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A. GROWTH OF THE SOUTH AFRICAN CAGE-DIVE INDUSTRY

Over the past 8 years the South African white shark cage-diving industry has grown at an alarming rate, not only in terms of the number of new operators entering the business (Figure 1), but also in terms of trips undertaken by existing operators (Figure 2) and the numbers of tourists transported annually (Figure 3).

B. WHAT DOES A TYPICAL SOUTH AFRICAN WHITE SHARK CAGE-DIVING OPERATION ENTAIL?

In most South African cage-diving operations a small number of tourists (usually 3-10) are taken out in small, fast boats (typically 8-10m catamarans) to offshore locations frequented by great whites. Immediately upon arrival at the site, the operators create a scent corridor by means of a process known as chumming. The chum, consisting of a finely minced mixture sardine and other fish products suspended in seawater, is slowly released into the current over a period of 4-6 hours to attract sharks. The quantity of chum released into the environment is usually 10-15 kg per 5-hour trip and never exceeds 50 kg per trip, but this is nevertheless sufficient to create a chum slick of several kilometers long, especially if there is a strong current. When patrolling white sharks cross such a chum slick, they sometimes swim up the scent path to investigate the source of the chemical attractants. Upon arrival at the boat, they are lured still closer to the boat by means of one or more pieces of bait attached to ropes. The most commonly used bait is a piece of shark meat, but some operators also use sardines enclosed in tough nylon bait bags. The Code of Conduct for cage-dive operators specifically prohibits the use of mammalian products as bait or chum, and strictly forbids feeding of the sharks at cage-dive sites, but the sharks do succeed in getting hold of some of the bait. The quantity of bait lost ranges from 0-22 kg per trip depending on the skill and attitude of the operator.

Once a particular shark shows a strong interest in the bait, a small, circular floating galvanized metal cage is lowered into the water to protect the divers. Two divers at a time then enter the cage to view and/or film the sharks underwater. On a typical trip most tourists see sharks from the boat, but relatively few of the tourists (approximately 35%) actually see the sharks underwater.

C. DOES THE CAGE-DIVING INDUSTRY HAVE A NEGATIVE IMPACT ON THE SHARKS OR ENVIRONMENT?

Before this question can be answered, it is important to understand that all forms of ecotourism have at least some detrimental effects on the environment. Even activities as "harmless" as game viewing in terrestrial game parks carry a heavy environmental price tag. Construction of roads, camps and picnic sites in game reserves require destruction of thousands of hectares of indigenous plants. Exhaust fumes emitted by cars pollute the environment, road dust slows plant growth and makes plants less palatable to herbivores, and thousands of animals are disturbed daily by road traffic. Hundreds of small animals are killed annually on the roads and the hunting patterns of the large carnivores are often altered by the presence of roads and cars. Tarred roads significantly change the thermal microclimate in the immediate vicinity of the roads, affecting the thermoregulatory behaviour of countless "cold-blooded" animals such as lizards, tortoises and snakes, and diversion of rainwater from the road surfaces has a significant effect on the nature and composition of road-side vegetation.

Why then do we permit and even promote ecotourism in terrestrial environments? The answer is simple: it is all a matter of pragmatism, economics and expediency. In most countries it is simply not economically viable to protect our natural heritage by totally excluding all human interference. Despite some negative environmental consequences, ecotourism is normally the least destructive way of utilizing a particular area. It is certainly less destructive than other options such as harvesting, urbanization or agriculture. Roads, camps, picnic sites, cars and tourists will inevitably have some negative effects on the environment, but with careful planning it is possible to minimize the detrimental effects of ecotourism and channel some of the funds generated by tourism into conservation. **Normally, therefore, ecotourism is a form of sustainable utilization of the environment with fewer ecological consequences than most other human activities.**

With this background information in mind, let's turn to the question of whether white shark cage-diving operations harm the environment. The answer is simple: ***of course they do!*** There is simply no possibility that the operators can make 100 trips per month to a few preferred cage-dive spots near ecologically sensitive offshore islands without causing some damage to the environment. Numerous planktonic organisms are destroyed by the propeller blades with every revolution of the boats' propellers.

The sound waves emitted by the revolving propellers cause even bigger problems. In the dense aquatic medium these sounds really bombard the sense organs of marine animals. The acoustic sense organs of marine vertebrates evolved to detect tiny vibrations in the water over long distances, and are simply not geared to deal with the massive sound emissions produced by boat engines. For marine vertebrates the sounds produced by boat propellers are probably similar to close-up exposure to the sounds of a disco, rock band or jackhammer on land - not very good for the ears!. It has been conclusively shown in the USA that long-term exposure to the sound waves produced by moving boats eventually cause progressive deafness in cetaceans like whales and dolphins. Propeller sounds presumably also damage the sensitive lateral line systems of sharks and other fish.

The more than 12 tons of chum released annually into the sea by the cage-dive industry must inevitably also have a slight effect on the environment in the immediate vicinity of the cage-dive sites. Chum particles settling on the bottom will have some effect on the complex interactions between bacteria, other microorganisms, scavengers, filter-feeders and similar organisms living on the sea floor. Chum particles in the water do attract hundreds of small fish, causing abnormal aggregations of small fish in the immediate vicinity of cage-dive boats. Seals, dolphins and coastal marine birds are occasionally disturbed or even injured by moving boats. Frequent attraction of sharks to cage-dive locations obviously do (at least temporarily) disturb them and alter their normal movement patterns and behaviour. White sharks do occasionally get injured during cage-dive operations.

From the above it is obvious that white shark viewing, like terrestrial game viewing, carries an environmental price tag. We must, however, bear the following in mind before we judge the cage-dive industry too harshly:

- Cage-dive boats represent ***only a tiny fraction of the total boat traffic is South African waters*** each day. The hundreds of commercial and recreational fishing boats operating in our waters probably produce more propeller noise per day than cage-dive operators produce in several years.

- Similarly, commercial and ***recreational fishing operations release more bait and chum into the water in a single day than released by cage-dive operators in years***. Fish factories ***have been pumping hundreds of tons of blood-laden wastewater into the sea for decades, without any obvious long-term detrimental effects on the environment.***

- Cage-dive operations also normally take place near offshore seal colonies. Seals are notoriously messy feeders that consume several kilograms of fish per day. When they feed, bits of flesh, blood and entrails from their prey are liberated into the water. Each seal also releases waste products in the form of urine and faeces into the environment. If we assume that each seal liberates only 100-300g of prey particles, urine and faeces into the water daily (a very conservative estimate), it becomes obvious that a colony of 50 000 seals will release some 5 000-15 000 kg of "natural chum" into the environment each day!. Compared to this the amount of chum released by the few cage-dive operators per day (< 200 kg/day for the most heavily utilized cage-dive locations), actually dwindles into total insignificance. ***If the ecosystem in the vicinity of seal islands is geared to deal with a massive daily input of 5-15 tons organic material, there is no chance that the tiny additional input of organic material from cage-dive operations can have a significant long-term ecological impact.***

- Commercial fishing operations, in particular, also inflict heavy ***physical damage*** on the environment. A single bottom trawl operation undoubtedly causes far more long-term environmental damage to marine life on the ocean floor than the anchors and boats of cage-dive operators. Fishing exacts a heavy toll on our declining shark and bony fish stocks and also results in death or injury to numerous sharks, seals, dolphins and coastal marine birds every day. ***In contrast to the continuous environmental damage caused by the fishing industry, the physical damage done to the environment by cage-dive operations is very slight.***

- The number of cage-diving trips to ecologically sensitive areas (e.g. more than 100 trips per month to Dyer Island during the summer months), is obviously a cause for some concern, but here, again, it is important to remain objective. We may well ask ourselves if some 3.3 trips per day is excessive compared to the hundreds of cars and tourists that daily enter equally sensitive conservation areas on land.

