by putting up notice-boards, leaflets, posters or selling species' identification cards and posters. This would likely increase visitors' enjoyment and feed back into businesses' profits.

Marine parks are a major attraction: 50.3% of divers and 38.2% of snorkelers interviewed said that the existence of the park had influenced their decision to visit St. Lucia. A few visitors (2.8% of answers) associated protection of the environment by regulations and enforcement with their most-enjoyed and best reef experiences (2.8% of answers). Evidence of active policing of the marine park and removal of garbage were attributes that would have improved the diving and snorkeling for visitors in St. Lucia (3% of answers combining questionnaires 1 and 2). A study on the Great Barrier Reef in Australia (AGBMcNair, 1994) showed that visitors expressed a strong desire to preserve the reef from damage, both from tourists themselves and pollution, to ensure future visitors would be able to share their enjoyment of its beauty. With such management, destinations can both attract and satisfy visitor expectations and enjoyment. Countries relying on reef tourism could benefit greatly from setting up marine parks and ensuring that pollution problems are addressed.

Marine parks allow fish stocks to recover from fishing pressure leading to more and older, thus larger, fish (e.g. Roberts & Polunin 1991, 1993; Attwood 1994; Bohnsack, 1998; Halpern & Warner 2002; Gell & Roberts, 2003). In the Leigh Marine Reserve in New Zealand, twenty years or so after fishing was banned, densities of fishable sized bream, *Pagrus auratus*, reached 5.8-8.7 times higher in the reserve compared to fished areas nearby (Babcock et al. 1999). In the Apo Island reserve in the Philippines, densities of large predatory reef fish increased 7-fold after 11 years of protection (Russ & Alcala, 1996). Five years after the inception of St. Lucia's marine managed area where four areas were designated 'no-take' zones, commercial fish biomass increased four fold inside the marine reserves and three fold in adjacent fishing grounds. Catches by artisanal fishers increased by between 46% and 90%, depending on the type of gear the fishers used (Gell & Roberts, 2003).

Visitors in this study perceived the much lower abundance of large versus small fish. Although fishing in eight of the dived sites in the SMMA has been prohibited since 1995, fish stocks are still recovering after severe over exploitation that occurred prior to the inception of the park. St. Lucia's reefs have typically few large fish and a greater number of small fish. The length of time required for a fish population to recover after exploitation varies with the species according to their longevity (Roberts et al. 2001). In the Merritt Island National Wildlife Refuge at Cape Canaveral, Florida, fish originating from the reserve that supplied adjacent areas as trophy fish began exceeding the size of trophy fish caught elsewhere after 9 years for spotted sea trout (longevity 15 years), 27 years for red drum (longevity 35 years), and 31 years for black drum (longevity 35 years) (Roberts et al. 2001). Fish in the SMMA therefore probably need longer than they have been given so far in order to attain larger sizes. 'Bigger fish' and 'more fish' were the two most popular attributes suggested that would have improved visitors' diving experience in St. Lucia. MPAs could therefore serve to both replenish and enhance fish stocks both within and adjacent to 'no-take' areas as has been shown in St. Lucia (Roberts et al, 2001), and improve visitor experiences within the park.

A study in another part of the Caribbean, the Turks and Caicos Islands, showed that an increase in Nassau grouper abundance and/or mean size would add value to the dive experience because most divers held preferences for viewing more fish and larger fish (Rudd & Tupper, 2002) and would be willing to pay more for small group dives when big fish were present.

This study suggests that in many cases, as long as reefs are not visibly damaged, and support plentiful fish life, they will be adequate to satisfy most visitors. Visitors cannot be relied on to identify more subtle differences in natural resource attributes that were measured in this study. However, quality does matter, illustrated by the fact that St. Lucia dive businesses already avoided certain sites because of degradation. Visitors are particularly sensitive to coral damage, underwater visibility, garbage and crowding. It is therefore in businesses' and countries' interests to manage their reefs and land practices that negatively affect the marine environment. People will pay more for higher quality sites, small groups and to see bigger fish, and demand good water clarity. Today the easy accessibility to information means reputations, whether good or bad, have the potential to travel far. To ensure sustainability of reef tourism, the quality of reef resources must be maintained.

5.6 References

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Chapter 6: Management of coral reef tourism

6.1 Abstract

For many countries, tourism is a profitable industry and its growth is encouraged. However, planning for, and management of tourism and its negative impacts has generally not kept pace with its development. Coral reef tourism is a case in point. Rapid expansion in reef tourism and associated infrastructure has, in many instances, been coupled with degradation of coral reefs. To date, reef management has typically involved establishing marine protected areas (MPAs). Some MPAs provide mooring buoys to reduce damage to reefs from anchoring. These measures, although beneficial, are insufficient to control tourism impacts to reefs or enable reefs to accommodate expansion in visitor numbers. MPAs need to employ additional control measures including restricting visitor numbers to sensitive sites, spreading visitor load over sites more equally and requiring tourist businesses to supervise visitors closely in the water to ensure that their behaviour does not damage reefs. Small islands, due to their size, cannot afford to degrade, let alone lose, their coral reefs. The case study of St. Lucia, West Indies, is used to illustrate how management of reef tourism could be adapted to reduce visitor impacts to the reefs, make fuller use of the country's marine resources and accommodate a growing tourism industry. If diver behaviour is strictly controlled, sites could potentially accommodate between 14,000 dives each per year, representing revenues from dive trips to tour businesses of US$560,000 per site per year. Without visitor management, site capacities for divers will remain at lower levels and furthermore, with continued reef degradation from visitors and pollution, some sites may become unusable for reef tourism. This could impose a cost of between US$160,000 to US$280,000 per site per year, underlining the importance of managing visitor behaviour and reef degrading pollutants.

6.2 INTRODUCTION

While tourism is one of the world's most successful industries (WTTC, 2002) and worldwide international arrivals, numbering at almost 700 million in 2000, continue to grow at an average rate of 7% annually (WTO, 2002), it is also an environmentally damaging one (Shah et al., 1997; Gössling, 2000; Becken, 2002). Many countries want to develop tourism for economic benefits but they fail to plan its management adequately, often resulting in detrimental consequences for their social and biological environment (Britton, 1977; Rodenburg, 1980; Miller & Auyong, 1991; Lindberg & Hawkins, 1993).

Coral reefs are increasingly exploited for tourism, particularly scuba diving and snorkeling (Orams, 1999). The economic benefits from tourism, together with other services provided by reefs, including coastal protection and provision of food, are worth about US$375 billion each year (Costanza et al., 1997). Despite their value, over half of the world's reefs are potentially threatened by human activity ranging from coastal development, destructive fishing practices, over-exploitation of resources and pollution (Bryant et al., 1998). Management strategies must encompass these anthropogenic threats if they are to protect reef resources effectively. Managing visitor behaviour and use of reefs is an important aspect. This chapter examines the different aspects of visitor management and identifies strategies that could facilitate a growth in tourism whilst preserving the integrity of the reef environment.

6.3 MANAGING CORAL REEFS FOR TOURISM

6.3.1 Marine protected areas and carrying capacity estimates

Marine protected areas (MPAs) are a means of managing uses of reefs and approximately 660 have been set up around the world to protect reefs and the species they support (Spalding et al, 2001). Some MPAs are partially or fully funded by visitors paying a fee to use reefs in the protected area. Current typical visitor management of MPAs includes the establishment of mooring buoys which prevent the use of anchors that would otherwise damage the reef. Limitations may also be put on the number of boats allowed to tie-up to a mooring. While these measures are important, they may not sufficiently curtail tourist damage to reefs. Most MPAs do not manage tourist impacts, especially those by divers and snorkelers, and yet this is critical for the protection of reefs, particularly if they are to accommodate a growth in tourism.

The impact of divers and snorkelers can be significant (Muthiga & McClanahan, 1997; Hawkins et al., 1999; Tratalos and Austin, 2001; Zakai and Chadwick-Furman, 2002) especially when there is a concentration of activity resulting in popular areas receiving more visitors than it can cope with. The term 'carrying capacity' is often used to refer to the number of people and animals that can use a resource without causing "unacceptable impacts" to a particular environment (RAC, 1993). Estimates of sustainable diver carrying capacities for reefs range from 4,000-7,000 dives per site per year (Table 6.1). They were based on the premise, that above those intensities of use, the reefs would suffer significant coral cover loss and high frequencies of colony damage (Riegl & Velimirov, 1991; Prior et al., 1995; Hawkins & Roberts, 1997; Zakai & Chadwick-Furman, 2002). However, the figures may be conservative as the reefs on which those carrying capacity estimates were based had little or no management of in-water impacts by divers and snorkelers.

TABLE 6.1 ESTIMATES OF CARRYING CAPACITIES FOR CORAL REEFS

No. dives per site per year	Location	Reference
4000 – 6000	Bonaire, Netherland Antilles	Dixon et al. 1993, 1994
up to 5,000	Eastern Australia	Harriott et al. 1997
5000 – 6000	Egypt, Bonaire and Saba	Hawkins & Roberts 1997, Hawkins et al. 1999
5000 – 6000	Eilat, Israel	Zakai & Chadwick-Furman, 2002
maximum of 7000	Sodwana Bay, South Africa	Schleyer & Tomalin, 2000

The carrying capacity of reefs for tourism is variable and dependent on other factors including: location of the reef in relation to other human activities and development, the type of activity the reef is being used for, and reef structure and composition (Salm, 1986; Clark, 1991; Harriott et al., 1997; Schleyer & Tomalin, 2000; Zakai & Chadwick-Furman, 2002). Carrying capacity will be influenced by the level of damaging activities and impacts present. Sites close to human settlement are often subjected to extractive activities including fishing and mining, and pollution from household, industrial and agricultural activities. A site being used to teach people how to dive is likely to receive more damage than if it is used by qualified divers, and if a site is being used by both divers and snorkelers, then impacts are likely to be greater. Reefs may be subjected to trampling and anchoring (Woodland & Hopper, 1977; Davis, 1977; Kay & Liddle, 1989; Visser & Njuguana, 1992; Hawkins & Roberts, 1993; Rajasuriya et al., 1995), in addition to impacts caused by swimming divers and snorkelers. Other factors that may affect the rate at which a reef is impacted by users include the use of a camera (Rouphael & Inglis, 2001; Chapters 2 and 3), if dives are done from shore rather than by boat and if night dives are carried out at the site (Chapter 2). Impacts will also vary according to the reef species present. Branching corals for example, have been found to be more susceptible than others to damage by divers (Rouphael & Inglis, 1997; Garrabou et al., 1998).

6.3.2 Choosing the tourism market

Countries need to identify the kind of tourism they wish to promote and the type of tourist they wish to cater for. Destinations are constantly evolving and characteristics of tourists and the destinations' environments are also changing. As illustrated by Butler's tourist destination cycle (Butler, 1980), initial explorers are few, restricted by lack of access, facilities, and local knowledge. As facilities and awareness grow the area becomes more popular and attracts increasing numbers of visitors. As levels of carrying capacity, measured as environmental factors such as water and air quality, physical factors such as transportation and accommodation, and social factors such as crowding or resentment by the local population are reached, the rate of increasing tourist numbers drops. Visitors may then find other areas more attractive and holiday elsewhere. Examples of where tourism development has followed this route can be found in parts of East Africa and its Island States. In the 1990's income from tourism dropped dramatically (40% in Kenya for example), partly due to environmental degradation caused by increased flows of organic wastes and nutrients, and inappropriate agricultural methods exacerbating run-off and siltation problems (Shah et al., 1997). Therefore, visitor perceptions can change over time, depending on which stage of the tourist destination cycle the country, or region, is in.

Instead of going for the mass tourism option, countries can opt for lower numbers of high-paying guests or high-value tourism which may help break the cycle. The Seychelles has adopted this policy and has regulated tourist development to include a range of accommodations including guest houses at US$40 per night, to bungalows such as those on Frégate Island at US$1955 per night (Gössling et al., 2002). The Seychelles realised that to attract wealthy visitors they needed to maintain a high quality environment and accordingly put half of their land under protection. However, despite those protective measures being implemented there are still problems including marine curio collecting and over-exploitation of reef fish, that need to be addressed (Gössling et al., 2002). This highlights the importance of monitoring reef resources and implementing educational programs that convey to people the justification for regulating the use and extraction of reef resources. The Maldives specifically target the up-market tourist (Inskeep, 1992) and the government encourages resorts to upgrade themselves to attract a higher-level of tourist clientele. The Mauritian government also promoted selective tourism, targeting affluent visitors, and resisted charter flight operations that catered to the masses of lower-spending tourists (Ramsamy, 1992).

