

# Human perturbations and conservation strategies for San Pedro Mártir Island, Islas del Golfo de California Reserve, México

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## Summary

Many sea-birds are dependent for breeding on islands free from both mammalian predators and high levels of human disturbance. Yet human use of small islands appears to be increasing in many parts of the world, including the >150 islands in the Gulf of California, México. For this reason, the frequency and activities of human visitors to San Pedro Mártir Island, one of the most important sea-bird nesting sites in México, were studied over the course of 14 months of field work between 1990 and 1992. On average >350 people per month visited the near-shore waters. The most important visitors were: (1) commercial fishers in small open boats called *pangas*; (2) commercial fishers in larger ships; (3) private sport-fishers; and (4) commercial environmental-tourism groups. Private sport-fishing boats were most frequently observed, but private sport-fishers rarely landed on shore and caused little apparent disturbance to nesting or roosting sea-birds or California sea-lions (*Zalophus californicus*). Commercial companies concerned with environmental tourism also caused little apparent disturbance to sea-birds or sea-lions, but only because the company that brought the majority of 'ecotourists' developed and followed guidelines to minimize disturbance. Disturbance caused by all tourists can be reduced at minimal cost to both tourists and protected-area managers. Commercial fishers were responsible for most of the apparent disturbances to sea-birds and sea-lions; decreasing this apparent impact will be more difficult. Most apparent human impact was found to be short term and localized. However, commercial fishers and scientific researchers have the potential to cause long-term changes to the terrestrial ecology of the island by introducing exotic species.

*Keywords:* sea-birds, disturbance, ecotourism, pinnipeds, Gulf of California, *Sula* spp.

## Introduction

The flora and fauna of many islands include a high percent-

age of endemic species or are important breeding areas for sea-birds, pinnipeds, and sea-turtles. Because there are often no terrestrial mammals, these native species frequently lack behavioural, ecological and reproductive defences against mammalian predation (Loope & Mueller-Dombois 1989). As a consequence of the introduction of non-native species, most islands have experienced the extinction of native species (Elton 1958; King 1985; Leader-Williams 1988; Atkinson 1989; Harrison 1989).

Because of the sensitivity of island species to human perturbation, it is important to have data on the frequency, activities, and potential impacts of human visitors in order to design and implement effective management plans. This is especially true when management must depend on voluntary compliance because of the remoteness of the island or because the priorities of the government preclude effective enforcement.

The 100 or more islands and islets in the Gulf of California, México, are thought to constitute one of the most ecologically-intact archipelagoes in the world (Case & Cody 1983). This is because their lack of fresh water has hampered human habitation and economic exploitation, they are not located near trade routes or areas of strategic importance, and the surrounding area has had few paved roads and a low human population density. In the last 30 years, a 175% increase in the human population of the region, as well as substantial road construction and over-exploitation of fish stocks along much of the coast have increased the accessibility and attractiveness of the islands to commercial fishers, tourists, and other potential visitors. The number of people using these islands, and the problems associated with human use appear to be increasing (Bourillón *et al.*, 1994; Velarde & Anderson 1994). On the basis of continued, rapid human population growth in the southwestern United States and northwestern México (Reich 1984), we suggest that, without regulation, human impact on the islands will increase in the near future.

We collected data on the frequency and activities of visitors to San Pedro Mártir Island in the central Gulf of California, and made qualitative observations on their apparent impacts on the terrestrial vertebrates. Like most islands in the Gulf of California, San Pedro Mártir is officially protected as part of the Islas del Golfo de California Reserve (SEDUE 1989), but at the time of this study there was no management plan and no enforcement. The purpose of this study was to determine the potential negative impacts of

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human visitors on the terrestrial fauna of San Pedro Mártir and to suggest realistic potential management actions to decrease the impact of human visitors.

## Methods

### Study area

San Pedro Mártir (28°24.8'N 112°16.7'W) is a small (*c.* 1.9 km<sup>2</sup>) island with no permanent human inhabitants. It is the most isolated island in the Gulf of California (50 km from the mainland coasts of both México and the Baja California peninsula, and 43 km from the nearest island), is ringed by steep cliffs as high as *c.* 150 m, has no sand beaches, and only poor anchorages.

From about 1885 to 1888, San Pedro Mártir was inhabited by *c.* 135 guano miners and their families (Goss 1888). Their activities caused most breeding sea-birds temporarily to abandon the island, decreased plant cover, and increased erosion. However, their most significant long-term impact appears to have been the introduction of roof rats (*Rattus rattus*), which may influence the species composition and breeding success of sea-birds (Tershy *et al.* 1992).