The real issue here is thus not whether cage-diving activities affect the environment (they obviously do have some effect), but whether cage-diving ecotourism can be classified as sustainable utilization of the environment. In terms of the information presented above, the physical impact of cage-diving on the environment is probably small enough to be regarded as sustainable, but cage-diving differs from terrestrial game viewing in two important respects: it involves ***active attraction of animals*** and also a ***greater degree of interaction between man and animal than is normally advisable.***

In terrestrial ecosystems we have had some unpleasant experiences with conditioning and habituation of animals in situations where animals were attracted with food for game-viewing purposes. The numerous problems created by feeding of baboons are well documented in literature. Bait-attracted lions soon learn to associate people and vehicles with food and become dangerous. Elephants attracted to viewing sites by oranges placed at water holes quickly discover that cars also sometimes contain oranges, with unpleasant consequences for a few innocent tourists. Illegal feeding of bears by the public in wildlife areas in the U.S.A. has led to a sharp escalation in the number of incidents in which bears injured or even killed members of the public.

One of the most serious objections against cage-diving is thus that repeated **interactions between humans and white sharks may result in conditioning of sharks to associate humans with food** and/or **cause sharks to lose their fear of man.** To evaluate the risk of this happening, it is necessary to understand exactly what conditioning is and what it entails to condition an animal.

D. WHAT EXACTLY IS CONDITIONING AND WHAT DOES THIS LEARNING PROCESS ENTAIL?

Conditioning is simply a type of learning in which the **instinctive reflex actions** of an animal in response to a given stimulus are altered as a result of the experience of the individual. For instance, if the animal repeatedly receives some stimulus (e.g. the sound of a ringing bell) every time it receives food, it may in time learn to associate the sound of the bell with food. After a while the sound of the bell becomes sufficient to elicit some kind of response from the animal. For instance, the sound of the bell alone may now be sufficient to attract the animal, activate its food-seeking reflexes, or even to initiate autonomic reflexes such as salivation and changes in heart rate.

- As far as could be established from a very intensive literature search, **ALL vertebrates**, including bony fish and sharks, and many invertebrates **CAN BE CONDITIONED** under the right circumstances. It **IS,** therefore**, AT LEAST THEORETICALLY POSSIBLE** that white sharks can also be conditioned to associate humans with food.
- It is, however, **NOT NEARLY AS EASY TO CONDITION ANIMALS AS LAYMEN AND THE PRESS OFTEN ASSUME!** Aquatic predators are continuously bombarded by a vast array of visual, olfactory, chemical and auditory stimuli whenever they are feeding or encounter a potential feeding situation, but they don't necessarily develop conditioned responses to all of these stimuli. **As a rule, conditioned responses only develop if they help the predator to obtain food more efficiently.**
- Conditioning of any animal thus requires **FREQUENT** and **REGULAR** application some kind of **REWARD** (e.g. food) or **PUNISHMENT** (e.g. pain) over a **FAIRLY LONG PERIOD OF TIME**. Also, **if the conditioned reflex is not maintained by regular positive reinforcement** (continued rewards once the reflex is established) **it becomes progressively weaker and eventually disappears**.
- For conditioning to occur, it is also important that the stimulus (e.g. the ringing bell) must applied **at exactly the right time (only before and during the reward period)**, if the animal is to form an association between the stimulus and the reward.
- If all these requirements are met, it usually takes **several successive days** of **INTENSIVE DAILY TRAINING** (with **NUMEROUS small rewards being given during every training session**) to train sharks and other fish to associate a particular stimulus with food.
- It is, however, **seldom possible to successfully condition animals if these requirements are not all met:**

    For instance, **if the training sessions are scheduled a few days or weeks apart at irregular intervals, with little or no positive reinforcement during these intervals, even advanced animals such as mammals often fail to form the necessary association between stimulus and reward.**

Similarly, most animals fail to associate a particular stimulus with food **if the stimulus is not regularly followed by the reward**. If fact, **withholding the reward when the stimulus is applied is a standard procedure to extinguish ("de-program") a conditioned response in experimental studies!**

E. HOW FAST CAN ANIMALS BE CONDITIONED AND HOW MANY REWARDS ARE REQUIRED?

Unfortunately there is no easy or simple answer to this question. Learning rate depends on a host of factors. The few selected examples below may, however, provide some rough answers.

Experiments with rats, bred specially for their intelligence and learning ability, showed that it is possible to fully condition animals to associate a particular stimulus with food in **as little as five days**. To accomplish this, however, each rat had to be given a total of **225 reinforcements** (45 small food rewards per day) spread over five successive days.

In a second experiment, using different animals from the same genetic stock, the rats required **7 days** to become fully conditioned when they received only **20 reinforcements** per day.

Although it required 5 and 7 days respectively to fully train **all** of the experimental animals in these experiments, **some individuals** apparently **learned faster than others**, showing the **first signs of conditioning on the second day (experiment 1) and fourth day (experiment 2)**. Even these fast learners, however, required 60-90 reinforcements (rewards for reacting "correctly" to the stimulus) before they developed consistent reflex responses to the stimulus.

Based on these two experiments (and many other experiments with similar results) it is probably safe to say that it usually **requires at least a day or two of intensive training** to condition mammals, and much **longer if the animals receive fewer** reinforcements per daily training session. Several studies show that the **number of rewards** received during training plays a crucial role in learning - **the more positive reinforcements the animal receives per training session the faster it learns**. The number of rewards alone, however, is often not the most important factor.

It is equally important that the **"correct" response of the animal to the stimulus must be consistently rewarded**. Let's assume, for instance, that it takes a minimum of 10 immediately reinforced conditioning stimuli per day to successfully train an animal within a given period. If we push up the number of conditioning stimuli to 30 per day, but only reward the animal every third time it shows a "correct" response, its learning rate will drop dramatically despite the fact that it is still receiving 10 reinforcements as before. **Occasional withholding** of a reward when the animal responds "correctly" thus serves as a **form of negative reinforcement** that counteracts the effect of the positive reinforcements that the animal receive.

Total withholding of rewards in a previously conditioned animal when it repeatedly responds "correctly" to the stimulus, however, usually causes **extreme frustration** in the animal and soon results in **total extinction** of the conditioned reflex (usually within 5-10 days).

There is thus **a fine balance between factors that promote conditioning and factors that counteract conditioning** in experimental studies, and probably also in all learning situations in the animal's natural environment.

The **Osteichthyes (Bony fish)** have much smaller brains than mammals such as rats, and it is **widely assumed that they are relatively "stupid" animals** that learn much slower than mammals. **Surprisingly, this does not seem to be true, at least not as far as simple learning processes such as development of conditioned reflexes are concerned!**

A large number of studies have been done on the learning ability of bony fish. In Russia alone, some 107 scientific papers on the learning ability and conditioning of the Osteichthyes have appeared, while the rest of the world produced at least 728 additional papers on this subject.

From this vast volume of literature we know that there are fairly big differences in the learning ability of species, as well as in the learning ability of individuals within a species. We also know that learning ability is often strongly influenced by a variety of social and environmental factors. In general the following principles apply:

- Within a species, **juveniles and young fish tend to learn faster than adults and older fish**.