Small islands, such as those in the Seychelles and the Caribbean have limited resources that they cannot afford to lose to unregulated tourism development or other activities that damage their natural environment. Such islands are in a perfect situation to profit from high value, low-volume tourism development. As resources become scarce, the value of good quality sites increases and regions can charge a premium for them (Medio, 1996 in Wells, 1997). It is therefore in a country's interest to control any form of development or activity, including that associated with tourism and other activities that may impact negatively on the environment.

6.3.3 Management options for reef tourism

To alleviate the pressures of reef tourism, options for management include: establishing mooring buoys, walkways or pontoons; implementing user fees; regulating use of sites; alternative and additional site creation; supervision and education of visitors; building control and sanitation and coral reef monitoring. These options are described below.

Mooring buoys

Mooring buoys have been used successfully to reduce, and where anchoring is not allowed, eliminate any further anchor damage to corals. At some parks, including Saba and Bonaire in the Netherlands Antilles, every dive site has its own mooring buoy and only one boat is allowed to use a mooring at a time. However, this system does not prevent boats from dropping divers and snorkelers off at a site and returning to pick them up without using a mooring. Management therefore needs other tools in addition to moorings to regulate use of sites. A charge can be levied on moorings to help finance their maintenance and pay towards marine park management costs. In the British Virgin Islands, mooring fees are US$1.85 per foot length of boat per day, increasing to US$2.75 per foot length of boat per day after the first day (British Virgin Islands Port Authority, 2003). In Hawaii, mooring fees are US$1.75 per foot length of boat per day (Ko Olina Marina, 2003).

Walkways and pontoons

Walkways help localise coral damage by trampling to a given area and have been used successfully in the Ras Mohammed National Park, Egypt (Ormond et al., 1997). Many pontoons are distributed throughout the Great Barrier Reef in Australia giving snorkelers a place to rest instead of standing on the reef.

Fees

Marine parks can charge a fee to divers and snorkelers wishing to visit sites within the protected area. The Hol Chan Marine Reserve and Half Moon Caye in Belize charge between US$2.50 and US$5.00 per visitor per day; the Fernando de Noronha Marine Park in Brazil charges US$4.25 per visitor per day; the British Virgin Islands charges divers US$1 per day; Bonaire Marine Park charges US$10 per diver per year; Saba Marine Park charges US$3.00 per dive and US$3.00 per week for snorkelers (Lindberg, 2001). In the Medes Islands protected area of Spain, spread over an area of 21.5 hectares, divers are charged a fee of US$2.2 per dive (Mundet & Ribera, 2001). These fees typically represent less than 1% of the total trip cost and studies suggest that fees could be increased without leading to siginificant reductions in visitation rates (Dixon, Scura & van't Hof, 1994; Walpole et al., 2001; Lee & Han, 2002).

Limiting the number of divers and snorkelers allowed to use a site

Although not widely adopted, site limits have been used to address problems of crowding and environmental degradation. On the island of Sipadan (16.4 hectares), the Malaysian authorities have enforced a limit of 100 divers allowed to dive on the island's reefs per day (Musa, 2002). In the Medes Islands, the government has set a limit of 450 dives per day (Mundet & Ribera, 2001). Where reef use is spread over larger areas, a tradeable permit system may be a more appropriate and effective means to control numbers of visitors (Cumberbatch, 2000). To implement such a scheme, dive carrying capacity for each site must be determined. The corresponding number of tradable permits are then issued to dive operators, which in total allow exactly the decided dive levels at each site, during the specified period for which permits are valid. As permits are in limited supply they obtain a scarcity value and any business can sell their excess permits to another business.

Increasing the number of sites available for diving and snorkeling

Opening up and using new sites for divers and snorkelers can alleviate pressure from heavily used sites. Other options include sinking ships for wreck diving and artificial reef construction (Chua & Chou, 1994; Wilhelmsson et al., 1998; Mead & Black, 1999), although consideration of the impact of these options on the marine environment would need to be addressed.

Education and in-water supervision

Briefings alone are insufficient to reduce visitors damaging the reef (see Chapters 2 and 3). Rates of contact and damage can be greatly reduced if all dive and snorkel leaders supervise their clients to prevent them from damaging the reef by intervening as soon as they see damaging behaviour. Groups of visitors will therefore have to be small enough to allow leaders to provide adequate supervision.

Building control and sanitation regulations

Strict building controls have been introduced in the Maldives and Mauritius limiting room numbers, tree cutting, height of structures and enforcing sewage treatment plants to be constructed for larger resorts (Ramsamy, 1992; Inskeep, 1992). Policies such as these work particularly well for small islands where the impact of mass tourism, and the development associated with it, would be environmentally unsustainable.

Implementing a monitoring program

Monitoring of reef resources, environmental parameters, and human activities enables trends and changes within the reef environment to be revealed. Scientific research facilitates the understanding of the impacts human activity has on resources and it also provides managers with a tool to assess the efficacy of management actions. In the process, research may also reveal new parameters or processes that need to be monitored and areas that need to be further researched. Information gathered from monitoring programs can also be used to educate the public so that they too can better understand and support management initiatives.

Programs monitoring the status of coral reefs have been implemented worldwide (Burke et al., 2002) and need not be entirely conducted by scientific staff. Volunteers are now supplementing more rigorous scientific monitoring efforts. Coral reef monitoring programs have been developed for tour operators, recreational divers and other volunteer groups wishing to plan reef survey programs, collect data, train local participants and ensure quality control (Musso & Inglis, 1998).

Monitoring should, if possible, be conducted over the long-term. In Florida, all national marine sanctuaries that contain coral reefs have ongoing monitoring programs (NOAA, 2003). Although monitoring programs provide information on coral reef communities which can be used to effectively manage human impacts, many places lack effective management strategies (Tissot & Brosnan, 2002). Problems arise from poor communication and liaison between science, management and policy. Efficient management requires integration, cooperation and collaboration among the public and government. Integrating education with monitoring programs is key to achieving this.

6.4 The case study of St. Lucia

Coral reefs in the eastern Caribbean island of St. Lucia are important assets for fishing and tourism (WTTC, 2002). In Soufrière, a town on the south west coast, conflict has existed since the 1980s between fishers and tourist businesses, and there has been concern over declining reef fish catches and reef health (Gell & Roberts, 2002). After several years of discourse and ineffectual legislation set up to protect some of the reefs in the vicinity of Soufrière, the government approved a proposal put forward by a committee, in consultation with stakeholders, to establish a marine and coastal resource management area. The Soufrière Marine Management Area (SMMA) was officially launched in 1995. It covers 11km of coast (Fig. 2.1, Chapter 2), extends 100m from the shore and is divided into zones. The zones include marine reserves where all extractive uses are forbidden but diving is allowed, fishing priority areas where recreation is allowed but fishing takes precedence, yacht mooring areas where recreation is allowed in tandem with mooring, and multiple use areas where all uses are permitted.

Since the SMMA's inception, commercial fish biomass has increased four fold inside the marine reserves and three fold in adjacent fishing grounds (Roberts et al., 2001; Gell et al., in prep). However, despite the success of the SMMA, the quality of St. Lucia's reefs has declined. Reefs in the SMMA, and one area 7km north of it, have shown a decrease in coral cover from an average of 40 ± 1.2 % (mean ± standard error) in 1995 to 31 ± 1.0 % (mean ± standard error) in 2001 (Schelten, 2002). Another study which sampled at a larger scale showed that the average coral cover at 15m depth from ten sites within the SMMA was 37%, and ranged from 17 to 55 ± 3.7 % (± standard error) in 1995 (Hawkins & Roberts, unpublished data). By 2002, the average coral cover had dropped to 27%, with a range of 12.5 to 45.5 ± 3.6 % (± standard error) (Hawkins & Roberts, unpublished data). Coral cover loss was correlated with sediment pollution levels (Schelten, 2002). A higher loss of 27% was found in areas of high sediment, compared to a loss of 19% in low sediment areas. Household and other waste has also affected sites, such as at the 'Pinnacles' site, where divers have noticed excessive garbage (see Chapter 5) and reported other negative aspects including coral damage (e.g. broken and dead looking pieces of coral) and poor underwater visibility. Underwater visibility is directly affected by levels of suspended sediment. Tourists in St. Lucia, including divers and snorkelers, cause damage to the reef by kicking or knocking into it and stirring up sediment which then settles on the corals (see Chapters 2 and 3). Thus, the combined impacts from visitors and pollution could affect the scope for tourism growth by degrading sites to a point of unusability.

The moorings within the SMMA are of two types. Those for dive and snorkel boats and those designated for yachts. Yachts are charged a fee according to their size and length of stay, ranging from US$10 for vessels of 35ft or less for a stay of up to two days, to US$25 for vessels of over 65ft staying for up to seven days. The revenue that yacht mooring fees contribute to total park revenue, including diver fees and donations, fluctuates from year to year. Between 1995 and 2000, yearly revenue from yacht mooring fees represented between 35 and 66% of total revenue, and averaged 52%. Yacht fees in 2001 totalled US$50,000, representing 62% of all SMMA revenue collected (SMMA data, 2001). Yacht fees in St. Lucia are low compared to the British Virgin Islands (BVI Port Authority, 2003) and Hawaii (Ko Olina Marina, 2003), where for a vessel of 35ft, fees would range from US$61 to 65 per day compared to US$10 in the SMMA. A fee system is also in place for divers and snorkelers. Divers in St. Lucia are charged US$4 per day or US$12 per year and snorkelers US$1 per day. Between 1995 to 2000, yearly revenue from diver fees represented between 33 and 65% of total park revenue and averaged 48%. In 2001, snorkeler fees were introduced and revenue from those in combination with diver fees, contributed some 36% of total park revenue (SMMA data, 2001). Compared to other Caribbean destinations, these fees are of similar magnitude but other marine parks in the world manage to have much higher fees such as in the Philippines, where parks charge anything from US$1 to US$50 per person per entry (Lindberg, 2001). Studies in St. Lucia show that most visitors are willing to pay more than that being asked (Chapter 4). If the park charged what 75% of visitors were willing to pay, the daily and annual fee for divers would be US$6 and US$20 respectively, and the daily snorkeler fee would be US$2. Those fees would represent an increase in park revenue of 62%. Yacht fees could also be increased to comparable levels charged elsewhere in the Caribbean.

What is currently not in place is a system to spread the pressure of divers and snorkelers evenly between the sites. There is great disparity in dive site use by tourist businesses, and tourist activity is concentrated in a few locations (Table 6.2).

TABLE 6.2 DISTRIBUTION OF DIVE SITE USE IN ST. LUCIA (YEAR 2000) AND CORRESPONDING ESTIMATE OF NUMBER OF DIVES DONE AT EACH USING 2001 DATA. SITES IN BOLD ARE THOSE WITHIN THE SOUFRIÈRE MARINE MANAGEMENT AREA (SMMA)

	Site	No. dives (to nearest hundred)**	% dives*		Site	No. dives (to nearest hundred)**	% dives*
1	**Anse Chastanet**	**28,100**	**20.5**	23	Le Wash	600	0.4
2	Anse Cochon (n)	14,000	10.2	24	The Arch	500	0.4
3	Lesleen M	11,300	8.3	25	Other	500	0.4
4	**Coral Gardens**	**8,300**	**6.1**	26	Oceron Point	500	0.3
5	**Pinnacles**	**7,400**	**5.4**	27	Saline Point	300	0.2
6	**Trou Diable**	**7,100**	**5.2**	28	Petit Trou	200	0.2
7	**Piton Wall**	**6,000**	**4.4**	29	Bourget Rocks	200	0.2
8	**Malgretoute**	**5,900**	**4.3**	30	Rosmund's Trench	200	0.1
9	**Turtle Reef**	**5,600**	**4.1**	31	North Beach	200	0.1
10	Virgin Cove	5,200	3.8	32	Anse Galet	200	0.1
11	**Grand Caille**	**5,100**	**3.7**	33	Cariblue Bay	200	0.1
12	**Fairyland**	**4,500**	**3.3**	34	Secret Garden	100	0.1
13	**Superman's Flight**	**3,700**	**2.7**	35	Smuggler's Cove	100	0.1
14	La Toc beach	3,400	2.5	36	Blue Water	0	0.0
15	Anse la Raye Wall	3,200	2.4	37	Cutty Cove	0	0.0
16	**Jalousie**	**3,100**	**2.2**	38	Jambette Point	0	0.0
17	Virgin Point	3,000	2.2	39	Barrel O' Beef	0	0.0
18	Choc Reef	2,500	1.8	**40**	**Hummingbird Wall**	**0**	**0.0**
19	Pigeon Island	1,800	1.3	**41**	**Blue Hole**	**0**	**0.0**
20	Anse Cochon (south)	1,600	1.2	42	Wauwinet Wreck	0	0.0
21	Rust Cove	1,400	1.0	43	Fish Feeding Point	0	0.0
22	Daini Koyomaru	700	0.5	44	Fond Blanc	0	0.0

*Based on SMMA data (2000). **Estimates based on interview data, calculated by multiplying the average number of divers by the average number of dives done per trip.