Today, San Pedro Mártir has high densities of wildlife over most of its surface. It has two endemic lizards. The colonies of Brown Boobies (*Sula leucogaster*) and Blue-footed Boobies (*S. nebouxi*) are amongst the world's largest, and the colonies of Brown Pelicans (*Pelecanus occidentalis*) and Red-billed Tropicbirds (*Phaethon aethereus*) are amongst the largest in México (Tershy *et al.* 1992; Tershy & Breese 1997; B.R. Tershy, unpublished data). Almost the entire shoreline is used by California sea-lions (*Zalophus californianus*) for resting and breeding (Zavala-Gonzalez 1990), and, from March to June, by the Yellow-footed Gull (*Larus livens*), endemic to the Gulf of California, for nesting. From January to July, most of the upper surface of the island is covered with nesting boobies at a density of 0.25–0.65 nests/10m<sup>2</sup>, and nesting Brown Pelicans (Tershy *et al.* 1992).

### Data collection

Data on human use were collected during three periods, which amounted to 14 months at the islands, namely 20 March–4 August 1990, 13 February–3 July 1991 and 19 January–15 May 1992. Most observations were made from the south-east side of the island where we had a field camp (near the edge of a 32 m cliff overlooking the ocean), and six sea-bird study plots *c.* 70 m–*c.* 300 m above sea level. The field camp and all of the sea-bird study plots had unobstructed ocean views of *c.* 70°–240° which allowed us to observe all boats and onshore activity on the south-eastern half of the island. We could easily hear approaching boats often before we could see them, because there was no background noise from other motors in the area. Our field camp was one of the only areas on the islands without nesting sea-birds, the landing area we used was submerged on the highest

**Table 1** The six classes and 23 sub-classes of visitors to islands in the Gulf of California. The 17 sub-classes visiting San Pedro Mártir Island are in italics. The eight classes and sub-classes used in analysis are indicated by\*.

**\*Commercial fishers in pangas** (travelling and fishing in 5–9 m open boats):

*diving*: for lobsters, scallops, sea cucumbers, octopus, and/or spear fishing

*shark fishing*: using gill nets or long-lines

*hand-line fishing*: for groupers and other 'fin fishes'

*gill-net fishing*: for 'fin fishes'

**\*Commercial fishers in ships** (travelling in >15-m ships):

*shrimp trawler*: primarily for shrimp

*bottom trawler*: for 'fin fishes'

*purse seiner*: for sardine and anchovy

*shark fishing*: using gill nets or long-lines

*hand-line fishing*: from shore and from small boats for 'fin fishes'

**Commercial tourist:**

*environmental tourism* (non-extractive viewing of flora, fauna, and scenery)

*sport fishers*

\**SCUBA-divers* (sport fishers & SCUBA-divers combined for this analysis)

kayakers

yacht charters (sail boats)

**Private tourist:** (came to the island independently in privately-owned boat)

*sport fishers*

\**SCUBA-divers* (sport fishers & SCUBA-divers combined for this analysis)

\**yachts (sail boats)*

ecotourism

kayakers

**\*Research and photography:**

*research* (usually biologists – ecologists)

*photography* (film, still and video)

**\*Government:**

*navy patrols*

*navigation-light maintenance and repair*

tides so it was not used by breeding sea-birds or sea-lions, and the sea-birds on our study plots were habituated to our presence.

During the period from one hour before sunrise to two to three hours after sunset, we looked and listened for boats daily. When we detected a boat, we began periodic *ad libitum* sampling through 10×40 binoculars or a 25× spotting scope in order to determine the type of boat, its name or other identifying characteristics, the number of occupants, the date and time of arrival at the island, and the direction it came from (in order to determine the probable port of departure). Observations were initiated after arrival to determine the activities of the occupants (see below), and how many days the boat remained at the island.

We divided visitors into six major classes based on our previous observations of human activities in these islands: commercial fishers in ships; commercial fishers in pangas (open skiffs powered by outboard motors); commercial tours

**Table 2** Visits to San Pedro Mártir Island by month for 1990 (upper numbers in each row), 1991 (middle numbers), and 1992 (lower numbers). Boat visits: number of visits to island by boats (each visit by same boat counted separately). Boat days: total number of days all boats spent at island. People visits: number of people who visited island and its near-shore waters (includes all people regardless of whether they stayed on boat or also went ashore). Person days: number of people who visited the island by number of days they visited. People to shore: minimum number of people who went ashore one or more times during their visit. People to colony: minimum number of people who climbed to upper island to booby colony one or more times during their visit. Disturbance events: see Methods section for definition and list of disturbances. Data standardized by taking mean daily value for each month and multiplying by 30. Totals for each year are not comparable because of different study periods. Dash indicates no data recorded.

<i>Month</i>	<i>Boat visits</i>	<i>Boat days</i>	<i>People visits</i>	<i>Person days</i>	<i>People to shore</i>	<i>People to colony</i>	<i>Disturbance events</i>
January	–	–	–	–	–	–	–
	8	9	23	56	3	0	0
February	–	–	–	–	–	–	–
	22	32	600	898	28	28	0
	27	35	418	458	128	113	5
March	33	33	408	408	60	60	–
	20	24	736	887	174	173	4
	34	38	487	508	73	69	2
April	21	21	221	221	70	35	–
	21	23	255	263	65	63	1
	50	59	352	397	21	21	3
May	37	52	343	512	105	46	–
	47	64	266	345	55	22	23
	40	56	288	404	30	24	2
June	16	26	205	347	32	10	–
	85	158	717	1279	113	6	98
	–	–	–	–	–	–	–
July	27	40	258	387	38	2	–
	–	–	–	–	–	–	–
	–	–	–	–	–	–	–
<i>Yearly</i>	134	172	1435	1875	305	153	–
	195	301	2574	3672	435	292	126
	159	197	1568	1823	255	227	12
<i>Total</i>	488	670	5577	7370	995	672	138

(staff and tourists); private tourists; researchers and photographers; and government personnel. Depending on their activities and mode of travel, these six classes of users could be further divided into a total of 23 sub-classes (Table 1).