- Individuals belonging to **social species** (schooling species) **tend to learn faster than solitary migrants**, but when individuals are trained together, social interactions between individuals (food stealing, dominance) often inhibit effective training, creating a false impression of the actual learning ability of the species.

- **Territorial species** (e.g. mouth-breeders) tend to **learn faster** than non-territorial species, provided that territorial interactions do not interfere with their training.

- **Water temperature has a marked ability on the learning ability of almost all fish**. Optimal learning is usually only achieved within a relatively narrow, species specific temperature range. Exposure of fish to temperatures lower or higher than the limits of this narrow temperature range often dramatically increases the time it takes to condition an animal.

- Once a conditioned reflex has become firmly established, however, **short-term drops in water temperature do not inhibit or abolish the previously conditioned reflex.** In other words, the animal still "remembers" its conditioned responses after days or weeks of temperature-induced inactivity and it can once again react according to its previous "programming" once water temperature increases.

Several studies show that many species of bony fish can be conditioned as fast as mammals if training takes place under optimal conditions for learning (right experimental setup and thermal conditions). For instance, **goldfish, perch and mouth-breeders** have all on occasion been successfully trained to respond to a stimulus in **as little as 8 days, even with as few as 10 reinforcements** (food rewards for correct reaction to the stimulus) **per day**.

With more intensive training (more reinforcements per day) some fish can even be

trained in less than 5 days. For instance, in one study on Tilapia in which the fish were intensively trained (60 reinforcements per day) to distinguish between light and dark, a few of the fish were showing the first signs of conditioning by the middle of the third day. By the fifth day all of the experimental animals had been fully conditioned. This is certainly comparable to the rate of learning in the rats mentioned above.

Studies on fish also show that they respond much like mammals when rewards are withheld. Occasional withholding of the reward when the fish gives the "correct" response to the stimulus **slows down the rate of training drastically**. Total withholding of rewards when the fish repeatedly performs the "correct" actions in response to the stimulus results in **extinction of the conditioned reflex**. Several studies, however, suggest that **extinction of conditioned reflexes is slower in fish than in mammals (usually 8-30 days).** In other words, **fish tend to "remember" their conditioning longer once they are fully conditioned.**

Much less is known of learning processes and conditioning in **CHONDRICHTYES (SHARKS AND RAYS).** Dr **Eugenie Clark** (1959, 1961& 1963) was one of the first scientists to investigate the learning ability of captive sharks. Working at the Cape Haze Marine Laboratory in Florida, she demonstrated that both lemon sharks and nurse sharks can be trained to strike a floating board with their noses and they are capable of developing conditioned reflexes in response to the ringing of a submerged bell. A few years later scientists based at the **Natal Sharks Board** (South Africa) demonstrated conclusively that many other shark species (dusky sharks, Zambezi sharks, black-tipped sharks and hammerhead sharks) could also be conditioned.

These early experiments were all conducted on groups of sharks housed together in a single tank, with individual sharks competing for food during the training process. During training it frequently happened that a particular shark would hit the target with its nose (the "correct" response for receiving a reward), but that another shark would steal the reward, resulting in inadequate reinforcement for the first shark.

As a result of this type of experimental design, the false impression was created that sharks are fairly slow learners. Eugenie Clark's two lemon sharks, for instance, required 6 weeks of preliminary training (508 reinforcements) and one week of advanced training (27 reinforcements) to develop conditioned reflexes. Most of the sharks tested by the Natal Sharks Board also required almost a month of training (with numerous daily reinforcements being given) for conditioned responses to develop.

In a series of later experiments, Aronson et al (1967) demonstrated that juvenile nurse sharks could actually be conditioned much more rapidly if the experimental setup is improved and the animals are housed separately:

> In the first experiment a single isolated juvenile nurse shark was trained to strike a submerged target in order to obtain food. On the first day the shark was continuously supplied with small food rewards, and a bell was sounded every time the shark ate. On the second day the food was placed directly in front of the target in such a way that the shark would accidentally strike the target every time it ate, thus ringing the bell. On the third day the shark already showed the first signs of conditioning, striking the target twice even before the food had been introduced. By the fifth day the shark was fully conditioned to associate the target with food, striking the target 8 times in less than 3 minutes without food being

presented. **This clearly shows that it is possible to condition a shark to respond to a stimulus in as little as 3-5 days, provided it receives numerous reinforcements (rewards) whenever it shows the desired response during the training period**.

In a second experiment, two young nurse sharks housed in separate tanks were trained to associate the sound of a buzzer with the impending arrival of food in a screened-off feeding section of the tank, move to this feeding area, strike a target there and then receive food. **One individual mastered this complicated procedure in three days, and the other required only 9 days!**

On the basis of the above and other evidence, there is no reason to believe that bony fish and sharks are such slow learners as is frequently claimed. Nor is it true that they have "such bad memories" that "they forget what they have learned within a few minutes, a few hours or a day or two at most" as is often alleged. During Eugenie Clark's experiment on lemon sharks a cold spell set in soon after the two sharks had been fully conditioned, causing water temperatures in the shark enclosure to drop. **During this midwinter cold spell of 10 weeks the conditioned sharks did not feed at all, but surprisingly they retained their conditioned reflexes during this period**. As soon as the water temperature rose again, they once more readily pressed the target with their noses when it was presented to them. This shows that some shark species, at least, can retain conditioned reflexes for fairly long periods without continuous reinforcement.

To my knowledge no experiments have been done to determine how total or partial **withholding of rewards** affect the rate of extinction of conditioned reflexes in sharks. If they react like bony fish towards withholding of rewards, it may take a considerable time (days or even weeks) to "deprogram" a shark once it has been conditioned in some way.

IN EVALUATING THE ABOVE INFORMATION IT IMPORTANT, HOWEVER, NOT TO JUMP TO UNJUSTIFIABLE CONCLUSIONS REGARDING CONDITIONING OF WHITE SHARKS. In most of the above experiments **optimal, or near optimal, conditions for learning were deliberately created by the researchers.** The experimental animals were **ALMOST CONTINUOUSLY TRAINED over SEVERAL CONSECUTIVE DAYS** using **DOZENS OR EVEN HUNDREDS OF SMALL REINFORCEMENTS**, all of which **were APPLIED AT EXACTLY THE RIGHT MOMENT** to ensure that the experimental animals have the **best possible chance to associate the stimulus and reward.**

f. What can be deduced from studies on other species re conditioning in white sharks?

It is always dangerous to extrapolate the behaviour of one species from what we know about other species, but comparative studies do provide us with some basic guidelines and at least give us some idea of what to expect. Based on all the available evidence, the following assumptions seem reasonable:

- **White sharks** can probably be conditioned to associate objects (possibly also boats, cages and divers) **with food**.

- **Chumming alone probably** CANNOT condition white sharks (sharks cannot feed on the finely minced chum, and the presence of chum in the water thus does not, by itself, constitute a reward. The chum corridor is merely one of many similar scent paths in the very complex olfactory environment in the immediate vicinity of a seal colony).

- The **BAIT** used by the cage-dive operators thus probably **constitutes the only reward that the sharks receive**.

- **If the white sharks** NEVER take the bait (receive at least some reward) **conditioning** (forming of an association between a stimulus (sound, object, diver) and a reward (food)) is theoretically impossible, **irrespective of how many times the sharks visit cage-diving locations or how long they stay**. In other words, the **sharks may possibly become habituated** to the presence of the boat, shark cage or divers and perhaps even lose their fear of these strange objects, **but they will** NEVER form an association between these objects and food.

