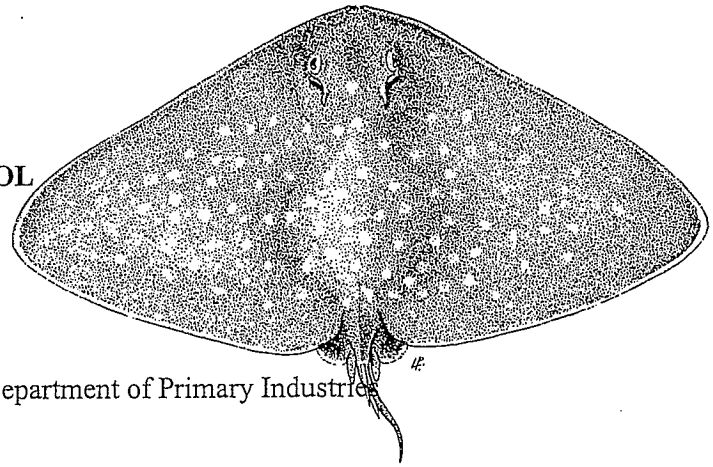
Australian Shark Assessment Report

ATTACHMENT

d) Management of Shark Control Programs (Dudley and Gribble 1999)

26

MANAGEMENT OF SHARK CONTROL PROGRAMMES



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1. INTRODUCTION

Shark control "fisheries" are either fully or heavily subsidised, their objective being to minimize shark numbers in the vicinity of bathing beaches to reduce the risk of shark attack. Economically, the justification is enhancement of coastal tourism. Passive barrier nets - or fences - which exclude but do not capture sharks, provide another method of protection. A barrier was built off a Durban beach in 1907 and more were built off several other KwaZulu-Natal beaches in the late 1950s (Davies 1964). One was constructed at Coogee, New South Wales, in 1929 (Anon 1935). These barriers proved impractical to maintain in heavy surf and no longer exist (Davies 1964, Coppleson and Goadby 1988). A fence was used to protect the private bathing beach at the Florida home of a former president of the USA (Reader's Digest 1986). Enclosures have existed at some Croatian beaches since the 1920s and, although their status today is unknown, some were still in existence as recently as 1995 (I.K. Fergusson, The Shark Trust, pers. comm.). Barrier nets are in still in use in some sheltered environments such as at Sydney Harbour, Queensland's Gold Coast marinas and Hong Kong. Such barrier nets are not considered further here.

Three major shark control (or "meshing") programmes - which between them catch about 2500 sharks annually - are known to exist. These are in New South Wales (NSW) and Queensland, Australia, and KwaZulu-Natal (KZN), South Africa. In addition, large-mesh shark nets provide bather protection off the beaches of Dunedin, New Zealand. Shark control has been conducted in the past by the state government of Hawaii but this has been discontinued. Shark nets of an unknown type were in use at the main bathing beach in Qingdao (Shantung Province, China) in 1982 (R.B. Clark, University of Newcastle, pers. comm.). Whether such nets still exist there or elsewhere in China is unknown. The focus of this report is on the management of the three major programmes.

2. KWAZULU-NATAL SHARK CONTROL PROGRAMME (NATAL SHARKS BOARD)

2.1 Species targeted by programme

The objective of these programmes is to catch those shark species which are regarded as potentially dangerous. One or more individuals of each of 14 species of shark are captured each year (Table 1). Of these, three species are believed to have been responsible for most attacks, the bull (Zambezi) shark (*Carcharhinus leucas*), the great white shark (*Carcharodon carcharias*) and the tiger shark (*Galeocerdo cuvier*). Associated bycatch species, which may be discarded, are listed in Table 2 together with mean annual catches and the percentage released.

2.2 Distribution of programme

The geographical limits of the programme are Richards Bay (28°48'S, 32°06'E) in the north and Mzamba (31°05'S, 30°11'E) in the south, the latter falling just outside the province of KwaZulu-Natal. All the shark species caught in the programme have a considerably wider distribution in the western Indian Ocean (Compagno 1984a,b) than the netted region (Dudley and Cliff 1993a).