In 2000, six sites received more than half of all dives (50.3%) and one site in particular, Anse Chastanet received 20.5%. Using the most recent 2001 data obtained from my interviews with dive operators (Chapter 4), the total number of dives done in St. Lucia was estimated at 137,000 dives per annum. If one assumes that site use followed the same distribution as in 2000, approximately 84,800 of all dives would have been done at sites within the SMMA, with 28,000 dives done at Anse Chastanet alone. For the year 2001, the number of dives at most sites was within researchers' estimates of carrying capacity set at between 4,000 to 7000 dives per site per year, but some sites exceeded these values by a lot. Five sites had above the maximum of 7,000 dives per site per year suggested by Schleyer & Tomalin (2000) and the most popular site, Anse Chastanet, received four times the maximum recommended capacity.

Based on interviews with divers and dive businesses (Chapter 5), certain sites appeared to have exceeded their carrying capacity, particularly in terms of crowding and aesthetics, for example Anse Cochon and Anse Chastanet. Sites with visibly damaged corals and coral rubble are less attractive to divers (Vanclay, 1988; Westmacott et al., 2000) and visitors to St.Lucia's sites did not like seeing broken or dead corals (Chapter 5). Jameson et al. (1999) proposed that management action was required if sites consisted of 4% or greater of broken coral colonies, or if the percentage cover of coral rubble equalled or exceeded 3%.

6.4.1 Management options for St. Lucia's reef-tourism

Preventing the degradation of St. Lucia's remaining reefs is paramount if the islands' reef-tourism is to survive and expand. Management needs to include a combination of previously mentioned strategies, and three options with the greatest potential for reducing in-water tourism impacts are outlined below.

Managing reef users' behaviour

Briefings, in conjunction with dive leader intervention with divers seen to be damaging the reef, have been found to reduce diver contact rates with the reef by half for boat dives, and by two-thirds for both boat and shore dives (Chapter 2). Companies taking visitors on tours to the reef should therefore ask their staff to give briefings and tell people that leaders will approach them if they are seen to be damaging the reef, and that if they continue to damage the reef, they will be asked to end their dive. If dive leaders intervened when they saw their clients damaging the reef, they could reduce contact rates significantly and sites within the SMMA may be able to withstand use greater than the maximum carrying capacity estimate of 7000. If one assumes dive leader intervention could reduce contact rates by a half to two-thirds, carrying capacity could be increased to 14,000 and possibly withstand use of up to 21,000 dives per site per year in well-regulated areas. These estimates do not include impacts to the reefs from other sources, and therefore a precautionary approach would be to use the lower carrying capacity estimate of 14,000 dives per site per year or less.

Increasing the number of dive sites

All dive and snorkel sites in the SMMA are effectively adjacent to one another, or adjacent to zones being used for other activities. Increasing the number of dives sites within the SMMA is therefore unlikely to be an option unless zones such as yacht mooring areas, were to be closed and opened up for divers and snorkelers. However, areas along the coast to the south and north of the SMMA may have reef areas that could be used. This option would have associated costs, including the installation of further mooring buoys, necessary to avoid damage to the reefs by anchoring. Increasing the number of sites available for diver and snorkeler use could accommodate visitors from the more heavily used sites within the SMMA, therefore releasing some of the visitor pressure. The wreck Lesleen M, is popular with divers and was the third most-dived site in 2000 (Table 6.2). Creating another or several more artificial reefs may be a good method to provide more of this type of dive. This would require detailed research to determine how feasible such an operation would be and would depend on the environmental impacts of creating such sites and identification of appropriate sites.

Some sites are being degraded by sediment pollution (Sladek Nowlis et al., 1997; Schelten, 2002), and as a consequence, are no longer being used by dive companies. Examples include Hummingbird wall and Bat Cave, both of which are in the SMMA. Given that sites in the SMMA are already being intensively dived, and that the number of sites in the SMMA cannot be increased, the loss of Hummingbird wall and Bat Cave comes at a cost in terms of overall scope for growth of the island's reef tourism. Using theoretical carrying capacity estimates that range from 4000 to 7000 dives per year (Table 6.1) and an average cost of US$40 per dive (using St. Lucia's dive business prices in 2001), the cost of sediment pollution per site per year could range from US$160,000 to US$280,000. That cost is conservative because it does not include other foregone income to businesses reaped from providing transport, accommodation or other goods and services associated with visitors staying in St. Lucia. At present, the inability to use sites affected by sediment pollution does not present a problem because other sites can be used. However, if St. Lucia is to expand its tourism industry, the number of dive and snorkel sites will have to increase once the present sites reach their carrying capacity limits. Not being able to use sites because of sediment pollution could result in significant economic losses and prevent further expansion of the island's reef tourism.

More equal distribution of divers and snorkelers among sites

In 2001, 137,000 dives occurred, spread over approximately 42 sites. If these dives had been distributed equally, this would have amounted to 3,262 dives per site, which is well below the recommended carrying capacities. However, over 60% of dives in 2001 were done in the SMMA, divided primarily between 11 sites, which equates to 7,473 dives per SMMA site, per year if divided equally. This is just above recommended carrying capacities. Reefs could withstand this pressure better if diver and snorkeler behaviour was managed (see below). As site use within the SMMA is unlikely to drop, the first step would be to implement a site-specific maximum number of dives per year, possibly using a scheme of tradeable permits. Site use outside of the SMMA could potentially be increased as their use is below recommended carrying capacities. Depending on the carrying capacity level chosen, diver numbers and estimated additional revenues would differ (Table 6.3).

TABLE 6.3 POTENTIAL INCREASES IN CARRYING CAPACITY PER SITE OUTSIDE OF THE SMMA AND THEIR ESTIMATED ECOLOGICAL AND ECONOMIC IMPACTS

	Carrying capacity levels (no. dives site^{-1} yr^{-1})			
	4,000	**5,000**	**6,000**	**7,000**
No. of additional dives that could be done per year [a]	2232	3232	4232	5232
No. additional divers per year [b]	558	808	1058	1308
Additional economic revenue per year [c] (US$ million)	89,280	129,280	169,280	209,280
Estimated total no. of additional contacts with the reef yr^{-1} without dive leader intervention [d]	22,320	32,320	42,320	52,320
Estimated range of total no. of additional contacts with the reef yr^{-1} with dive leader intervention [e]	7,440 to 11,160	10,773 to 16,160	14,105 to 21,160	17,440 to 26,160

Estimates assume number of dives carried out outside of the SMMA equal 54,800 (40% of 2001 estimates) and that 31 sites are available for use. Equal distribution of dives throughout these sites equals 1768 dives per site per year. a = no. dives that could be done in addition to 1768 dives per site per year for each carrying capacity level; b = no. additional dives divided by 4 (the average no. dives done per diver per trip, Chapter 1); c = average cost per dive is US$40 (Chapter 4); d = no. additional dives multiplied by (0.25 x 40) (mean no. contacts per min x mean time spent on dive in mins, Chapter 2); e = contact rates reduced by half and two-thirds with dive leader intervention (by half for boat dives only, and by two-thirds for both boat and shore dives).

An increase in the number of divers, and therefore dives, would result in further reef damage, the magnitude of which would depend on the presence or absence of diver-intervention measures, and on other pressures related to human activities. Pressures could act individually or synergistically with diver pressure thus reducing a site's ability to withstand particular carrying capacities.
To predict the impact of increased dives, detailed records of numbers and distribution of users, including snorkelers, are required, however no such data are currently available. Companies should also take into account the fact that crowding may become a problem, which could prevent them from expanding to the maximum potential carrying capacities at individual sites. Crowding is an issue that has already detracted from visitors' enjoyment of St. Lucia's reefs, particularly so for divers (Chapter 5).

A summary of options for managing St. Lucia's reef tourism is shown overleaf (Table 6.4).

TABLE 6.4 OPTIONS FOR MANAGING ST. LUCIA'S REEF TOURISM

Options	Pros	Cons
Increase marine park fees (Chapter 4): • By the amount that 75% of visitors sampled would be willing to pay i.e. US$6 per diver per day US$20 per diver per year US$2 per snorkeler per day	This would increase park revenues by US$15,900 per year and pay for minimum park management standards.	There would be an administrative and printing cost to changing present ticket booklets to incorporate the new fee amount. There may be a reduction in number of divers or snorkelers visiting sites in the marine park.
• By the amount that 50% of visitors sampled would be willing to pay i.e. US$7 per diver per day US$30 per diver per year US$4 per snorkeler per day	This would increase park revenues by US$32,800 per year and almost cover the costs of ideal park management standards. A decrease in visitor numbers due to an increase in fees could help sites stay within their carrying capacity limit.	
Increase marine park mooring fees to comparable prices found elsewhere in the Caribbean*	This would increase park revenues to improve management standards.	There may be a drop in numbers of yachts stopping over in the marine park.
Spread the use of sites by divers and snorkelers more equitably (Chapter 6)	This would relieve the pressure of excessive numbers of divers and snorkelers at the most popular sites.	Unless visitors' behaviour in the water is controlled, limiting numbers of people allowed to use a site may not prevent it from being degraded.
Increase number of sites available for diving and snorkeling outside of the park (Chapter 6)	This would accommodate an increase in numbers of divers and snorkelers and take the pressure off some of the sites within the park.	There may be conflict with other uses e.g. fishing and industry. Moorings would have to be installed and maintained at additional cost to the marine park.
Improve the quality of dive sites* • reduce pollution e.g. sediment, household waste, sewage	Sites that are currently not used because of pollution from excessive sediment and garbage could be re-opened for tourism. Pollution at current sites would be reduced.	This would require initiation and enforcement of measures to reduce pollution by government departments, industry and the public.
Require all dive and snorkel leaders to intervene with damaging behaviour (Chapter 2)	Could reduce diver contact rates by between a half and two-thirds thereby allowing sites to increase their carrying capacities.	Leaders would require appropriate training and a form of enforcement would be necessary.

* This was not studied in this thesis but is listed as a suggestion.

6.5 CONCLUSION

Managers of coral reefs need to implement a mixture of regulatory measures to maximise benefits from tourism whilst maintaining the quality of the resource. There needs to be a much more careful allocation of numbers of divers and snorkelers to sites, and sites need to be matched with activities based on their ability to absorb damage resulting from them. Training dives for example, should only be allowed at sites without corals or other susceptible life forms. Management options should include a combination of tourist-impact amelioration measures such as: provision of moorings, walkways and pontoons; limitations on numbers of people allowed at sites over a given period; closer supervision of divers and snorkelers, and increasing sites available for use. Fees from divers and snorkelers in addition to yacht mooring fees could meet the cost of implementing reef management measures. Fees are currently low compared to overall trip costs or what people are willing to pay, and yacht mooring costs are lower in St. Lucia than elsewhere in the Caribbean. Diver, snorkeler and yacht mooring fees could be increased, particularly if regions are attracting a higher-paying clientele.

St. Lucia, like other small islands, has a growing tourism industry based on its reefs. With the growing quest for natural and unspoilt coral reefs, these islands are in a prime position to benefit from marketing their product to the high-value tourist. By adopting the management options outlined in this chapter, in combination with tighter regulations of other, often land-based, activities that affect the marine environment, countries could protect their coral reefs whilst simultaneously accommodating an expansion in their tourism industry.