- If, however, the sharks **do succeed in getting hold of some bait** (as inevitably happens in all cage-dive situations), the **likelihood of conditioning occurring will depend on a complex interplay of factors:**

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    a. The **total number** and **frequency** of white shark visits to cage-dive sites.
    b. The **time interval** between such white shark visits to cage-dive sites.
    c) The **duration** of such white shark visits to the cage-dive sites.
    d) The **size of rewards** received by the white sharks during such visits.
    e) The **number of rewards** received by the white sharks during visits.
    f) **How often the conditioning stimulus (e.g. presence of cage or diver) had been applied just before or during the reward period** (i.e. number and frequency of **positive reinforcements** received in the presence of the conditioning stimulus).
    g) **How often the conditioning stimulus had been applied without reward or had been accompanied harassment, pain or injury to the shark** (i.e. the number and frequency of **negative reinforcements** received in the presence of the conditioning stimulus) .

- If white sharks resort amongst the fastest learners in the animal kingdom, it would **THEORETICALLY** be possible to condition a white shark in as little as **2-3 days of intensive training**. This, however, would require that the shark **stays in the immediate vicinity of the boat for most of this period** and is **systematically and very consistently rewarded** on **every occasion** it exhibits the **desired response** to a **specific, consistently applied stimulus**. Personal observations made on 61 cage-dive trips plus reports from scientific observers for a further 37 trips suggest that **such a worst-case scenario is highly unlikely, probably nearly impossible, within the context of normal commercial cage-dive operations.**

- The situation at the cage-dive sites bears little or not resemblance to the unique aquarium environment that was specially created by Aronson et al (1967) to induce rapid training of sharks in their experiments. Conditions at cage-dive sites have **far more in common with the conditions that existed in the early conditioning experiments of Eugenie Clark and the Natal Sharks Board**, where sharks interfered with each other, baits were lost of stolen by other sharks in the tank, and conditioned reflexes were not always consistently rewarded. Under such conditions a **minimum of 15-35 daily training sessions with many reinforcements per session** were required to effectively condition the sharks

- In the absence of any concrete experimental data on the learning ability of white sharks, however, it is best to **assume** that they learn faster than other species and **err on the safe side** when evaluating the potential conditioning effect of cage-diving on the white shark population. Using this precautionary principle, I suggest the following arbitrary criteria for judging the potential conditioning effects of cage-diving:

  a. **Sharks making less than four visits/year to cage-dive sites probably cannot be conditioned at all** (unless the visits take place on successive days and the sharks receive several hours of intense training on each of these visits, which is highly unlikely)
  b. **Sharks making 5-10 visits to cage-dive sites/year probably cannot be conditioned if their visits are irregular, punctuated by long absences and they don't receive a substantial number of positive reinforcements on each visit.**
  a. **Sharks making 5-10 visits to cage-dive sites over a short period of time (e.g. a few weeks) should, however, be cause for concern, especially if they receive substantial rewards during this period.**
  b. **Sharks making more than 10 visits to cage-dive sites/year can potentially be conditioned if the right combination of circumstances exist**, and should be carefully monitored for signs of habituation or conditioning.

G. do white sharks visit cage-dive sites often enough FOR conditionING to take place?

At present South Africa cage-diving operations are still restricted to three regions: False Bay near Cape Town (2 operators), Mossel Bay on the East Coast (2 operators) and Dyer Island near Gans Bay (6 cage-diving operators and 1 non-diving shark viewing operation).

1. WHITE SHARK VISITATION PATTERNS AT CAGE-DIVE OPERATIONS IN FALSE BAY AND MOSSEL BAY

At this stage of our investigation we have very little detailed information on the exact frequency of white shark visits to cage dive operations in **False Bay**. Figures supplied by Chris Fallows, one of the cage-dive operators in the area, suggest that the frequency of **revisits to cage-dive sites may be fairly low.** In 51 trips undertaken in 1998, a total of 97 different sharks were seen, of which 23 were tagged for easier subsequent identification. Only 6 of the 23 tagged sharks (**26%)** were seen again, and the **maximum number of repeat visits was 6** during the course of the year, with fairly long intervals between visits. If these few figures give a true reflection of the situation in False Bay, the sharks here probably received insufficient exposure to cage-diving operations for conditioning to be a problem. This, however, would have to be verified by scientific observers over a period of time before any final conclusions can be reached.

We have more detailed information for white sharks visits to cage-dive operations at **Mossel Bay**. Roy Portaway, one of the cage-dive operators in this region, has fortunately kept records (and I.D. photographs) of all easily recognizable visiting white sharks (sharks with recognizable scars and/or other distinguishing features) since the start of his cage-diving business. Several of the data sheets were incomplete, and some of the notes and sketches were a bit cryptic, but his records also contained much useful information. The **data presented below** is **probably somewhat biased** because many identifications were based on scars that may have faded or disappeared over time, and **the number of sharks that re-visited the area after long absences were probably underestimated**. Records on the numbers of sharks that re-visited cage-dive sites over shorter periods were, however, probably as accurate as the records obtained by many scientific observers.

The available data for Mossel Bay suggest that white sharks here are mostly transient visitors to the local seal colonies and that they probably don't visit cage-dive frequently enough for conditioning to be a serious problem (Figure 4).

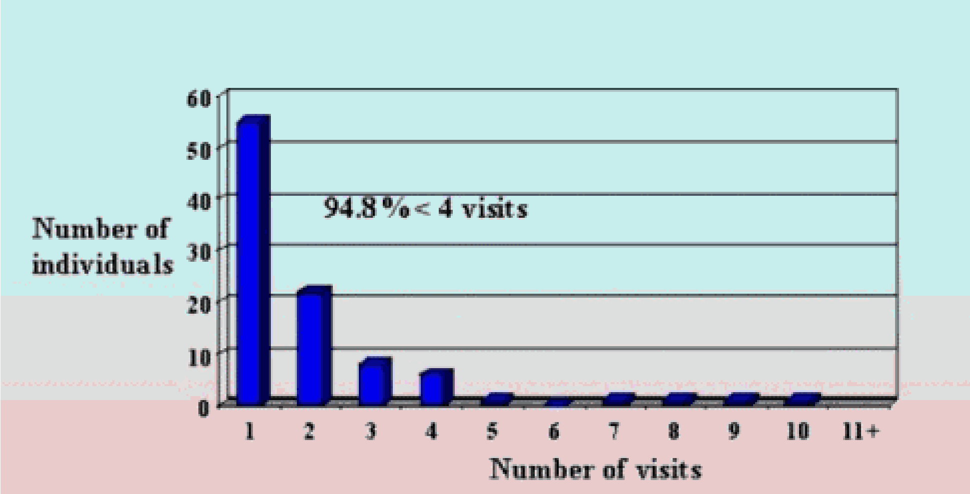

Figure 4: Frequency of visits of 96 individual white sharks to cage-dive sites at Mossel Bay (1996-1998)

As can be seen from Figure 4, the vast majority (94.8%) of white sharks made 4 or fewer visits to cage-dive operations during the observation period. If our assumptions about the learning ability of sharks are correct, there is thus little or no chance that these specific individuals could have been conditioned during these few visits. The visits of the remaining 5 individuals (sharks 24, 29, 55, 72 and 73) were so irregular (Table 1) that conditioning would also have been unlikely.