Because we were only able to see half the island, and landings and arrivals were made at the site which we could not see, our data only represent the minimum number of visitors to the island. However, the island is very small, and most boats that we could hear eventually came into our field of view. In 1991 and 1992, we often used kayaks to visit the north-west part of the island (which was normally out of our view) when we knew boats were there. We attempted to talk to at least one individual in each group of visitors (by radio or in person) to determine their port of departure, length of stay, and activities.

We recorded whether each group of visitors was respon-

sible for one or more of the following apparent impacts: (1) visible pollution caused by the disposal of gas, oil, or plastics; (2) disturbance of sea-birds or sea-lions, which we defined as causing adult sea-birds or sea-lions to temporarily leave the island for the relative safety of the air or water; and, (3) killing sea-lions, or indirectly killing sea-bird eggs and chicks by scaring away the guarding parent and exposing the young to predation and/or, alternatively, overheating.

We were not able to collect quantitative data on impacts of visitors (pollution and disturbance to terrestrial fauna) for three reasons: (1) boats on the north-west half of the island were not visible from our field camp; (2) boats on the south-east half of the island were observed continuously; and (3) we were unable to quantify the severity of a disturbance, or consistently to separate sequential disturbances by the same group of visitors. However, we felt that an indicator of the relative potential impact of different categories of visitors

would help in the design of effective management strategies for this and other islands in the Gulf of California.

Because the island has such high densities of sea-birds and sea-lions, we automatically assumed that during the sea-bird breeding season anyone who landed on the island outside of our field camp area scared sea-birds or sea-lions, or caused indirect egg and chick mortality. We feel this assumption was justified because we ourselves were rarely able to land anywhere on the island, other than our field camp site, without causing resting sea-birds or sea-lions to flee, and only with great care were we able to avoid scaring sea-birds with eggs or chicks and sea-lions with young pups.

Because of the difficulties associated with collecting data on apparent impacts, we feel it would be misleading to subdivide apparent impacts by type or severity. Instead we present the numbers of all apparent impacts combined for each category of visitor.

## Results

During our research in the winter, spring, and summer over a three-year period, 488 boat visits brought a total of 5577 people to the near-shore waters of the island (Table 2). Most boats stayed at the island for one day or less (mean duration 1.29 days, range = 1–12 days,  $n = 488$  boat visits). The seasonal distribution of visits was highly variable among the three years of our study. However, there were more boats at the island in May and June, than in the other months of the study (Table 2).

During our study, San Pedro Mártir was visited by people in 17 (74%) categories of visitors (Table 1). Private sport-fishing vessels and commercial fishing pangas spent the most time at the island (Fig. 1A). Commercial environmental tours, commercial fishers in ships, commercial sport-fishing and commercial SCUBA-dive tours, accounted for most of the person days spent in the island's near-shore waters (Fig. 1B). Environmental tourism groups were responsible for the vast majority of people landing on shore (Fig. 1C) and walking up onto the sea-bird colonies on the middle and upper parts of the island (Fig. 1D). At least 17.8% of the 5577 visitors made one or more landings on the shore of the island where both Yellow-footed Gulls and California sea-lions breed, and 12% of visitors climbed onto the middle and upper parts of the island where Brown Boobies, Blue-footed Boobies, and Brown Pelicans all breed (Table 2). During our study period, most landings were in February and March during the sea-bird breeding season (Table 2).

Using data from 1991 (our most complete field season), we compared the numbers of person days (Fig. 1B) and apparent impacts (Fig. 1E) for each visitor category. Commercial fishers in pangas had significantly more apparent impacts per person day (48 of 169, i.e. 28%) than all other categories of visitors ( $\chi^2$  contingency table analysis comparing commercial fishers in pangas to all categories,  $\chi^2 < 40.0$ ,  $p < 0.0001$  for all comparisons). Commercial fishers in ships had a significantly fewer apparent impacts per person day (56 of 801, 7%) than

commercial fishers in pangas, and significantly more than all other categories ( $\chi^2 < 25$ ,  $p < 0.0001$  for all comparisons). Commercial environmental tourism groups had the lowest rate of apparent impacts per person day (5 of 1150, i.e. 0.4%) ( $\chi^2 < 9$ ,  $p < 0.005$  for all comparisons). The other categories of visitors (commercial sport-fishing/SCUBA, private sport-fishers, private yachts, researchers and photographers, and government) had intermediate impact rates (1.4%–5.6%) and there were no significant differences among them.