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Chapter 7: General discussion

The aims of this thesis were to:

(1) determine the damage that divers and snorkelers inflicted on reefs and whether visitor, dive/ snorkel leader, or site characteristics could be used as predictors of damage;

(2) determine the economic gains from dive and snorkel tourism for the country's tourism industry, for the dive and snorkel companies and for the marine park, and whether visitors would be willing to pay more to use sites within the marine park than they were currently paying;

(3) determine whether the quality of the reef environment affected visitor appreciation and how visitor perception of reef quality compared with biological and physical attributes measured by professional ecologists;

and

(4) use the information derived from the above to estimate the capacity of different reef sites for diving and snorkeling.

The degree to which these aims were achieved is discussed below.

7.1 Predicting damage to reefs

Observations of divers and snorkelers swimming on St. Lucia's reefs indicated that damage by diving or snorkeling could be predicted from diver and snorkeler, dive and site characteristics (Chapters 2 and 3). Trends found linking increased damage levels with the beginning of dive or snorkel excursions and use of a camera were similar to other observation studies done on reefs elsewhere. Despite the similarity between divers and snorkelers in more frequent contacts with the reef occurring early on during their dive or snorkel excursion, the underlying behaviours that produce this pattern are different for the two groups. Divers spent their first few minutes adjusting their equipment, and on shore dives, they had to swim over reef in shallow water, which brought them closer to the sea floor. In contrast to divers, snorkelers have less equipment to deal with and so most of their contacts are most likely due to walking across the reef in shallow water until it is deep enough to swim.

This research also revealed that higher levels of diver damage were recorded at night versus diving in the day, and on shore versus boat dives. It should be noted that the site used for shore and night diving in St. Lucia however, had reef formations starting at a depth of 2-3m and divers endeavoured to drop below the surface of the water even in these shallow depths, which necessarily brought them close to the reef. It is possible that diver contact with the reef on those dives could therefore be higher than expected for shore diving elsewhere if reefs are at greater depths.

This study is also among the few, if not the first, to quantify snorkeler damage. Snorkelers who wore a life vest had virtually no contacts with the reef since the inflated vests kept them on the surface of the water and snorkelers overall had generally far fewer contacts with the reef than divers. However, the popularity of certain sites for snorkeling means that damage by snorkelers at these sites could equal that of a few divers (Chapter 3). Many of St. Lucia's reefs are in relatively deep water and certainly not exposed at low tide, and so snorkeler contacts with the reef were mostly minimal. Reefs elsewhere in the world, which are in shallow water, such as those in the Indo-Pacific, are more likely to be trampled by snorkelers. Total impact by snorkelers on reefs would probably be greater than observed here for St. Lucia, since I recorded mainly impacts from swimming and none from snorkelers walking on reef.

Although briefing by dive leaders has been cited as one of the most effective ways of reducing diver damage to reefs, my research indicated that if briefings were given by local staff, whether to divers or snorkelers, it had no such effect (Chapters 2 and 3). It is possible that if briefings had been more detailed, visitors would have been more careful, but given the time constraints by which most tour businesses operate, it appears that briefings alone are insufficient to make any difference. If transport to a dive site is sufficiently long, and boat engine noise permits, briefings can be given effectively on the boat. Extended periods spent talking with visitors, giving them information on marine life and how the latter might be affected by their impacts can only be beneficial. In Medio et al.'s (1997) study, there was opportunity to do this (boat journeys were typically over 30mins), and divers spent the entire week diving on the reef. After receiving a full briefing once, shorter briefings were carried out. However, for many companies, new divers arrive daily, sites are much closer, boats are too noisy and schedules too tight. In such cases, extra vigilance and intervention by group leaders is necessary (Chapter 2). Only then can visitors' behaviour be noticed and dealt with. In fact, comments from visitors that I interviewed indicated that they had not been aware of their impacts to the reef and certainly did not mind being asked to change their behaviour in order to reduce their damage to the reef. Visitors even reported enjoying their dives less because they saw other divers damaging the reef (Chapter 5). Intervention and management of visitors would therefore reduce damage to the reef and ensure that visitors' experience of the reef was not spoilt by the behaviour of others.

7.2 THE SOCIO-ECONOMIC IMPACT OF DIVE AND SNORKEL TOURISM

The socio-economic value and importance of St. Lucia's reefs was apparent from the considerable revenue reaped from reef tours by dive and snorkel businesses and the fact that most jobs within those businesses were being done by St. Lucians (Chapter 4). The value of reefs in St. Lucia's marine protected area was highlighted by what visitors were willing to pay to visit them and by the fact that almost half of visitors said the presence of the protected area influenced their decision to visit the island. What also became apparent was that the fees to visit sites in the protected area were probably too low. My interviews with divers and snorkelers showed that virtually all of them would be willing to pay above the current fee. The fees could probably be raised substantially without causing a noticeable reduction in visitor numbers to those sites. However, even if numbers were reduced, this could have a positive effect due to fewer people visiting the sites resulting in less pressure and associated impacts. Fewer divers may also make it easier to keep within the theoretical carrying capacity (Chapter 6).

7.3 Visitor perceptions of reef attributes

The ecological quality of the reef, represented by fish and coral, and physical parameters affected visitors' appreciation of it. The most important motive for divers and snorkelers was seeing marine life and despite St. Lucia having few large animals, visitors still enjoyed their visit to the reef (Chapter 5). This is probably because the sites they were taken to were of good enough quality, apart from a handful of sites that stood out as being particularly polluted with garbage or with a lot of damaged coral (Chapter 5). Although visitors' recollections of certain things, such as numbers of fish and amount of coral in general were not accurate, they were aware of different sizes of fish, water clarity and garbage. One problem with comparing people's perceptions of, for example, numbers of fish with measurements taken by scientists of fish numbers is that we are comparing things of different magnitude. One is an overall impression of a site with respect to fish, and the other is a very precise measurement. Bearing this in mind, we should therefore not expect to always find that the two are linked, and that we should consider alternative methods. The results from this study, however, indicate that marine park managers and tourist businesses could put more effort into informing visitors about the marine life that is present. They could explain why certain sites might have more damaged coral or sediment than others and thereby justify why certain restrictions or controls are in place. Local communities and authorities could also be targeted to reduce garbage and waste entering the marine environment. In addition, government agencies and planning authorities could be alerted as to how their activities affect the quality of the marine environment, and the tourism which depends on it.

7.4 Carrying capacities of St. Lucia's reefs

The spread of diving and snorkeling activity on St. Lucia's reefs is currently heavily biased towards sites within the marine park compared to those outside (Chapter 6). There are also two sites within the park that are particularly popular with dive companies, due to their close proximity to resorts, and therefore easy access, and/or due to marketing. As a result, tourists coming to St. Lucia strive to visit these sites. One site, Anse Chastanet, received 20% of all diving activity over the period of the study, amounting to about 28,000 dives per year. This was well above theoretical carrying capacity suggested by other researchers (Chapter 6). Carrying capacities could be increased if dive leader intervention measures (Chapter 2) were adopted, possibly increasing the maximum theoretical values of 7,000 dives per site per year by 2-3 fold. Similar intervention by snorkel leaders could raise the carrying capacities of snorkeling sites.

Clearly, sites exposed to additional pressures, such as sediment pollution from nearby rivers, organic or chemical waste from human settlement, agriculture and industry, and sites that have suffered from disease or storm damage, may require lower carrying capacities to be set.

7.5 Conclusion and implications for management

The information on dive site use throughout St. Lucia (Chapter 6) shows that certain sites are far more popular than others. This together with evidence of tourist impacts to reefs (Chapters 2 and 3) and visitors' and dive business members' perceptions of them (Chapter 5), indicate that some of St. Lucia's reefs are probably being degraded because of over-use and damage by tourists and pollution from other human activities. Management of St. Lucia's reefs therefore needs to take into account the various impacts to the marine environment and act on them. St. Lucia's marine protected area is a popular attraction with visitors and these same visitors could help fund more of the management costs if user fees (Chapter 4) and yacht mooring fees were increased (Chapter 6).

Management strategies include increased visitor supervision, limitations put on the number of divers and snorkelers allowed to use any one site over a given time and establishment of new sites so as to increase the number of sites available for tourism. Enforcement of regulations would necessarily require increased patrolling and monitoring by marine park staff and funding for this could come from increased user and mooring fees (Chapters 4 and 6).

Other negative impacts, including sediment and garbage pollution which reduce the aesthetics of the reefs and detract from visitors' enjoyment, could be reduced by improving waste treatment and garbage disposal.

The quality of the marine environment is important to both tourists and residents and impacts that reduce reef quality could affect the viability of industries that rely on that resource. Tourists contribute substantially to St. Lucia's economy and could potentially contribute more to funding the management and protection of its marine resources. A combination of managing visitor behaviour, site use, land-based activities, public education and enforcement of marine park regulations could help make St. Lucia's reef-tourism a long-term, profitable and sustainable venture.

APPENDIX A: Questionnaire 1

Date	Time
Site	
Name	
D Ref ____	

The following questions are based **solely** on your **last dive.**

1. Was there a particular highlight during your last dive? If so, what was it?

2. Was there a particular bad or low point during your last dive? If so, what was it?

3. In your opinion, how did you rate the following:

	5 *very good*	**4** *good*	**3** *average*	**2** *poor*	**1** *very poor*	**0** *no opinion*
numbers of fish	☐	☐	☐	☐	☐	☐
numbers of small fish	☐	☐	☐	☐	☐	☐
numbers of big fish	☐	☐	☐	☐	☐	☐
number of different types of fish	☐	☐	☐	☐	☐	☐
amount of living coral	☐	☐	☐	☐	☐	☐
numbers of large corals	☐	☐	☐	☐	☐	☐
number of different types of coral	☐	☐	☐	☐	☐	☐
underwater visibility	☐	☐	☐	☐	☐	☐

4. For the same factors as above, was it more than or less than you expected?

	5 *a lot more than than expected*	**4** *more than expected*	**3** *same as expected*	**2** *less than expected*	**1** *a lot less than expected*	**0** *no opinion*
numbers of fish	☐	☐	☐	☐	☐	☐
numbers of small fish	☐	☐	☐	☐	☐	☐
numbers of big fish	☐	☐	☐	☐	☐	☐
number of different types of fish	☐	☐	☐	☐	☐	☐
amount of living coral	☐	☐	☐	☐	☐	☐
numbers of large corals	☐	☐	☐	☐	☐	☐
number of different types of coral	☐	☐	☐	☐	☐	☐
underwater visibility distance	☐	☐	☐	☐	☐	☐

5. How much of the following did you notice?

	4 *a lot*	**3** *some*	**2** *a little*	**1** *none*	**0** *no opinion*
amount of damaged coral	☐	☐	☐	☐	☐

*what kind of damage did you notice?*______________________________

amount of sediment (silt) on coral	☐	☐	☐	☐	☐
amount of trash at the site	☐	☐	☐	☐	☐

6. Did the following factors affect your enjoyment of the dive ?

	increased enjoyment: *a lot*	*a little*	*made no difference*	*decreased enjoyment:* *a little*	*a lot*	*no opinion don't know*
	5	**4**	**3**	**2**	**1**	**0**
amount of damaged coral	□	□	□	□	□	□
amount of sediment on coral	□	□	□	□	□	□
amount of trash at the site	□	□	□	□	□	□
number of divers in the group	□	□	□	□	□	□

7. Overall, how satisfied were you with the dive ?

very satisfied	*satisfied*	*neither satisfied nor dissatisfied*	*dissatisfied*	*very dissatisfied*	*no opinion*
□	□	□	□	□	□
5	**4**	**3**	**2**	**1**	**0**

8. Is there anything particular to the marine environment that would have improved your dive today?

9. How many dives have you done so far on this trip?

10. How many dives do you plan on doing?

11. Approximately how many dives have you logged in total?

12. What is your highest diving qualification?
□ Resort/training dive □ Novice/Open Water □ Sports Diver/Divemaster □ Instructor

13. Are you a member of an environmental organisation(s)? Yes □ No □
If YES, which one(s)?

14. Do you read any articles on marine life in magazines or newspapers? Yes □ No □
If YES, which magazine(s) or newspaper(s)?

15. Where are you staying? *Name:*______________________________________

16. Is there anything else about your dive that you would like to tell me about?

THANK YOU VERY MUCH!