Furthermore, there is also no indication from the data in Table 1 that the interval between successive visits progressively decreased from the first to the last visits, as may perhaps be expected if sharks had been entrained or conditioned to associate boats with food. (Table 1).

2. WHITE SHARK VISITATION PATTERNS AT CAGE-DIVING OPERATIONS AT DYER ISLAND, GANSBAAI

Data for this area were gathered by myself (61 trips) and trained scientific observers (mostly postgraduate students) placed on different cage-dive boats (a further 37 trips) during the course of 1998. Sharks were identified from unique variations in fin shape and form, fin notches and other permanent scars, and characteristic pigmentation patterns on their heads, flanks and tails. The data presented below are thus based on visual observations only, and should be regarded as **preliminary results**. We still need to verify our findings by monitoring the detailed movements of animals tagged with sonic transmitters.

Visual observations always carry an inherent bias. As a rule only about a third of the sharks that visit cage-dive locations come close enough to the boat for positive identification, and a single scientific observer based on a boat can only monitor those few identifiable individuals that visit that particular boat. From the few occasions we had been able to place scientific observers on several different boats on the same day, we know that at least some sharks do visit several different cage-dive operators during the course of the same day. The graphical representation below, being based on frequency of visits of white sharks to a single boat at a time, thus **underestimates the actual frequency of visits of white sharks to cage-dive operations in the area**. It is still useful, however, to illustrate the **general pattern** of white shark visits to a typical cage-dive operation at Dyer Island, and for comparison with the Mossel Bay data.

In contrast to the situation for Mossel Bay, white sharks at Dyer Island seemingly stay in the area longer, resulting in more contact between sharks and cage-dive operations and a higher frequency of visits (Figure 5):

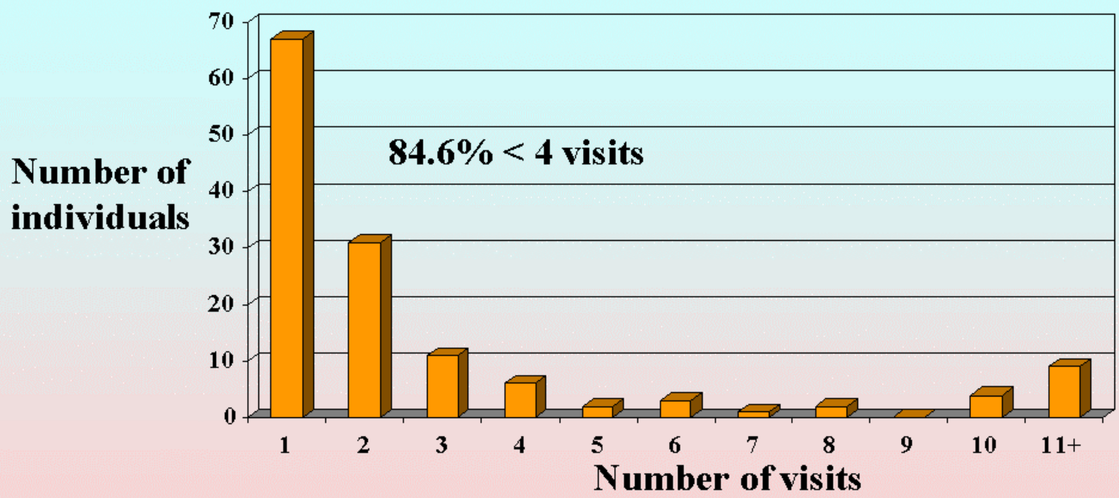

Figure 5: Frequency of visits of 136 individual white sharks to cage-dive sites at Dyer Island (1998-1999)

Approximately **85%** of the Dyer Island sharks probably also visited cage-dive operations **too infrequently to be conditioned**, but in contrast to the situation at Mossel Bay, 11 individuals (8% of the sharks) visited the observer's boat more than 10 times during the study period. The maximum number of visits recorded for a single individual was 21 for within a period of 13 months. The actual number of visits made, however, may be considerably higher if some of these individuals visited more than one cage-dive operator/day.

The difference between the white shark visitation patterns for Mossel Bay (Figure 4) and the more heavily exploited cage-dive localities at Dyer Island (Figure 5), raises some concern about potential long-term problems with conditioning of sharks at Dyer Island, especially if the **number of repeat visitors has been underestimated.**

If sharks visit cage-dive locations in a completely random manner without being influenced by cage-dive operations, we would theoretically expect a Gaussian distribution as in Figure 4. If, however, peaks appear towards the end of the distribution curve as in Figure 5, it shows that some of the sharks no longer conform to the random patterns exhibited by the rest of the population in the area. There could be many explanations for this, and one should not jump to hasty conclusions, but one possibility is that cage-dive activities may be having some effect on some of the sharks, causing them to stay in the area for longer periods.

At least some of the white sharks at Dyer Island probably made **enough visits** to cage-diving sites for us **to take the possibility of conditioning seriously**. In general, however, the **fairly irregular intervals between visits, punctuated by long absences** (Table 2), **would have made effective conditioning difficult**. Sharks apparently typically stayed in the vicinity of Dyer Island for a few days to a few weeks (during which period they made fairly regular visits to cage-dive operations), and then disappeared from the area for considerable periods.

The **mean interval between the visits** of the 10 most frequent visitors to cage-dive operations at Dyer Island was quite long (**31.9 + 80.6 days**), but this was mainly the result of very prolonged absences of a few individuals. With absences of longer than 10 days excluded from the data, the mean interval between successive visits is only **2.4 + 2.2** days.

This is certainly a **short enough interval** for us to begin to worry about the **theoretical possibility of conditioning occurring, particularly when it is taken into account that the actual number and frequency of visits must have been under estimated (because the observers had not been present in the area all of the time and because they only recorded visits to a single boat at a time). Hopefully tagging of white sharks with sonic transmitters will soon provide us with more accurate information on the actual frequency of visits of such frequent visitors to cage-dive operations**.

From the above, it is clear that there may well be some justification for concern about the number and frequency of repeat visits of certain individual white sharks to Dyer Island cage-dive operations. In a potential conditioning situation, however, it is not only the number of training sessions that is important, but also the duration of visits and the number of rewards received. If the sharks don't stay long enough for training to occur or don't receive adequate rewards, even numerous, closely spaced visits won't result in conditioning.

At present we do not have much data on the exact duration of visits of white sharks to cage-dive sites in the FALSE BAY AND MOSSEL BAY areas. A detailed investigation by scientific observers has not yet been carried out. Chris Fallows reports that the duration of white shark visits to his cage-diving operations in False Bay ranges from less than a minute to a maximum of roughly 90 minutes, with the average shark staying at the boat for approximately 10 minutes. For the Mossel Bay area Jacky Portaway estimates that contact times range from a few minutes to as much as 3 hours, with the average shark staying perhaps 20 minutes.

For the **DYER ISLAND** area we have much more detailed information on the duration of visits of individual sharks to cage-diving operations. The data in Table 3 (below) was collected by Nicole Keuler, an internship student from Long Island University in the USA. It provides a good indication of daily events at cage-dive operations when a scientific observer is on board, but it may perhaps not be representative of what happens when such an observer is absent!

Between 09/02/1999 and 19/04/1999 she accompanied four different cage-dive operators on a total of 22 trips. A total of 52 sharks were seen (mean of 2.36 sharks per trip) and the duration of their visits and contact times were accurately determined. **Contact time** was regarded as the **sum of all those short periods at various times during the trip** that an individual shark showed up and **spent some time in close proximity to the boat (10-20m radius) or made a series of**

investigative passes at the bait, cage or divers. A shark was considered to have received a reward every time it managed to mouth the bait, irrespective of whether it actually removed and swallowed some tissue.