In general, use by environmental-tourism groups was highest in the late winter and spring, and use by private sport-fishers, and commercial panga and ship fishers, was highest in the spring and summer (Fig. 2).

The number of panga fishers in March, April, and May (the three months covered in every year of research) increased significantly between 1990 and 1992 (Fig. 2A; Kruskal-Wallis nonparametric ANOVA  $H = 5.695$ ,  $p < 0.05$ ). No other user groups showed a significant change in numbers between 1990 and 1992.

Visitors to the island came from 12 different ports representing four states in México, namely Sonora, Sinaloa, Baja California, and Baja California Sur. Of boats from known ports, over half (53%) left from Bahía Kino, Sonora, the town closest to the island. These visitors from Bahía Kino comprised 96% of total private sport-fishers, and 57% of all commercial fishers in pangas. Commercial fishers using both ships and pangas came from seven different ports, including Mazatlan (900 km to the SE), Topolobampo (500 km SE), and San Felipe (600 km NW).

### Private and commercial tourists

Private sport-fishers were responsible for 38% of all boat days, more than any of the other categories of visitors (Fig. 1A). They rarely ventured onto the island (Fig. 1C, D), or threw noticeable quantities of trash, oil, or gas into the water. Therefore, their apparent impact on the island was minor compared to other groups (Fig. 1E).

Visitors on commercial sport-fishing/SCUBA-dive tours rarely landed on the island (Fig. 1C, D). Like private sport-fishers, they occasionally travelled too close to shore and scared resting sea-birds and sea-lions. Some individuals on sport-fishing/SCUBA-dive tours landed on the island to view terrestrial wildlife or explore (Fig. 1C, D). Crew members on commercial sport-fishing/SCUBA-diving boats regularly dumped plastic litter into the near-shore waters.

### Government, researchers, and photographers

Navy patrols caused little apparent impact because they did not land on the island, but navigation-light maintenance and repair workers climbed to the light on the upper part of the island in the spring, and caused an undetermined amount of nest failure in the colonies of boobies and Brown Pelicans.

During our 14 months of field work, nine commercial film teams and over 70 commercial still-photographers