APPENDIX B: Questionnaire 2

Date	Time
Place	
Name	
M/F	

Questionnaire for visitors planning to dive or snorkel in St. Lucia

1. What is your main reason for visiting St. Lucia?
   To dive or snorkel ☐ For a general holiday ☐ To visit friends or relatives ☐
   For work or business ☐ Other *please specify* ☐____________________

2. Have you dived or snorkelled in this area on a previous visit? Yes ☐ No ☐

3. How long are you staying? ________weeks ________ days

4. Where are you staying? Name of hotel/guest house/or friends & family
   ____

DIVERS ONLY

5. How many dives do you plan to do on this trip? _____ day _____ night

6. Is this a dive package? Yes☐ No☐

7. How many dives have you logged so far on this trip? ________

8. Approximately, how many dives have you logged in total?_______

9. Do you need to rent any of your diving equipment? No☐
   Yes☐: Mask☐ Snorkel☐ Fins☐ Booties☐ Wetsuit☐ BCD☐ Reg☐ U/W Light☐

10. Will you be/are you doing any photography on your dives? No☐
    Yes☐ , What kind of camera will you be/are you using? ________________________
    Is it your own? Yes☐ No☐

DIVERS & SNORKELLERS

11. On average, how often do you snorkel? not at all☐ every day☐, ___days a week

12. Do you need to rent any snorkelling equipment? No☐ Yes☐ : Mask☐ Snorkel☐ Fins☐

13. Where have you dived and/or snorkelled on this trip in St.Lucia?

14. What are your 3 main motives for diving or snorkelling in St. Lucia? *Choose three and place in order 1=most imp, 3=least imp.*
    ☐ to view marine life in its natural environment___ ☐ for photography___
    ☐ for the enjoyment of diving or snorkelling itself___ ☐ for being active out-of-doors ___
    ☐ to be with friends or relatives___ ☐ other: *please specify*
    ☐ for the adventure / fun___

15. On your dive or snorkel, how important are the following to you?

	very important	*important*	*average*	*not so important*	*not important at all*	*no opinion (don't know)*
lots of fish	□	□	□	□	□	□
big fish	□	□	□	□	□	□
different types of fish	□	□	□	□	□	□
lots of living coral	□	□	□	□	□	□
different types of coral	□	□	□	□	□	□
particular species	□	□	□	□	□	□
(please specify) ________________________						
clear water	□	□	□	□	□	□
trash free sites	□	□	□	□	□	□

16. Roughly how many other people were in your immediate vicinity during your last dive and/or snorkel?

No of divers ___was this □ too many □ about right □ don't know/didn't notice
No of snorkellers ___was this □ too many □ about right □ don't know/didn't notice

17. Overall, how satisfied were you with your diving and / or snorkelling in St. Lucia?

	very satisfied	*satisfied*	*neither satisfied nor dissatisfied*	*dissatisfied*	*very dissatisfied*	*no opinion*
Diving	□	□	□	□	□	□
Snorkelling	□	□	□	□	□	□

18. Overall, what have you enjoyed most about the marine environment of St. Lucia?

19. Has anything in particular reduced your enjoyment of the marine environment of St. Lucia?

20. Aside from the marine environment, is there anything in particular that would improve your diving or snorkelling experience in St. Lucia? *Prompts: Signs, Information boards/leaflets, Shelter, Litter bins, Refreshments, Toilet, less touting....*

21. Have you visited any other coral reefs in the world? No□ Yes□
    a. Which would you say was the best reef and why?

    Name of reef/area: Country: Reason:

    b. Which was the worst reef and why?

    Name of reef/area: Country: Reason:

22. Approximately, what is the total (personal) cost of your holiday? _________ *note currency*

23. Was it a package holiday? No□ Yes□ *what does it include?*
room□ airfare□ airport transfers□ diving□ tours□ meals□ *(circle) b'fast lunch dinner*

24. Can you tell me approximately what your airfare cost? No□ Yes□ _______ *note currency*

25. Roughly how much spending money have you allowed yourself on this trip?_____

26. What is your country of residence?________________________

27. Please tick the age category that applies to you

    □ under 20 □ 30-39 □ 50-59
    □ 20-29 □ 40-49 □ 60 or above

28. Are you a member of an environmental group or organisation? No□
    Yes□ *which one(s)?*

29. Do you read any articles on marine life in magazines or newspapers? No□
    Yes□ *which magazine(s) or newspaper(s)?*

30. Is there anything else about your diving or snorkelling that you would like to tell me about?

Thank you very much!

APPENDIX C: Questionnaire 3

Date	Time	Site	Org / Ind
D/S	M / F	Gp size	Weather
Name		Ref	

Questions for divers and snorkellers

1. In your opinion, for this site, how did you rate the following?

	5 *very good*	**4** *good*	**3** *average*	**2** *poor*	**1** *very poor*	**0** *no opinion*
fish life	□	□	□	□	□	□
coral life	□	□	□	□	□	□
underwater visibility	□	□	□	□	□	□
overall satisfaction	□	□	□	□	□	□

2. Is this the first time that you are trying out snorkelling or diving? **1**Yes □ **2**No □
3. Approximately how many dives have you logged in your total dive history?
4. What is your highest diving qualification?
5. Were you required to wear a flotation vest while in the water? **1**Yes □ **2**No □
6. What are your views on flotation vests? **5** *Like very much* **4** **3** *Neutral* **2** **1** *Dislike very much*
7. Was your decision to come to St. Lucia in any way influenced positively by the existence of the marine park? **1**□Yes **2**□ No
8. Now that you have been in the marine park, has your experience
   a. Satisfied your expectation □**3**
   b. Exceeded your expectation □**4**
   c. Not satisfied your expectations □**1**
   d. Made no difference □**2**

Revenues from your user fee go directly into management of the existing marine park and into programs that include: scientific research, monitoring of the marine environment e.g.coral, fish & water quality, public information, provisiton + maintenance of moorings, promotion of technologies & surveillance and inforcement. To increase the effectiveness of the marine park, the SMMA has identified further areas for development:

Rank

- ►Increase implementation and enforcement of existing policies e.g. ↑patrols carried out by the rangers, so improving the effectiveness of protection..............
- ►Develop alternative employment programs for fishermen who are displaced by no-fishing zones..
- ►Increase facilities for users of the marine park such as developing snorkel trails..................
- ►Train fishermen in deep sea fishing techniques to divert pressure from the near-shore resources..
- ►Establish a trust fund to acquire critical land and beach area for conservation purposes..........
- ►Develop programs to share information and experiences with other marine parks e.g. the ranger exchange program...

9. These ideas could be developed only if revenues were increased, for example by increasing user fees. If you were assured that any increases in user fees would be used to promote these activities, what is the maximum you would be willing to pay for access to reefs in the marine park? (All fees are in US dollars)

Divers	Per day	a. 5.00	Per year a. 15	**Snorkellers**	Per day a. 2.00
		b. 6.00	*(valid for* b. 20		b. 3.00
		c. 7.00	*12 months)* c. 30		c. 4.00
		d. 8.00	d. 50		d. 5.00
		e. no increase	e. no increase		e. no increase

10. At present there is no annual snorkel user fee. Would you have preferred to pay for an annual fee? 1Yes □ 2No □

11. What is the maximum you would be willing to pay for an annual snorkel fee?
a. 10 b. 15 c. 20 d. 30 e. 50

12. With regard to the 6 areas listed for development, could you please rank each on a scale of 0-10 according to how important they are to you?
(**1**=not important, **2**=slightly important, **10** =very important, **0**=don't know)

Lastly we would like to ask you some questions about yourself:

13. Are you a member of any environmental conservation organisation(s)? **2** No □ **1**Yes □
*Which?*________________________

14. Do you read any articles on marine life in magazines or newspapers? **2**No □ **1**Yes □
*Which?*________________________

15. Please could you indicate the total annual income level that best fits your household?

a. up to $20,000 c. from $40,001 to $60,000 e. above $80,001

b. from $20,001 to $40,000 d. from $60,001 to $80,000

16. Is there anything else that you would like to add?

APPENDIX D: Questionnaire 4

Date

1. Name ☐dive shop ☐hotel ☐other (specify)________________

2. When did this operation open?

3. Are you affiliated to a hotel? If yes, which?________________________________

4. Is the hotel a separate business from the dive shop? ☐Yes ☐No

5. Please could you indicate what sites you dive and snorkel at on the attached map?

6. Has the introduction of the SMMA/CMMA user fee for **divers**, caused you to change how much you use these fee-paying sites?

☐**Yes**

Sites used less often:

Sites used more often:

Sites no longer used:

☐ **No**, made no difference

7. Has the introduction of the SMMA/CMMA user fee for **snorkellers**, caused you change how much you use these fee-paying sites?

☐**Yes**

Sites used less often:

Sites used more often:

Sites no longer used:

☐ **No**, made no difference

8. What is your boat capacity?

Boat	Boat type *eg dive boat, catamaran, fishing boat*	Capacity *define whether for snorkellers or divers*
1		
2		
3		
4		
5		

9. Is the ownership of the dive shop
    a. completely local
    b. completely foreign
    c. other:________% local owned

hotel:
    a. completely local
    b. completely foreign
    c. other:________% local owned

10. On average, how many divers do you get a year?

11. What is the average number of dives done per diver?

12. On average, how many snorkellers do you get a year?

13. On average, how many snorkel trips (organised ones) do the snorkellers take?

14. What is the average package value per diver per stay?

15. Do you have a retail store associated with the dive shop/hotel? ☐Yes ☐No

16. What is your estimate of gross value of revenue generated annually from total sales?

17. What is your annual net profit?

18. What percentage of total sales are derived from:
    a. Diving and snorkelling
    b. Equipment rental
    c. Retail sales

19. Does this vary throughout the year i.e. High and low season?

20. Through whom are packages sold offshore?
    a. tour operators
    b. travel agency
    c. dive shop's own marketing office
    d. other dive shops
    e. other

21. On average, how much revenue do you make annually from packages sold offshore?

22. Are there any taxes or fees that you are required to:
    a. collect and remit eg SMMA fees, room tax____

    b. pay____
    (to local/central government, any other association)

23. How many employees do you have?

	St. Lucian		Other Caribbean		Other non-Caribbean	
	Full time	Part time	Full time	Part time	Full time	Part time
Management						
Average salary EC $						
Instructors						
Average salary EC $						
Divemasters						
Average salary EC $						
Other						

24. Do you think that dive tourism has increased? If yes/no what do you think this is due to? *E.g. marketing, increase in Eco-tourism, presence of Marine Park, quality of service....*

THANK YOU VERY MUCH!

Map of St. Lucia (next page) –used to mark location of sites used by business for their dive and snorkel trips.