The impression was gained that many of the white sharks that visited cage-dive operations, stayed in the area for fairly long periods during the course of the day, often making several separate visits to cage-dive operations. Staying time (the time interval between first and last visits) ranged from zero (passing shark not interested in the boat) to 116 minutes (Table 3). The mean staying time was 18.81 minutes. Much of this time, however, was not spent near the boat. The actual contact time (involving active interaction between the shark and humans, bait or man-made objects) was remarkably short, ranging from 0 - 5.68 min per shark, with a mean of only 1.4 minutes/shark. Even for the trip with the highest level of shark activity (31/03/1999) the total contact time for all 5 sharks combined was only 12.07 minutes during the entire trip!

Operator	Date	Staying time (minutes)	Total number of visits	Total number of passes	Contact time (minutes)	Number of "rewards"
SCS	02/09/1999	2	1	6	1.13	0
SCS	10/02/1999	91	2	14	4.08	0
"	"	17	2	3	0.85	0
"	"	32	3	0	0.00	0
MD	21/02/1999	0	0	0	0.00	0
MD	23/02/1999	2	1	1	0.30	0
"	"	5	1	3	2.02	1
SCS	24/02/1999	116	4	6	3.53	2
SCS	26/02/1999	8	2	3	0.57	0
"	"	63	2	6	1.55	1
WSE	27/02/1999	1	1	1	0.25	0
"	"	10	2	4	0.92	0
WSE	11/03/1999	16	2	3	0.25	1
"	"	13	2	2	0.52	0
SCS	12/03/1999	25	3	8	2.67	1
"	"	50	3	9	2.83	0
"	"	3	1	6	1.97	0
SCS	14/03/1999	5	1	3	0.80	0
"	"	13	2	3	0.85	0
"	"	1	1	1	0.13	0
"	"	5	1	3	1.75	1
"	"	1	1	3	0.85	0
SCS	23/03/1999	13	2	3	0.75	0
GWE	24/03/1999	1	1	2	0.48	0
GWE	25/03/1999	22	2	3	0.50	0
"	"	12	2	7	2.63	1
"	"	2	1	2	0.53	0
SCS	25/03/1999	1	0	0	0	0
"	"	22	2	7	2.45	0
"	"	12	2	22	5.68	1
"	"	2	1	2	0.55	0
MD	27/03/1999	115	2	6	1.15	0
"	"	2	1	3	0.43	0

WSE	30/03/1999	5	1	3	0.32	0
WSE	31/03/1999	5	1	4	1.02	0
"	"	2	1	2	0.60	1
"	"	1	1	3	1.08	1
"	"	15	2	13	4.07	2
"	"	16	1	13	5.30	2
MD	01/04/1999	108	3	7	1.25	0
SCS	06/04/1999	30	2	8	2.18	1
"	"	1	1	2	0.32	0
"	"	17	2	7	2.13	0
"	"	2	2	3	0.62	0
WSE	08/04/1999	46	3	5	0.85	1
"	"	1	1	4	1.78	1
SCS	13/04/1999	1	1	3	0.85	0
"	"	9	3	9	2.98	0
"	"	25	3	10	3.13	2
SCS	19/04/1999	2	1	0	0	0
"	"	1	1	3	0.52	0
"	"	8	2	5	0.82	0
TOTAL		978	86	249	72.79	20
MEAN		18.81	1.65	4.79	1.40	0.38
S.D.		29.2	0.83	4.1	1.35	0.63

During the observation period the 52 sharks made a total of 249 passes, mostly at the bait, receiving only 20 potential rewards in the process - one possible reward for every 12.45 passes. Operator Date Staying time (minutes) Total number of visits Total number of passes Contact time (minutes) Number of "rewards"

From the data presented above, **the contact times appear to be too short for conditioning to take place even if a particular shark visits cage-dive sites several days in succession.** The **small number of rewards received**, and **the fact that the sharks receive 12x more negative reinforcement (withholding of rewards) than positive reinforcement (obtaining of rewards)**, would also make conditioning highly unlikely.

Under **IDEAL CIRCUMSTANCES**, with a scientific observer on board and the operator trying to conform to the regulations in the Code of Conduct, **THE CHANCES THAT A SHARK WILL RECEIVE SUFFICIENT REWARDS FOR CONDITIONING TO TAKE PLACE SEEM FAIRLY REMOTE**.

Unfortunately, too many cage-dive operators still tend to ignore the code of conduct when there are no scientific observers on board. Film footage secretly obtained from 29 tourists after they had been out with various operators shows that only one operator in the area consistently attempts to withhold bait from the sharks even when scientific observers are not present. Two of the other operators only bend the rules a slightly, occasionally allowing a shark to get hold of the bait to give the tourists a bit of a show, but normally not losing large quantities of bait in the process. The remaining operators often allow sharks to take the bait in order to draw them closer to the cage for viewing purposes or tagging and other pseudo-scientific activities. **At least one operator still regularly dumps his excess bait** (often one or two gully sharks with an estimated mass of as much as 22 kg**) into the water** just before he leaves for the harbour.

Most operators also frequently infringe the rules about feeding of the sharks when they have film crews on board**. Film footage obtained from professional film crews** show that **several operators allow sharks to take the bait repeatedly when films are being made to provide the camera men with good action shots**. One piece of uncut original film footage supplied to me by a French TV team shows a shark taking 21 pieces of bait within 39 minutes, swallowing an estimated 10-25 kg of food in the process. **At least one operator also permits his crew and film crews to dive with white sharks without the protection of shark cages. This introduces a different type of interaction with the sharks that could easily lead to habituation, if not conditioning.**

Although the data from Table 3 suggest that conditioning is unlikely, infringements of the Code of Conduct like these make it impossible to estimate the actual number and size of rewards that sharks receive. More complete data can only be obtained if all the operators consistently stick to the stipulations in the Code of Conduct (unlikely) or if sufficient funds can be found to place scientific observers on cage-dive boats in the guise of paying tourists.

We have been trying for some months now to find sponsors that can provide funding for placing some scientific observers disguised as tourists on each of the 11 shark viewing vessels (3 trips per vessel). We require an amount of R 20 000 to pay the fares of such observers (11 vessels x 3 trips per vessel x R600), but so far we have not been able to obtain these funds. **For the moment, therefore, it is difficult to provide a final answer to the question of whether the sharks receive sufficient food rewards for conditioning to be a theoretical possibility.**

I. IS THERE A LINK BETWEEN CAGE-DIVE OPERATIONS AND SHARK ATTACKS ALONG OUR COASTLINE?

In 1998 a large number of shark attacks (13) took place in South African waters. There has been a great deal of speculation in the media that this "increased incidence of shark attacks" along our coast may be linked to the growth of the cage-dive industry. **At present, however, there is no scientific evidence that supports this view.**

It is important that journalists consider all the facts and avoid sensationalistic reporting on the matter. White sharks are protected animals and conservationists have been trying for years to dispel the "Jaws" image associated with these animals. In its natural environment the great white shark is a beautiful, magnificent and stately animal, certainly as worthy of protection as any of our terrestrial predators such as lions or leopards.