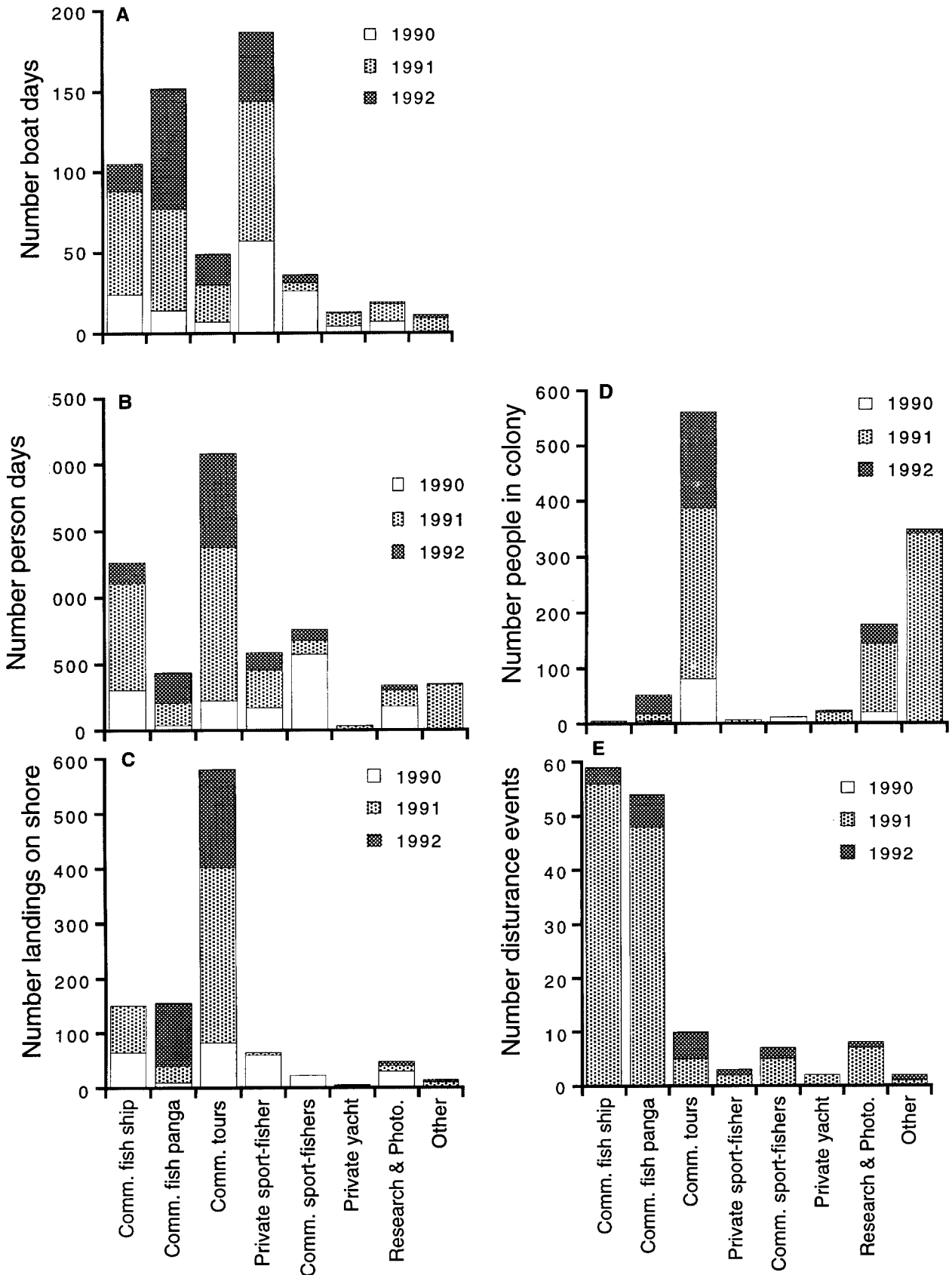
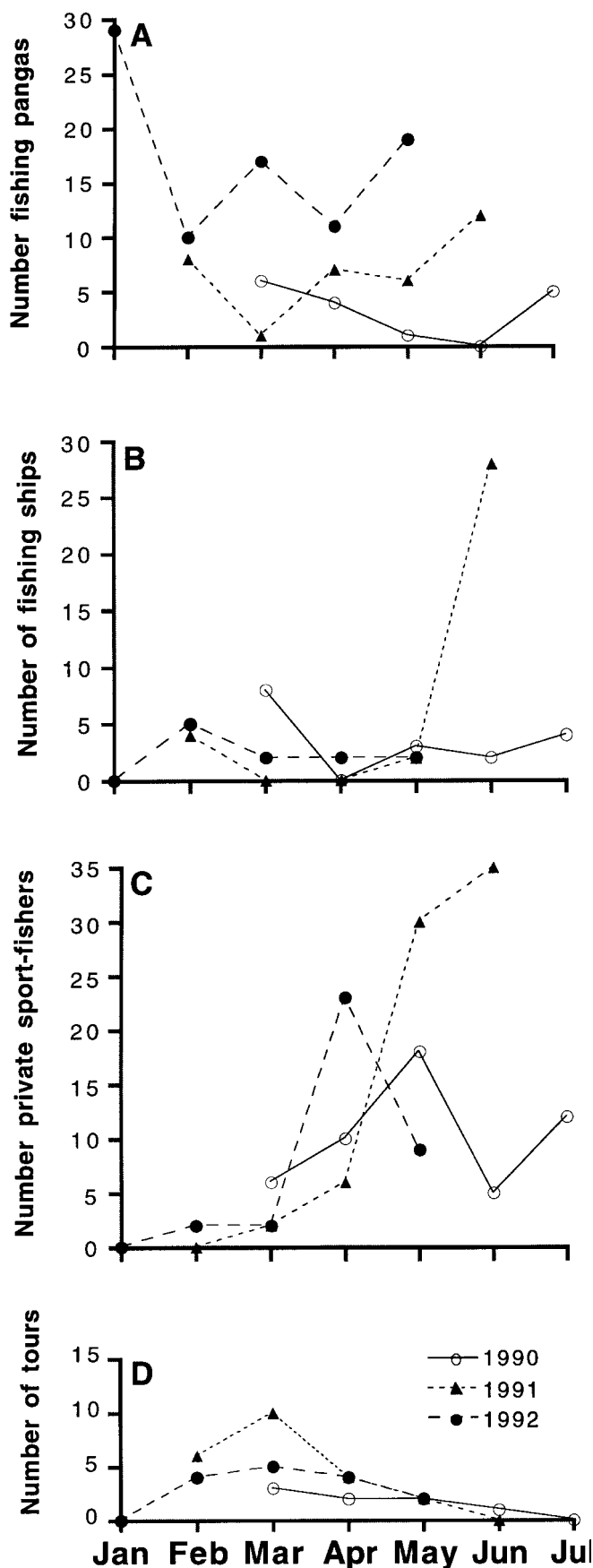


Figure 1 Human use of San Pedro Mártir Island in each of the three field seasons: 1990 (solid bars); 1991 (stippled bars); and 1992 (open bars), for each category of visitors. (A) The number of boats that came to the island multiplied by the duration of their stay in days. (B) The number of people who visited the island's near-shore waters multiplied by the duration of their visit in days. (C) The number of people landing on the shore of the island. (D) The number of people climbing to the seabird colony on the middle and upper part of the island. (E) The number of disturbance events (see Methods) in 1991 and 1992 only.



visited the island. Many photographers approached nesting sea-birds too closely, and were unaware of behavioural indicators of stress. Photographers also caused more severe disturbances at nests *en route* to, or adjacent to, subjects they were pursuing.