St Lucia


For more on St. Luci
visit us at
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Soaring to new heights.
LeSport
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Club St Lucia
Pigeon Island National Landmark
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Gros Islet
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GOLF COURSE
Glencastle
Rainbow
RODNEY BAY MARINA
Rex St Lucian
Royal St Lucian
Papillon
Bay Gardens
Palm Tree
Islander
Windjammer Landing
Orange Grove
East Winds
Wyndham Morgan Bay
GABLEWOODS SHOPPING MALL
Sandals Halcyon Cove
Friendship Inn
Castries
Modern Inn
Charles Airport
Auberge Seraphine
Sandals La Toc
Castries City Walk
GOLF COURSE
Babonneau
MARQUIS PLANTATION
Grande Anse Bay
Turtle Watching
GRANDE ANSE ESTATE
Four Roads Junction
Marigot Beach Club
Seahorse Inn
Inn on the Bay
Hurricane Hole
LOUVET ESTATE
Piton Flore Trail
River Rock Waterfall
Anse La Raye
Barre de L'isle Trail
Explore Fond D'Or
Dennery
Canaries
ERRARD PLANTATION
Anse La Liberté
Camping & Hiking
Mandelé Point
Prasiin Protected Landscape
East Coast Trail
Frégate Islands
Praslin Island
Anse Chastanet
Mamiku Gardens
Fox Grove
Soufriere
The Still Plantation
Soufriere Marine Management Association
Stonefield Estate
DIAMOND FALLS
BOTANICAL GARDENS
SULPHUR SPRINGS
Ladera Resort
Descartiers Trail
Fond Waterfall
Latille Falls
Micoud
Jalousie Hilton
Gros Piton Trail
The Blue Hole
Choiseul
Balembouche Estate
Laborie
Scorpion L
Savannes Bay
Mankoté Mangrove
Bel Vue Sugar Mill
Skyway Inn
Club Aquarius
Hewanorra International Airport
Maria Islands
Vieux Fort
Kamitral
Moule à Chique
Key to Map
Hotels
Nature Sites
Trails
Heritage Tourism Sites
Dive Sites
Airports
Main Roads
Minor Roads and Tracks
Forest Reserve
HelenAir
Caribbean
Growing to serve you better

APPENDIX E: Content of a typical dive brief

Good morning everyone. I would like to introduce to you Felix our boat captain and Javid our boat assistant. I am André and I will be leading you on your dive today. This site is called Piton Wall. It has many different corals and sponges and reef fish including snapper, parrotfish, trumpetfish and moray eels. The dive will be 40 minutes. We will enter the water from the back of the boat. Put on your BCDs and mask first, then make your way to the stern and put on your fins. First we will drop down to 60ft for 20 minutes and then come up to about 40ft for the last 20 minutes. Make sure you remember to always stay behind me, within sight and never deeper than me. Those of you with computers are allowed to go a bit deeper but you are responsible for monitoring your own dive profiles and must keep me within sight at all times. ***We are in the marine park. Please do not touch the coral and watch your fins so that you don't kick up sediment. If I see anyone touching the coral I will give you this sign (leader signals with hand) which means 'diver aware' and will ask you to come up higher above the reef.** I will carry with me a rattle. If you hear this sound (dive leader makes sound) then I have found something of interest such as a turtle or lobster to show you. At any point, if you do not see your buddy or me, look for one minute, and if you still do not find either of us, surface slowly. I will surface if anyone is missing for longer than one minute and if there are no problems, we will re-descend and continue the dive. Let me know when you reach 700psi. Anyone who wants to terminate their dive or who reaches 700psi before the end of the 40 minutes should signal me first and then ascend. Remember your safety stop at 15ft for 3mins and on the surface, signal to Felix that you want to be picked up. At the end of the dive I will signal for the group to ascend and we will do our safety stop. You must all have a minimum of 500psi back at the surface. Do not swim under the surface of the water to the boat because Felix will not be able to see you. At the ladder, take off your fins and weight belt and hand them to Javid before climbing up. Javid will be happy to help anyone who needs extra assistance with tanks. Those of you waiting to board please give the person climbing up space in case any part of their equipment comes loose and falls.
Thank you, are there any questions?

* The section in bold is the part that was added on my request. All dives including those two sentences were what I called 'briefing'. If dives did not include these words I called it a 'no briefing'. Dive leaders were then instructed to intervene on certain dives which I called 'intervention'.

psi = pounds per square inch, which is the air pressure within a diver's tank. A dive tank with air pressure of 700psi is approximately half full.

APPENDIX F: Kernel density estimates for significant variables used in the logistic regressions

1. Occurrence of impact

1.1 Constant

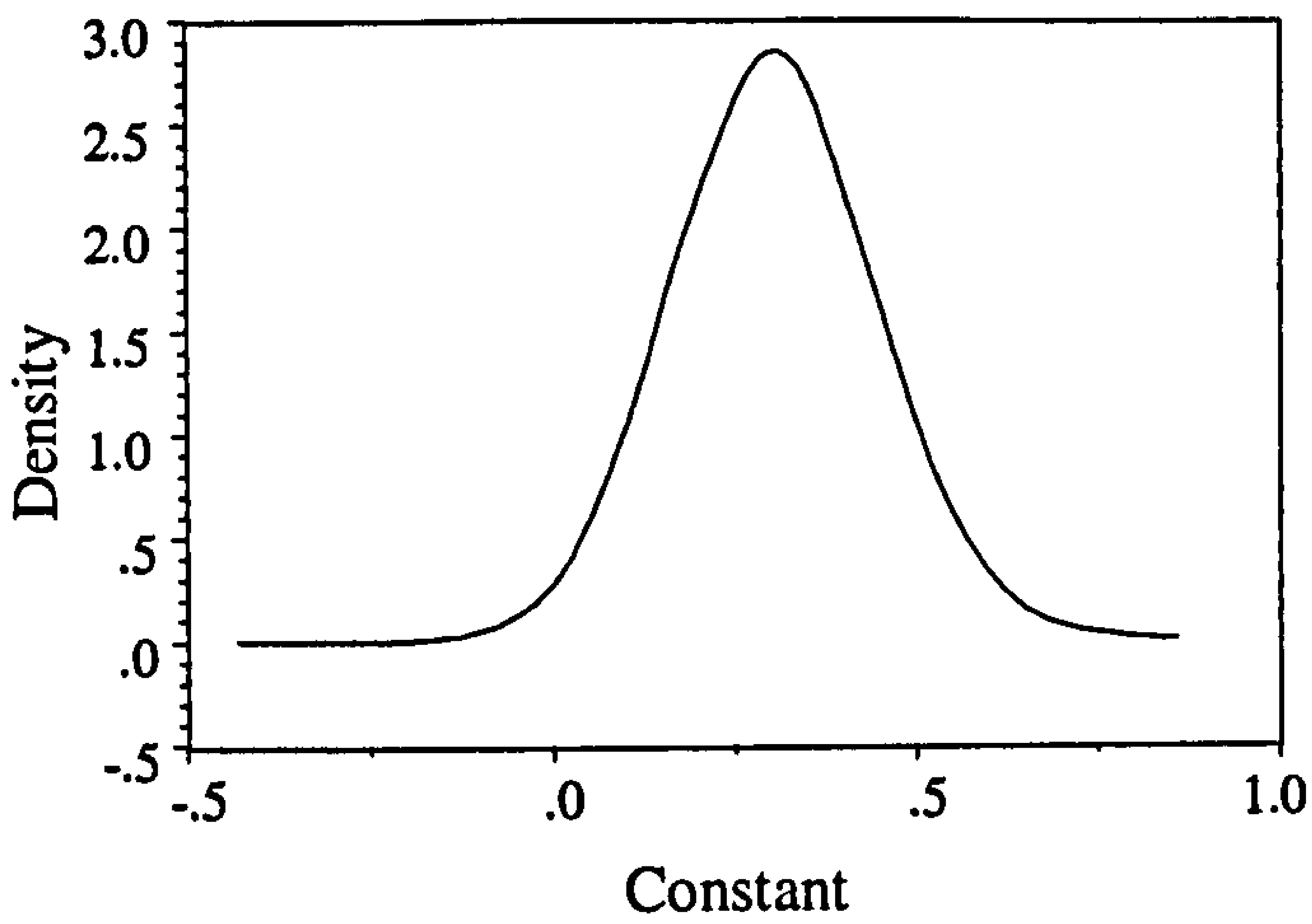

Fig. 1 Kernel density estimate distribution for constant

Kernel Density Estimator for Constant

Observations	= 9983
Points plotted	= 100
Bandwidth	= .019748
Statistics for abscissa values	
Mean	= .304976
Standard Deviation	= .138400
Minimum	=-.422800
Maximum	= .839600
Kernel Function	= Logistic
Cross val. M.S.E.	= .000000
Results matrix	= KERNEL

1.2 Shore dive

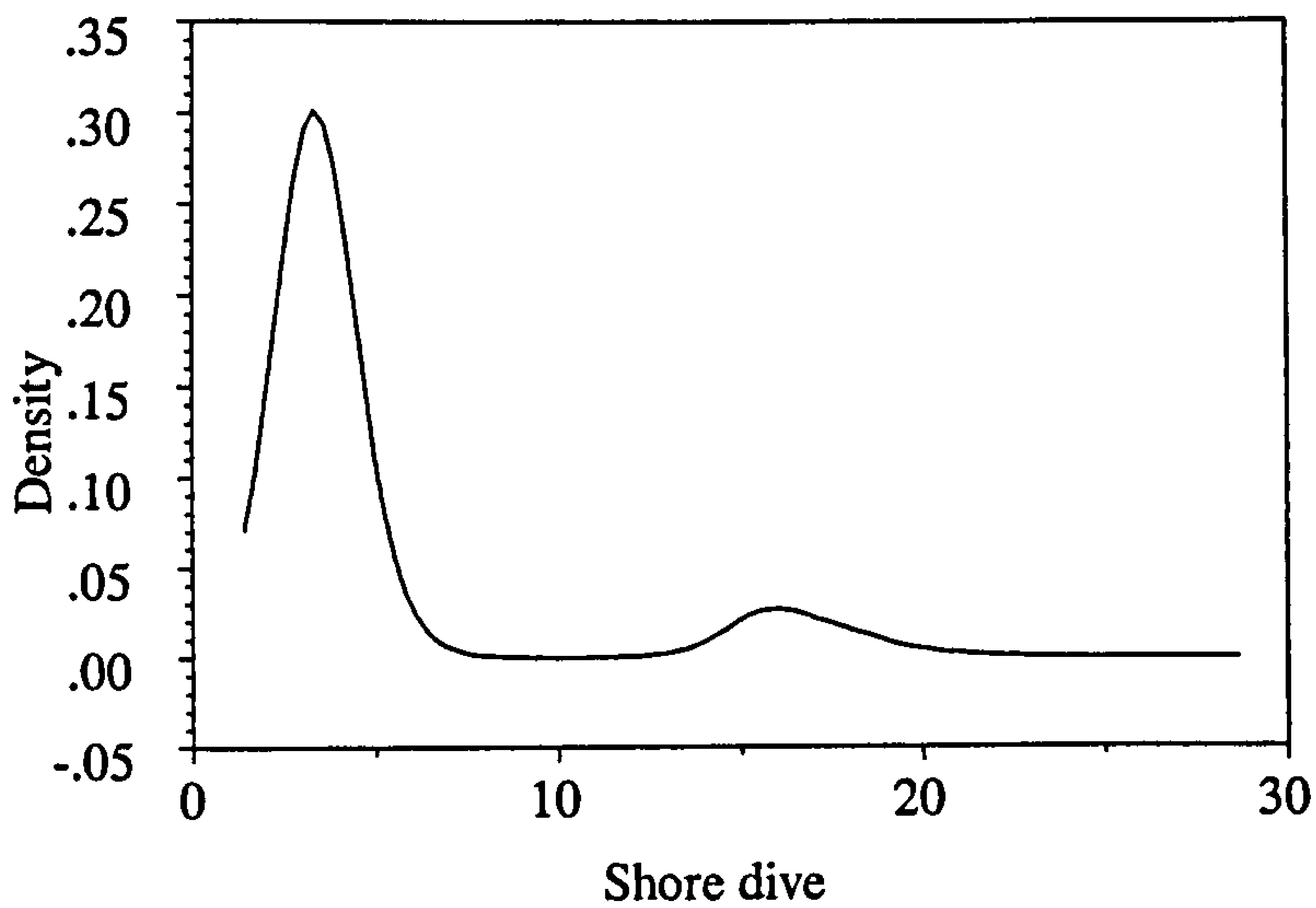

Fig. 2 Kernel density estimate for shore dive

Kernel Density Estimator for shore dive

Observations	= 9983
Points plotted	= 100
Bandwidth	= .611567
Statistics for abscissa values	
Mean	= 4.898967
Standard Deviation	= 4.286012
Minimum	= 1.754100
Maximum	=28.065900
Kernel Function	= Logistic
Cross val. M.S.E.	= .000000
Results matrix	= KERNEL