Like lions or leopards white sharks are **potentially dangerous** under **certain circumstances**, but they are nothing like the vicious, man-eating monsters often depicted in the press. **Humans are certainly not part of their natural prey and they actually very rarely attack humans**. In South African waters divers encounter numerous great whites every year while spearfishing or scuba diving off deep reefs. In the vast majority of encounters the sharks simply ignore the divers and just swim past. In a few cases they appear to be curious, swimming up to the diver and circling a few times before moving off. Only in a small number of cases (perhaps 1-5% of encounters) do they show some signs of aggression, usually when there is blood in the water from spearfishing activities.

Actual attacks on humans are extremely rare events - many more people are struck by lightning in South Africa than are bitten by white sharks. In the unlikely event of a person actually being attacked by a great white, there is **also a good chance of actually surviving the attack**. In the vast majority of cases white shark attacks on humans do not seem to have much to

do with feeding. **They often abort the attack after one or two exploratory bites** and **seldom remove tissue from the victim** as they would do when feeding on normal prey such as seals.
At present, there is no evidence of any link between white shark attacks along our coast and the activities of the cage-diving industry. The following facts should be kept in mind when reporting on the issue:

1. For many decades there has been a steady worldwide trend for shark attacks to increase
This steady worldwide increase in the number of shark attacks per year has nothing to do with increasing shark numbers or sharks becoming more aggressive. The **main reason for the increased number of shark attacks is human population growth and ever-increasing numbers of humans invading the sea.** The statistics for Florida in the USA (Figure 6) clearly illustrate this link between population growth and shark attacks.

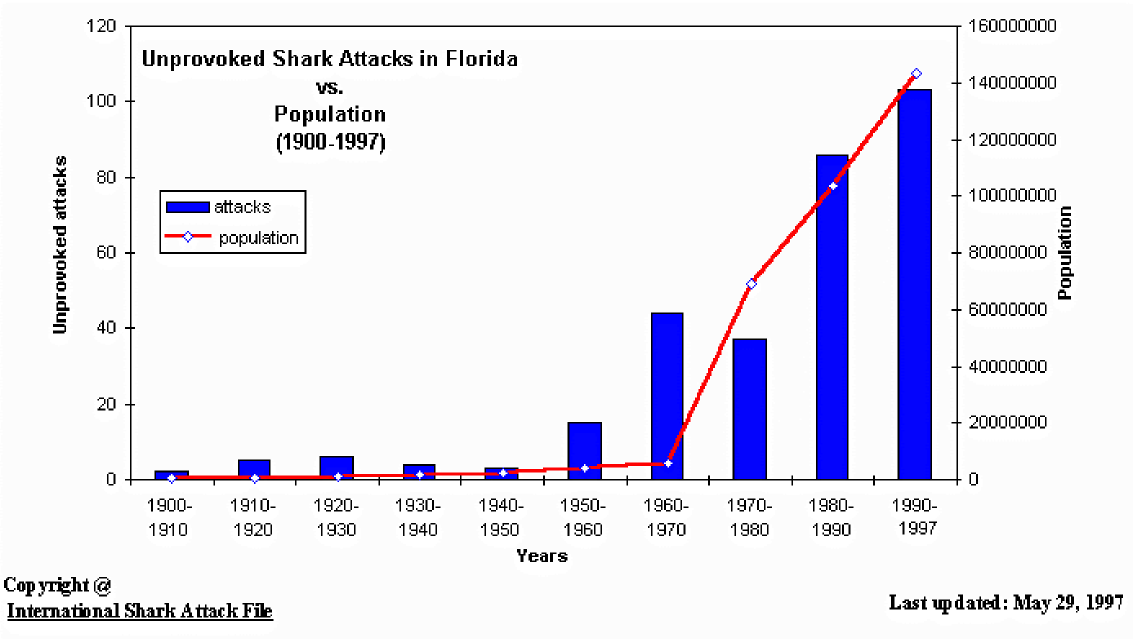

Figure 6: Shark attacks in Florida, USA as a function of human population growth

The sharp escalation in Florida shark attacks over the past four decades occurred despite the fact that **cage-diving is prohibited in this state** and that the shark population has decreased as a result of excessive shark fishing. **The increased number of shark attacks thus seems to be almost entirely related to the fact that increasing numbers of surfers, bathers and divers are entering the ocean and thus coming into contact with sharks.**

Also note that there are cycles with **good periods** (with a low incidence of shark attacks) **and bad periods** (with a much higher incidence of shark attacks). For instance, during the sixties there were considerably more shark attacks in Florida than during the seventies, although the human population was much larger in the seventies.

In some cases the increased numbers of shark attacks during such bad periods can be explained by environmental factors, (global climatic changes, warmer water temperatures, higher rainfall with rivers pouring large volumes of discoloured water into the sea, altered fish migration routes etc), but **in most cases we simply don't have good explanations for these periodic increases in shark attacks.**

2. In South Africa there has been a similar trend for shark attacks to steadily increase over the years

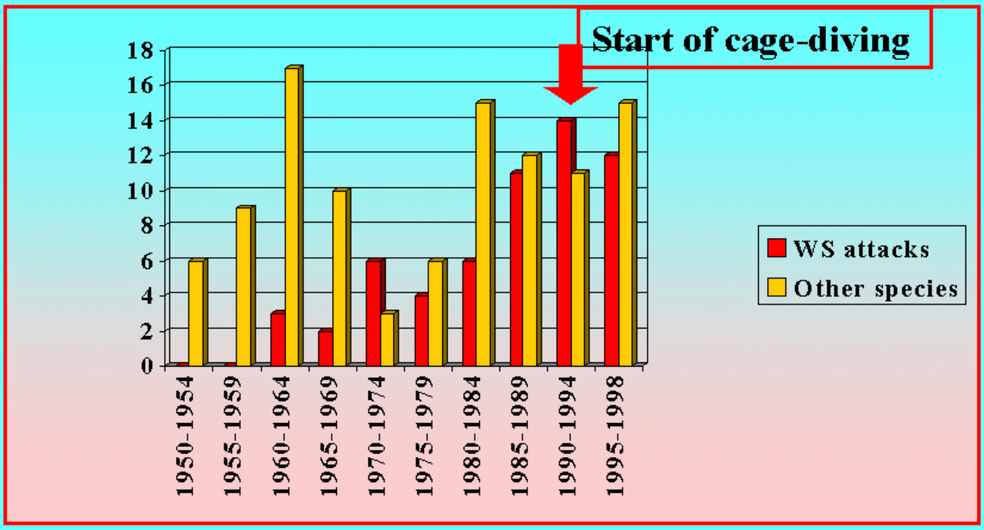

Figure 7: **Shark attacks in South Africa since 1950 (all data obtained from the International Shark Attack File)**

This trend clearly started long before the commencement of cage-diving operations (Figure 7) and is very similar to shark attack trends in Florida and other parts of the world (Figure 6)

During the fifties and early sixties Natal, with its subtropical climate and warm water, was the main coastal tourist destination in South Africa. As tourist numbers grew, the incidence of attacks by the more tropical shark species escalated rapidly, forcing the authorities to deploy shark nets along many of the most popular beaches. The decline in shark attacks during the late sixties and early seventies (Figure 8) was probably mainly the result of the toll taken by the shark nets.