**Commercial fishers**

Commercial fishing ships anchored at the island and occasionally deployed as many as 18 men along the shore (Fig. 1C) to fish with hand lines. Although they rarely ventured to the upper part of the island (Fig. 1D), they disturbed sea-lions and nesting Yellow-footed Gulls (Fig. 1E). Most ship-based fishers visited the island in the summer (Fig. 2B), when nesting sea-birds are less vulnerable to disturbance, but sea-lions are pupping.

Some fishing ships tied off to rocks on the island. House mice (*Mus musculus*), rats (*Rattus norvegicus* and *R. rattus*), and ants are common on fishing ships (B.R. Tershy, personal observations 1990–1992), and could travel to the island on mooring lines tied to shore.

Shark fishers begin visiting San Pedro Mártir in late May. They used either  $\leq 1$ km long drift gill nets, or long-lines with about 250 hooks. According to local fishers, the use of long-lines is decreasing because gill nets are more efficient and easier to handle (L. Bourillón, personal communication, 1994). We observed shark fishers clubbing or harpooning up to four sea-lions per long-line for use as bait.

Commercial fishers occasionally collected Yellow-footed Gull and Heermann’s Gull (*Larus heermanni*) eggs for their own consumption. Booby and pelican eggs apparently do not taste as good and we had no indication that they were collected during our study. We were not able to determine the extent of egg collection on San Pedro Mártir Island, but in 1993 egg collection may have been responsible for the near-complete breeding failure in a small (approximately 100 nests) colony of Heermann’s Gulls.

**Discussion**

Our results give only a general idea of human perturbations at San Pedro Mártir Island between 1990 and 1992. Furthermore, they must be interpreted with caution, because we were not on the island throughout the year, the months of coverage varied between years, we could not sample the entire island, we were not able to distinguish between different types of human perturbations which may have had very different impacts, and some users may have altered their behav-

**Figure 2** Seasonal distribution of visitors to San Pedro Mártir Island in each of the three field seasons: 1990 (open circles); 1991 (triangles); 1992 (closed circles), for the four categories of visitors that made the most visits to the island: (A) commercial fishers in pangas (B) commercial fishers in ships (C) private sport fishers and (D) commercial environmental tourism groups. Data for all months were standardized by calculating the mean daily value and multiplying it by 30.



our in response to our presence. Despite these shortcomings, these are the first published data on the human use of an island in the Islas del Golfo de California Reserve. Such data are badly needed to form the basis of sound management decisions in this newly-formed Reserve.

There is a long history of direct and indirect human perturbations to island ecosystems (e.g. King 1985; Cheke 1987; Burger & Gochfeld 1994). San Pedro Mártir Island, and other islands in the Islas del Golfo de California Reserve, have not been entirely spared from the negative impacts of human use and the introduction of exotic species (Goss 1888; Bahre 1983; Bourillón *et al.* 1994; Velarde & Anderson 1994). However, compared to other archipelagoes, they are remarkably undisturbed (Case & Cody 1983). Our data support this conclusion because most apparent human impacts were short-term and localized. However, the large number of visitors on San Pedro Mártir Island, the most isolated island in the Reserve, suggest that human use on other more-accessible islands may have more significant impacts.

### Private tourists

During our study, private tourists were responsible for more boat days than any other class of users (Fig. 1A). However, their apparent impact on the island was minor compared to other groups (Fig. 1E). Because 95% of private tourists came from Bahía Kino, it will be relatively easy to inform them about regulations or voluntary guidelines.

### Commercial tours

The apparent impact of commercial sport-fishing/SCUBA tours was also relatively minor (Fig. 1E). However, because these tour companies did not employ naturalist guides trained in low-impact wildlife viewing, passengers who landed on the island from these groups may be more likely to cause apparent impacts to terrestrial fauna than passengers on ecotours. Because only five to seven sport-fishing/SCUBA-dive tour companies visit the island, it should be relatively easy to disseminate information on low-impact use. However, since disposing of litter at sea is much easier than storing it on a ship, a well-designed education programme combined with mutually agreed-upon regulations and enforcement, may be necessary.

Commercial environmental-tourism groups want to view wildlife in a natural setting, but, in the process can cause localized disturbance of sea-lions and breeding birds (Edington & Edington 1986; Boo 1990, Velarde & Anderson 1994). On San Pedro Mártir Island, these groups have the potential to cause impacts because so many people landed on the island and climbed up to the colony (Figs. 1C, D). Furthermore, most environmental tours come to the island in the late winter and early spring (Fig. 2D), when nesting sea-birds are most vulnerable to disturbance-induced mortality to eggs or young chicks (Tershy *et al.* 1992). However, ecotour groups caused little apparent impact in relation to the number of

visitors (Fig. 1D, E). This is because the company that brought over 70% of the ecotourists to the island had well-trained guides and company guidelines on minimizing disturbance. This could change if more companies were permitted to bring tourists to the island without government regulation or industry-wide self-regulation.