1.3 Photographer

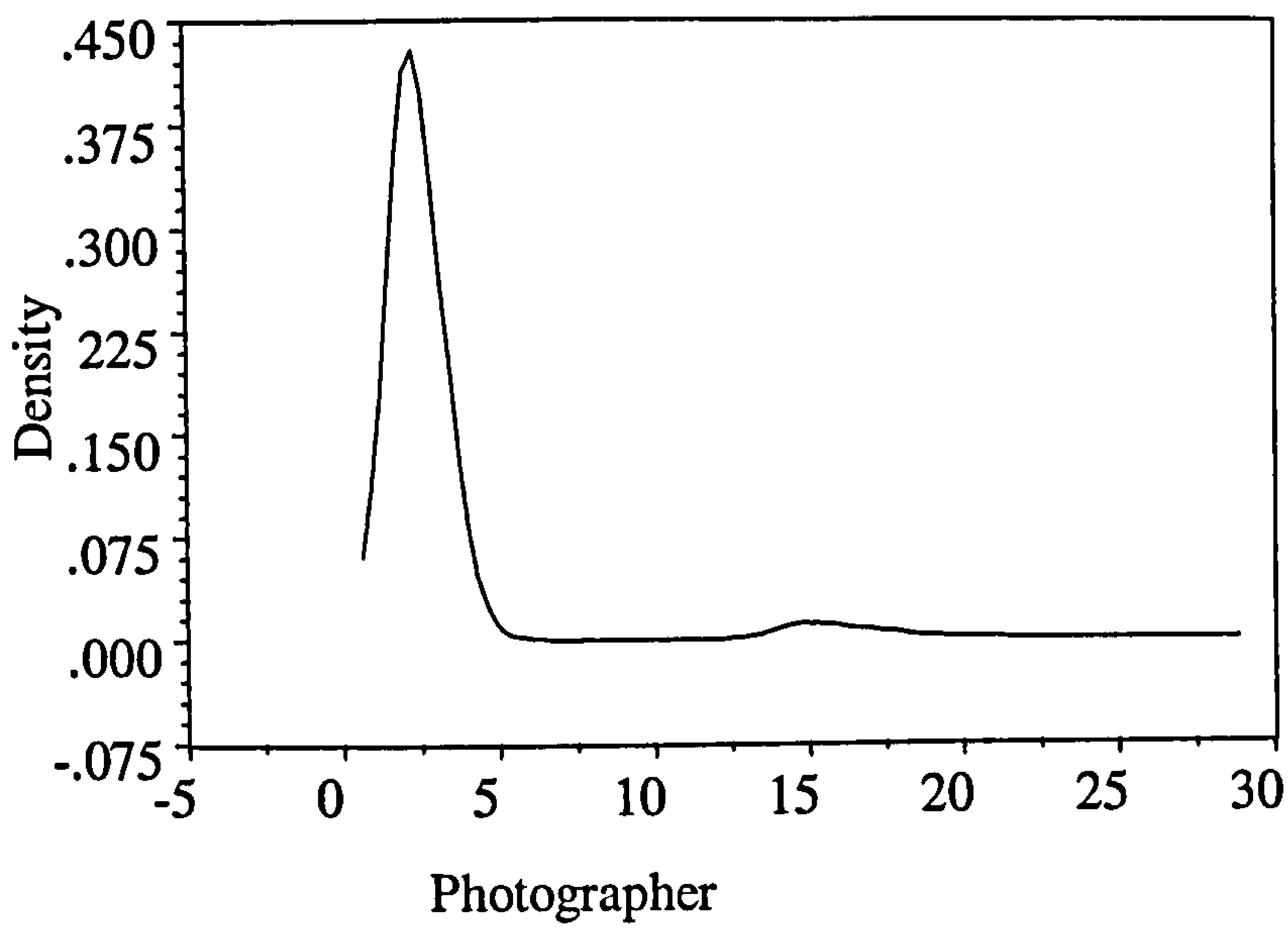

Fig. 3 Kernel density estimate for photographer

Kernel Density Estimator for photographer

Observations	=	9983
Points plotted	=	100
Bandwidth	=	.393733
Statistics for abscissa values		
Mean	=	2.930040
Standard Deviation	=	2.759378
Minimum	=	.734800
Maximum	=	28.475300
Kernel Function	=	Logistic
Cross val. M.S.E.	=	.000000
Results matrix	=	KERNEL

For all 9983 repetitions:

percentile	constant	photo-grapher	shore dive	log-likelihood	conver-gence
0.025	0.0377	1.3591	2.3630	-181.2737	0.0000
0.050	0.0792	1.4945	2.5166	-178.4885	0.0000
0.100	0.1280	1.6637	2.6882	-175.4517	0.0000
0.250	0.2118	1.9699	3.0097	-170.3769	0.0000
0.500	0.3041	2.3511	3.4350	-164.3010	0.0000
0.750	0.3970	2.8113	4.1170	-158.2830	0.0000
0.900	0.4817	3.4685	15.0839	-152.4632	0.0000
0.950	0.5336	3.7170	16.5644	-149.2722	0.0000
0.975	0.5797	15.1355	17.7552	-146.1770	0.0000

2. Occurrence of breakage

2.1 Constant

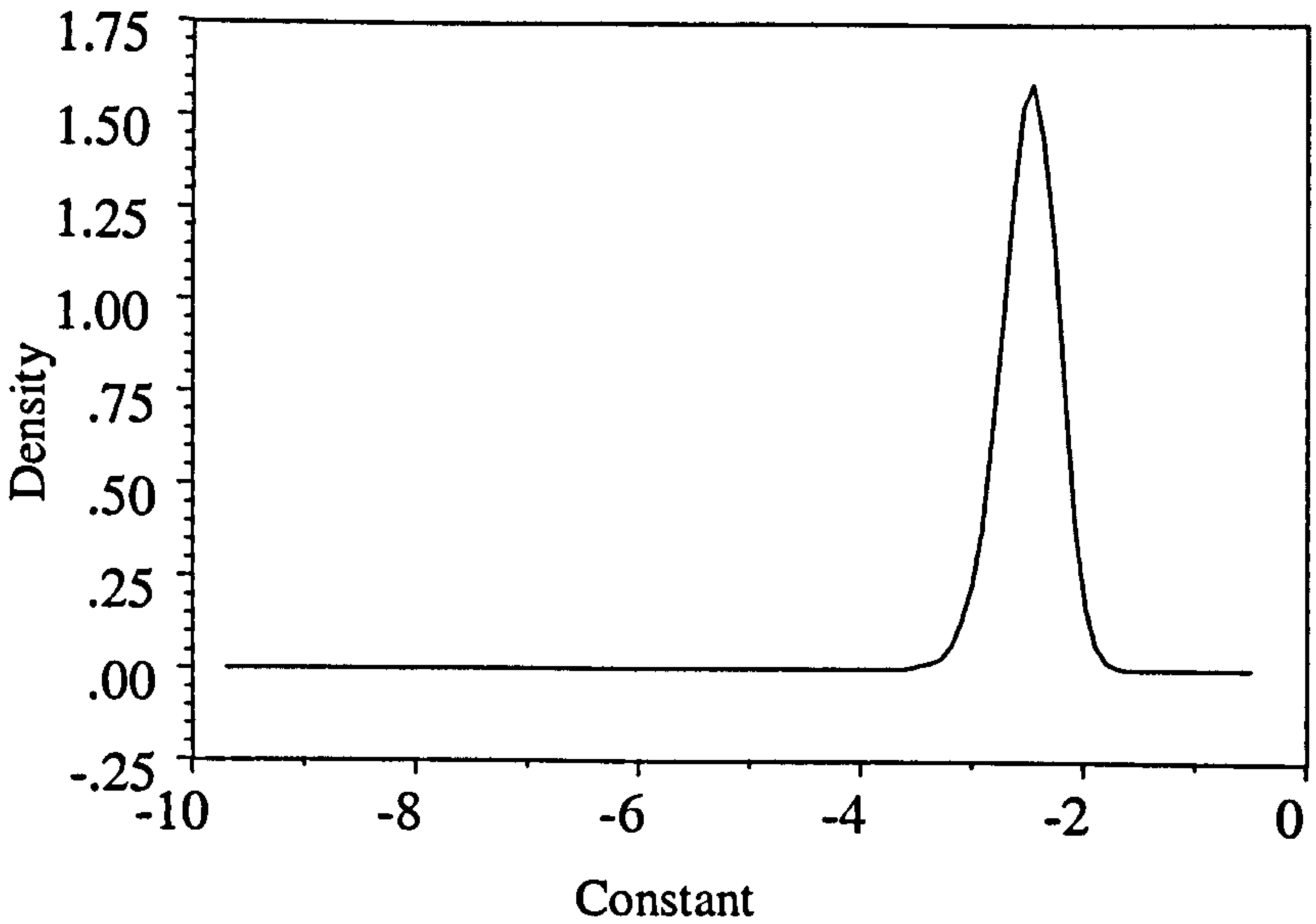

Fig. 4 Kernel density estimate for 'constant'

Kernel Density Estimator for constant

Observations	= 10,000
Points plotted	= 100
Bandwidth	= .040595
Statistics for abscissa values	
Mean	= -2.493252
Standard Deviation	= .284596
Minimum	= -9.746600
Maximum	= - .530300
Kernel Function	= Logistic
Cross val. M.S.E.	= .000000
Results matrix	= KERNEL

2.2 Intervention status

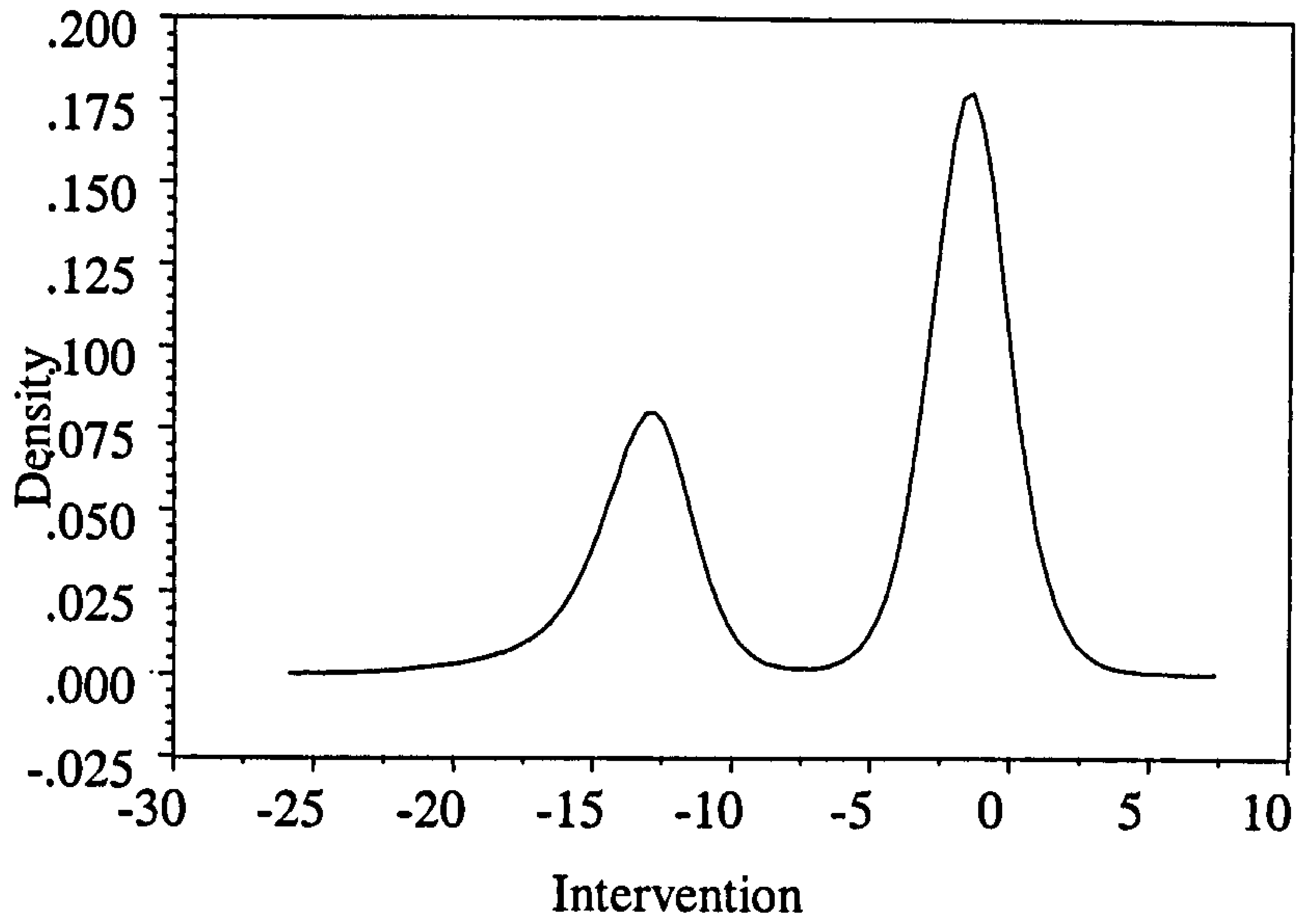

Fig. 5 Kernel density estimator for intervention

Kernel Density Estimator for intervention

Observations	= 10,000
Points plotted	= 100
Bandwidth	= .836970
Statistics for abscissa values	
Mean	= - 5.725569
Standard Deviation	= 5.867692
Minimum	= -25.380500
Maximum	= 6.525300
Kernel Function	= Logistic
Cross val. M.S.E.	= .000000
Results matrix	= KERNEL