By the mid-seventies several things were happening that would affect shark attack patterns. Shark nets continued to hold the numbers of the more tropical and subtropical shark species down, particularly in the vicinity of popular beaches. Oriental markets for shark meat and fins were opening up, resulting in commercial fisheries targeting ever-increasing numbers of small and medium-sized shark species. At the same time "sharking" became more popular as a macho sport among anglers and spearfishmen, further reducing the numbers of those species that had previously been responsible for most of the attacks in South African waters. As a consequence of this depletion of the shark population the chances of being attacked by one of these species actually decreased somewhat despite the growth in tourist numbers.

At more or less the same time the Cape coast with its colder water was becoming more popular as a tourist destination. The development of proper wetsuits made it possible for ever-increasing numbers of surfers, divers and spearfishermen to enter the cold water and stay there for fairly long periods. Divers also gradually shifted their focus from sheltered coastal bays and reefs to deeper water as equipment improved and stocks of crayfish, abalone and fish on the inshore reefs dwindled. This all greatly increased the chances of encounters with great whites, a species that prefers the colder waters of the Cape coast, frequents the slightly deeper water just beyond the breakers and regularly patrols the offshore reefs with their more abundant supply of fish and other prey.

As a consequence, white shark attacks have been steadily increasing since the seventies. This, however, is **a phenomenon** that is mainly linked to the **increasing numbers of people in the water** and **started long before the cage-dive industry began** (Figure 7). The graph clearly shows that there is **no evidence of an abnormal escalation of white shark attacks since the start of cage-diving activities.** In fact, the actual increases in the number of white shark attacks for periods 1990-1994 and 1995-1998 are **probably somewhat lower that the estimated figures would have been if one had to extrapolate from the trend of the previous 15 years!**

White sharks are the **only sharks that are attracted to cage-dive operations. The fact that attacks by other shark species have also been increasing steadily since the early eighties (despite the fact that their numbers have dwindled due to over-fishing), provides additional support for the view that the number of attacks is mostly a function of the numbers of people that enter the water.**

3. At present there is no correlation between white shark attacks and the growth of the cage-diving industry.

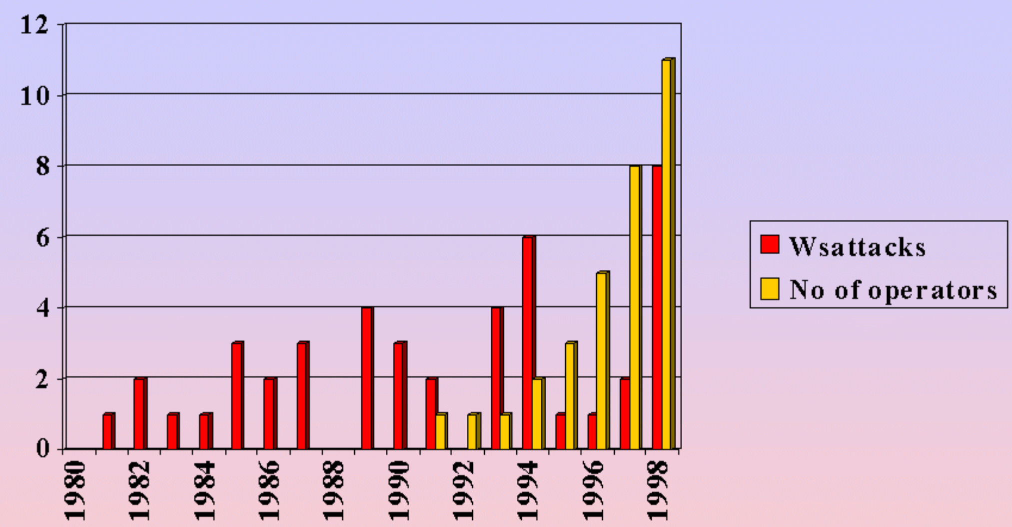

Figure 8: White shark attacks in South Africa and the growth in the white shark cage-diving industry (annual increase in the number of operators)

If we look at white shark attacks per year instead of per 5-year period as was done in Figure 7, it becomes evident that the pattern of white shark attacks is actually pretty erratic (Figure 8).

We clearly have good years with few or no attacks, and bad years with many attacks, but there is a general tendency for the number of attacks to increase as more and more people enter the water. **At present there is no reason to believe that the increase in white shark attacks since the start of cage-diving operations is anything more than a continuation of the trend that was already developing before this time**.

If the cage-diving industry had in some way been responsible for some of the white shark attacks, we would have expected a better correlation between the growth of the cage-diving industry and white shark attacks. There is, however, **little or no evidence of such a correlation**. In **1993 and 1994** when the industry was still in its infancy with **very few trips being undertaken** (and the **probability of conditioning or habituation occurring must have been fairly remote**), the incidence of white shark attacks was very high. Then in 1995, 1996 and 1997, when the industry was rapidly growing and the chances of the sharks being influenced were much higher, the incidence of white shark attacks was very low - in fact, lower than the mean for the period before cage-diving activities started!

In 1998 white shark attacks admittedly did reach a record level, and it is tempting to attribute this to the activities of the cage-diving industry. There is, however, **no evidence of such a link. During this period attacks by other shark species also increased dramatically**. All the available evidence point to the fact that 1998 was **simply one of the very bad years for shark attack**, similar to the bad years also occasionally experienced in other countries where cage-diving is banned. **Shark attack records for other countries show that it is not unusual for shark attacks to double or even triple in a certain year, and then suddenly drop back to normal.**

Something similar probably happened in South Africa in 1998. **From January to August 1998 we had a record number of shark attacks, of which 6-8 could possibly be attributed to white sharks. Then the shark attacks suddenly stopped, with no additional white shark attacks being recorded for the next 9 months, despite the fact that cage-diving activities continued unabated during this period!**

4. At present there is no apparent geographical link between cage-diving operations and white shark attack sites

Since the start of cage-diving operations there have been no white shark attacks in the immediate vicinity of cage-dive sites. The nearest attack to a cage-diving location was the two white shark attacks on divers at Pringle Bay, which is more than 50 km away from any cage-diving location. Most of the other attacks occurred higher up on the East Coast of South Africa, hundreds of kilometers away from the nearest cage-dive sites.

White sharks, however, do move long distances. A shark swimming at 3.2 km per hour could conceivably cover 50 km in a day or a few hundred kilometers in a week. **There is, therefore, at least some possibility that sharks from cage-dive sites could have been implicated in some of these attacks.**

One would have expected, however, that "conditioned or habituated" sharks would cause more problems in the immediate vicinity of cage-diving operations. So far there is little evidence of this. There have been no white shark attacks at the immensely popular beaches and surfing spots within a few kilometers of the cage-dive sites at Mossel Bay and False Bay. From what we know of white shark behaviour it is highly likely that some of the sharks from these cage-dive locations would also occasionally swim around just behind the breakers off these beaches. If they had indeed been conditioned to associate humans with food, one would have expected a greater number of incidents involving white sharks.

Divers working on Mossgas Project at Mossel Bay regularly carry out inspection and maintenance dives within a few hundred meters of the cage-dive location at the seal island. On these dives they frequently encounter white sharks, some of which undoubtedly must have had contact with the cage-dive operations. In general, however, these sharks reportedly give them few problems and do not act noticeably more aggressively than white sharks in other areas.

For Dyer Island there has been conflicting feedback from divers regarding the behaviour of white sharks in the area. Most professional abalone divers and many spearfishermen here report that they have encountered more great whites since the start of cage-dive operations and that at least some of the individuals appear to be more aggressive. Several very experienced spearfishermen, however, have rated that the sharks off Dyer Island as less aggressive than the white sharks they have encountered in other areas such as the deep banks off Agulhas and Struis Bay.