The scenery and most of the wildlife on the island can be seen from a small boat or kayak slowly travelling close to shore. Therefore, landing on the island may not significantly enhance the experience of visiting tourists. Representatives of the environmental-tourism company that brought most visitors to the island, Special Expeditions, felt that a no-landing policy would not decrease the quality of their tours (T. O'Brien, personal communication 1994). Since 1994, the Instituto Nacional de Ecología has not granted permits for tour companies to land passengers on San Pedro Mártir Island. This simple management action has not decreased the number of tour companies visiting the island, but has eliminated most of the potential for these visitors to disturb the terrestrial fauna, and increased the visitor carrying capacity of the island. Our impression is that most tourists who come to the island without permits would respect official signs with information on the effects of introduced species, wildlife disturbance, and regulations (including complete closure). Conservation International México, in conjunction with the Instituto Nacional de Ecología, recently posted such signs on the island.

### Government

Navy patrols caused little apparent impact, but navigation-light maintenance and repair workers caused booby and pelican nest failures when repairing the navigation light. They apparently visit San Pedro Mártir, and other islands in the area each year, and may cause disturbance to nesting sea-birds on other islands as well. Navigation-light maintenance and repair workers could reduce their impact on San Pedro Mártir and other islands if they visited in early June, when sea conditions are relatively calm, but sea-bird chicks are older, and less vulnerable to nest disturbance.

### Researchers and photographers

The combined impact of many photographers visiting San Pedro Mártir and other islands with nesting sea-birds may be significant. Photographers, and other visitors who land on the island, should be required to have permits and, at least on their first visit to the island, be accompanied by a guide familiar with San Pedro Mártir.

Researchers who are not careful can have significant short- and long-term impacts on the island. The visit to the island with the largest negative impact was a group of seven herpetologists who landed without a permit, during the peak sea-bird-breeding season in 1991. In their search for herpetofauna, they climbed to the upper part of the island and inadvertently scared sea-birds off their nests, which exposed

**Table 3** High-risk activities that have potential to introduce exotic plants and animals to islands and mitigating behaviours.

<i>Activity (ordered by increasing risk)</i>	<i>Example</i>	<i>Mitigating behaviours and comments</i>
Landing on islands	Inadvertently transporting seeds or small insects between islands, or between islands and mainland.	Check shoes and pant-cuffs for seeds and small insects. Minimize landings.
Unloading small-sized equipment on island	As above; also can transport lizards, snakes, spiders, and mice.	<i>Before arriving</i> , encase equipment in pest-free environment and seal with tape. <i>On the island</i> , unload equipment onto tarpaulin or plastic (children's) swimming-pool, and thoroughly check all boxes and equipment (use strong lantern if unloading after dark). <i>Between periods of use</i> , store equipment in sealed pest-free environment.
Unloading large-sized equipment on island	As above; can also introduce rats.	As above. Also, before leaving, thoroughly clean equipment of dirt etc.
Unloading foodstuffs on island	High probability that food will contain ants and/or cockroaches. Poultry can introduce avian diseases.	Unload all food deliveries onto tarpaulin or (children's) plastic swimming-pool, and thoroughly search for insects.
Living on island	As in all the above, probability of introductions increases with each arrival of personnel, food, and equipment.	Living on islands should be avoided unless justified by research, protection, or national defence. Inhabitants should be educated about danger of introduced species and should follow above guidelines.
Anchoring ships to island with large lines	Very high probability of introducing rats which are common on many ships.	Very dangerous, should be made illegal; easiest enforcement may be to establish c.100m cordon around island within which ships cannot anchor.
Ships running aground on island	As above.	Presently unavoidable, but constant danger. Continual upgrading of safety features of ships should be advocated.
Intentional introductions for experimental research	Males or sterilized animals and plants can introduce diseases to island populations.	Should not be allowed. If exceptions are made, researcher must be able to demonstrate that there is no threat of permanent introduction or disease.
Intentional introductions for other reasons	Primarily food plants and domesticated animals: cats, dogs, chickens, goats, rabbits and donkeys.	Should be made illegal and strictly enforced. Navy or other guardian personnel should be educated on dangers of introduced animals.

the eggs to over-heating and predation by gulls and ravens; we estimated 1000–2000 booby and pelican eggs were lost in this incident. Prior to our study, an international team of geologists landed a helicopter on the island during the peak of the breeding season and must have caused large-scale failure in the nests near their landing site.

Most researchers were more responsible, but they need to take extreme care to avoid disturbing nesting sea-birds, and, most importantly, to avoid introducing exotic species to the island (Table 3). Guidelines and regulations for researchers have recently been written into research permits.

### Commercial fishers

Panga fishers were the only group that showed a consistent increase in the number of visitors (Fig. 2a). This appears to be primarily due to the start of an intensive export-driven sea-cucumber (*Isostichopus fuscus*) fishery on the island. In 1990, we did not observe any divers collecting sea-cucumbers at San Pedro Mártir. In 1991, one group of three pangas made two trips from the town of Bahía de los Angeles to San Pedro Mártir to dive for sea-cucumbers. In 1992, pangas

from Bahía Kino visited the island at least 27 times to dive for sea-cucumbers. During a visit to the island in 1993, we talked to a group of 12 fishers who had set up a temporary sea-cucumber fishing and processing camp on the island which they used for two months. The camp was located on an important area for nesting Yellow-footed Gulls and breeding sea-lions; no gulls and few, if any, sea-lions bred there that year. Temporary fishing and processing camps usually attract additional panga fishers who can save money by selling their catch close to where it is captured, rather than travelling back to the nearest port and fish buyer. These temporary camps concentrate both commercial fishers and their negative impacts.