2.3 Photographer

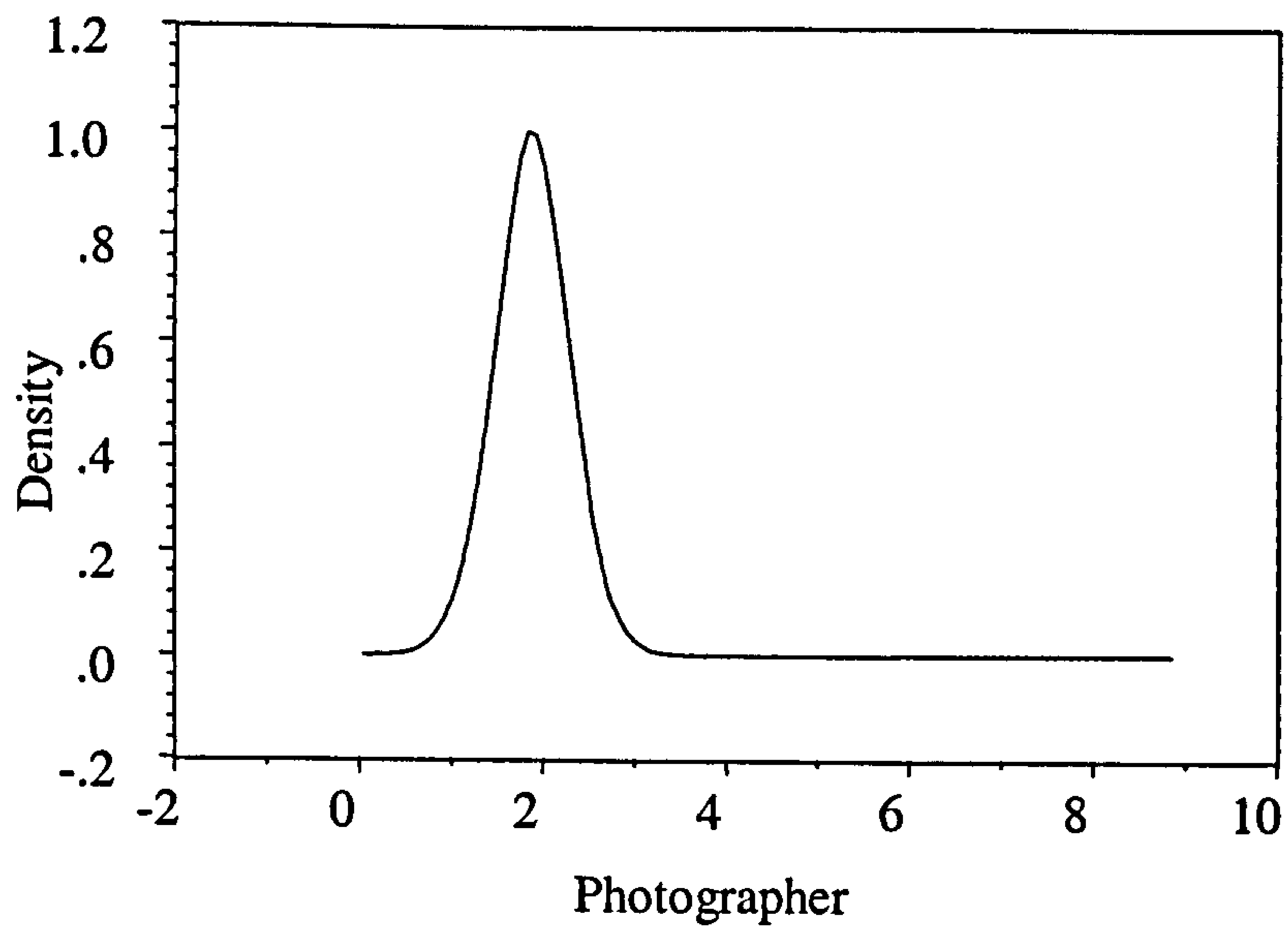

Fig. 6 Kernel density estimator for photographer

Kernel Density Estimator for photographer

Observations	=	10,000
Points plotted	=	100
Bandwidth	=	.059157
Statistics for abscissa values		
Mean	=	1.880176
Standard Deviation	=	.414725
Minimum	=	.024800
Maximum	=	8.787900
Kernel Function	=	Logistic
Cross val. M.S.E.	=	.000000
Results matrix	=	KERNEL

2.4 Cruiseship

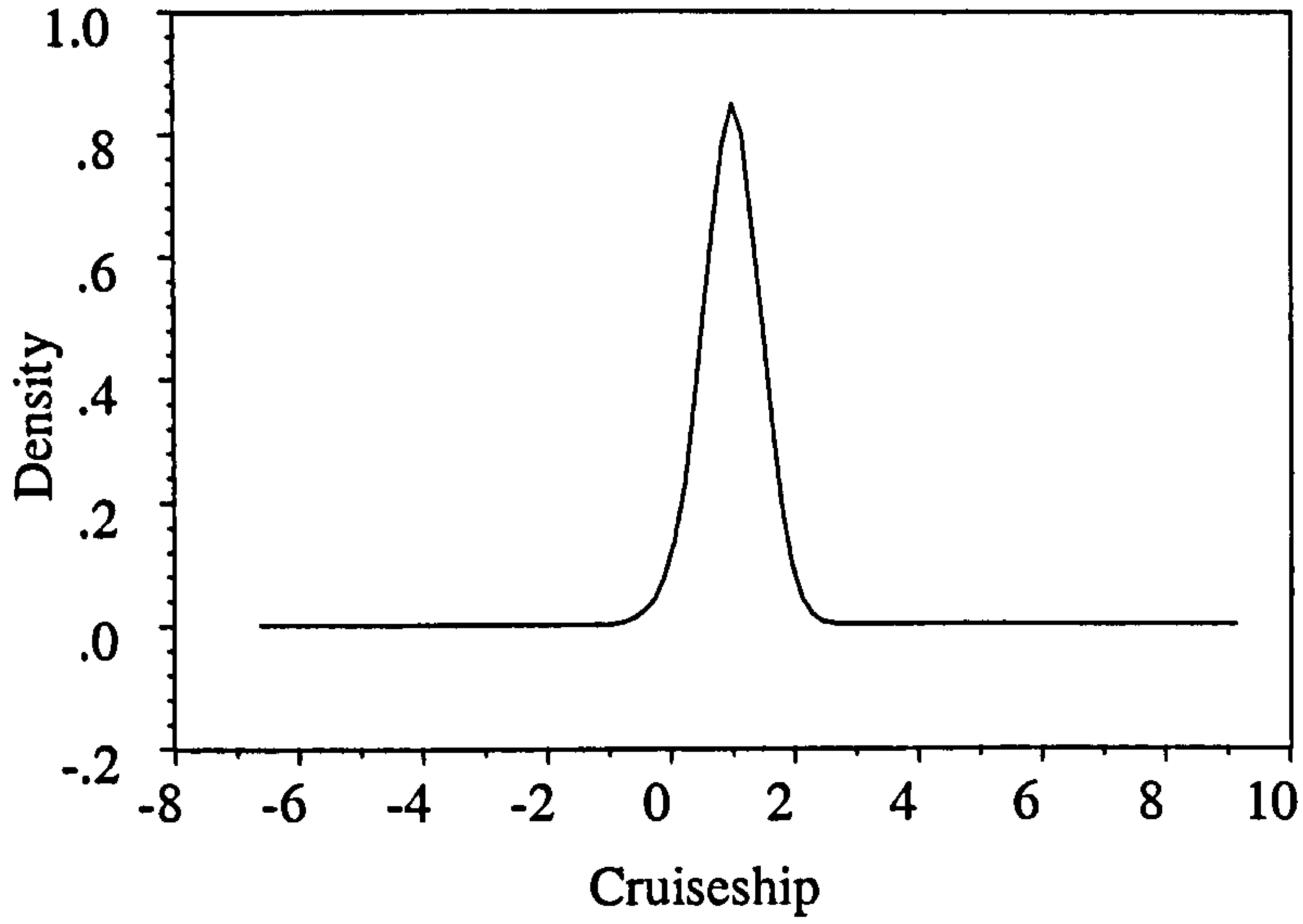

Fig. 7 Kernel density estimator for cruiseship

Kernel Density Estimator for cruiseship

Observations	= 10,000
Points plotted	= 100
Bandwidth	= .072308
Statistics for abscissa values	
Mean	= .971427
Standard Deviation	= .506923
Minimum	=-6.714100
Maximum	= 9.055500
Kernel Function	= Logistic
Cross val. M.S.E.	= .000000
Results matrix	= KERNEL

For all 10,000 repetitions:

percentile	constant	interven-tion	photo-grapher	cruise	log-likelihood	conver-gence
0.025	-3.0249	-16.3209	1.0802	-0.0262	-133.9326	0.0000
0.050	-2.9210	-14.8225	1.2165	0.1619	-129.9037	0.0000
0.100	-2.8116	-13.6890	1.3745	0.3632	-125.7941	0.0000
0.250	-2.6461	-12.5810	1.6207	0.6663	-118.9355	0.0000
0.500	-2.4778	-1.8779	1.8767	0.9917	-111.5439	0.0000
0.750	-2.3192	-1.3389	2.1436	1.2885	-104.1720	0.0000
0.900	-2.1894	-0.9188	2.3879	1.5613	-97.2741	0.0000
0.950	-2.1162	-0.6990	2.5308	1.7203	-92.9148	0.0000
0.975	-2.0461	-0.5378	2.6661	1.8635	-89.0059	0.0000

APPENDIX G: Range of environmental organisations belonged to, and material read by visitors

Environmental organisations/societies/clubs:
Audubon Society
Brazilian environmental organisation
Cape Cod Natural History Museum
Central Parks Conservancy (US)
Defenders of Wildlife (US)
Dolphin Conservation Society (UK)
Environmental institute
Greenpeace
Local wildlife group (Bristol, UK)
Marine Conservation (US)
Marine Conservation Society (UK)
National Trust (UK)
National Trust (St. Lucia)
Nature conservancy (UK)
Nature conservancy (US)
Project AWARE
Sea Education Association
Sierra Club
Somerset wildlife
Surf rider foundation
Surrey Wildlife Trust
Tourism Concern
Turtle conservation project in Grenada
Whale & dolphin society
Wildlife Conservation Society of New York, USA
Wildlife Trust
WWF
Job title or organisation worked for*:
Environmental Consultant
Environmental Lawyer
Environmental Protection Agency
Ranger for county regional park
County regional park
US Environmental Protection Agency
Environmental and planning law association of N. Ireland
Environmental and planning law association of UK
Reading material:
American marine organisation publications
Anchorage Daily News (local paper)
Aquarium magazines
Backpacker
Brazilian diving magazine
BSAC magazine
Cape Cod publications
Cape Cod Times (local paper)
Conde Nast Traveller
DAN magazine
DIVE

Reading material (continued):
Dive Training
DIVER
Divers World
Encyclopedia
Environmental engineering magazine
Escape magazine
Fish Identification books
German diving magazine
German magazines
Holiday magazines
Islands
National Geographic
National Geographic Adventure magazine
National Geographic Traveler
Natural History magazine
New York Times
Ocean realm
Outdoor magazine
Outside Magazine
PADI magazine
Rodale Scuba Diving
Scientific American
Scuba Diving magazine
Scuba Times
Sea Education Association publications
Sierra Club
Skin Diver
Smithsonian
Sport Diver
Sports Fishing magazines
Technical literature on water contaminants
The Telegraph newspaper
The Times newspaper
TIME magazine
Turtle Conservation newsletter
Various case laws & clean water act cases
Whale & Dolphin Society Newsletter
WWF publications
Yachting magazines
Television programs/ other:**
Discovery channel
Information on environmental matters read on the worldwideweb

* Counted as belonging to an environmental organisation;

** Counted together with reading material as reading articles on the environment.