The camps also increase the probability of introducing exotic species for two reasons. First, the large volume of equipment and supplies brought to shore may harbour exotic species. Second, the habitat modification caused by these camps may increase the ease with which exotic species can become established (Smallwood 1994), and attract birds typically associated with human dwellings, such as House Sparrows (*Passer domesticus*), Great-tailed Grackle (*Quiscalus mexicanus*), and Starlings (*Sturnus vulgaris*), which are not



resident on the island (Tershy *et al.* 1992; Tershy & Breese 1997). Prohibiting temporary camps, especially processing camps, would decrease the negative impacts of commercial fishers on San Pedro Mártir and other Gulf islands (see Fackler 1993, for a nearly identical problem in the Galapagos). Furthermore over-exploitation of sea-cucumbers may have long-term effects on the marine environment.

The harvest of sea-lions for shark bait, does not appear to be harming the Gulf of California's sea-lion population, which is growing at over 1.5% per year (Zavala-Gonzalez 1990). It may be less harmful than drift gill nets; these nets are non-selective, and if they become lost from the ship, can continue entangling sea-lions and other marine animals for years.

Commercial ship and panga fishers caused significantly more disturbance per person than did any other category of visitors. Compared to the other categories of visitors, it will be difficult to minimize their impact on the island for three reasons. First, commercial fishers departed from at least seven different ports, some of which were 600 km from the island. Second, there is no central organization through which information can be distributed to commercial fishers, or through which they can exchange information. Third, commercial fishers are thought to stress independence, self-reliance, and freedom from regimentation (McGoodwin 1990) and, unlike other groups that visited the island, their own comfort, safety, and economic gain may not always be congruent with protection of the island's ecosystem.

One exciting step recently taken to reach commercial fishers with information on protecting islands in the Biosphere Reserve is the production of a commercial-quality *Novela* or adult comic book (Figueroa 1996). Comic books are very popular amongst fishers and are often the only non-essential item, other than cigarettes, on fishing vessels or in camps. Figueroa's comic book has a traditional story-line in which a commercial fisher is the hero, and it contains a number of subtle messages about the protection of the islands.

## Conclusions

San Pedro Mártir Island probably received less human impact than many other islands in the Gulf of California because it is isolated, difficult to land on, and does not have good anchorages. Most apparent impacts were short-term and localized. However, the combined effect of all visitors may be significant, especially if human use increases. Fortunately the impacts of all tourists, professionals and navigation-light maintenance crews has been, or can be, minimized with little, if any, sacrifice by these users.

The apparent impacts caused by commercial fishers on the island also appear to be short-term and localized, however their disturbances are relatively frequent. Their use of the island appears to be increasing as fishing grounds closer to population centres are being over-fished, and they use better boats and larger outboard engines, which make it easier to exploit San Pedro Mártir and other distant fishing-grounds.

Minimizing the impact of commercial fishers will be a greater challenge for managers, and more research is needed on how and why commercial fishers use San Pedro Mártir and other Gulf of California islands.

The impacts of disturbance of terrestrial fauna and some forms of pollution are relatively short-term, and can be reversed with proper management and enforcement. The introduction of exotic species, such as rats, mice, cats, and ants, that can severely alter the existing community structure of the island, is a potential long-term, irreversible impact. Any type of human use can result in the introduction of exotic species, either directly (Table 3), or by habitat modification which may increase the probability that introduced species will become established, and attract birds normally associated with humans. Commercial fishers and researchers have the greatest potential to introduce new species to San Pedro Mártir and other islands because they camp on the island, and anchor large boats near shore. Stationing seasonal or year-round wardens on San Pedro Mártir and other islands would increase the probability of species introductions, and this should be taken into account when weighing the costs and benefits of different enforcement strategies.

An enforced prohibition or regulation of temporary fishing and processing camps within the island Biosphere Reserve will decrease the probability of both short-term and long-term negative impacts on San Pedro Mártir and other islands in the Gulf of California. Most researchers obtain permits to conduct research on San Pedro Mártir, and other Gulf of California islands. Precautions to avoid introductions, and other types of disturbance are required and are now written into these permits. Bilingual signs with information on the effects of introduced species and other disturbances, and regulations or guidelines for visitors have recently been posted and should help decrease the threat of short- and long-term negative impacts, especially by tourists.

Continued and improved protection of San Pedro Mártir and other Gulf of California islands should be made a high priority because of their intrinsic value, and because protection can be accomplished with minimal economic and social conflict. This represents a rare opportunity in a world where almost all significant wildlands have human inhabitants.

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