Table 1
Shark species caught regularly in the KZN programme

Species	Common name	Species	Common name
Carcharodon carcharias	Great white	*Isurus oxyrinchus*	Shortfin mako
Galeocerdo cuvier	Tiger	*Carcharias taurus*	Spotted ragged-tooth
Carcharhinus leucas	Bull (Zambezi)	*Carcharhinus amboinensis*	Java
Carcharhinus obscurus	Dusky	*Carcharhinus plumbeus*	Sandbar
Carcharhinus brachyurus	Copper	*Sphyrna zygaena*	Smooth hammerhead
Carcharhinus brevipinna	Spinner	*Sphyrna lewini*	Scalloped hammerhead
Carcharhinus limbatus	Blacktip	*Sphyrna mokarran*	Great hammerhead

Several other shark species are captured at a rate of less than one per year.

2.3 Development and current status of the programme

2.3.1 Methods of catching

Sharks nets were installed in response to the negative impact of shark attacks on local tourism. Encouraged by the success of the NSW meshing programme (Wallett 1983), the City Engineer of Durban installed 12 gill nets (shark nets) in 1952 (Davies 1964, Hands 1970). The first recorded meshing of beaches other than those under the control of the Durban City Council was the introduction of two nets at Amanzimtoti in August 1962 (Wallett 1983). In November 1997 there was a total of 41km of netting in the water, providing protection at 64 bathing areas.

Most of the nets are 213.5m long by 6.3m deep, made of black mesh material of 51cm and are set parallel to the coast in 10-14m of water, 300-500m from shore. The hang-in coefficient is 40%. The specifications have been modified slightly since the 1960s, one of the major changes being the joining of pairs of 106.75m nets in the early 1980s to form the current "double" nets. The nets at Durban, Anstey's Beach and Brighton Beach differ from those used elsewhere in that they are yellow and, although originally 137m long and 7.6m deep, since 1963 have measured 304.8m in length (Hands 1970).

The nets in an installation are set in two rows parallel with each other and to the beach. The rows are approximately 20m apart and staggered, with an overlap of some 20m. They are usually laid at, or near, the surface but tend to sink as they become fouled. (Wallett 1983). Each net is replaced with a clean one approximately every 10 days. The nets are serviced ("meshed") at first light from a fleet of 20 "skiboats" - open-deck boats with twin, tilting outboard motors - and a crew of five. Most of the boats are 5.5m monohulls which are launched through the surf but there are also five 6.5m boats, including both catamarans and monohulls, of which four operate from harbours.

2.3.2 Vessels used and evolution of fishing effort

The Durban nets were serviced initially by private contractors and there are no published details about the vessels used. In 1960 the City Engineer's Department of the Durban City Council took over the operation and a 13.4m boat, with an inboard motor and a crew of eight, was purpose-built. A second boat, measuring 15.2m, was introduced several years later (Davies 1964, Hands 1970). Such boats depended on harbours. When shark nets were installed elsewhere - off beaches with no harbour facilities - the smaller skiboats, suitable for surf launches, were introduced.

Table 2
Average annual catches in the KZN shark nets, 1981-1990,
of animals other than potentially dangerous sharks (from Dudley and Cliff 1993)

Species	Common name	Caught (nb)	Released (%)
Birds			
Sula capensis	Cape gannet	1.3	0
Phalacrocorax sp.	Cormorant	0.1	0
Spheniscus demersus	Jackass penguin	0.1	0
Turtles			
Eretmochelys imbricata	Hawksbill	1.8	28
Lepidochelys olivacea	Olive ridley	1.1	27
Caretta caretta	Loggerhead	42.6	35
Chelonia mydas	Green	14.0	34
Cheloniidae	Unidentified turtle	1.1	73
Dermochelys coriacea	Leatherback	6.8	35
Cetaceans			
Sousa plumbea	Indo-Pacific humpbacked dolphin	6.1	2
Delphinus delphis	Common dolphin	36.3	4
Tursiops truncatus	Bottlenose dolphin	34.9	1
Stenella coeruloealba	Striped dolphin	0.3	33
Stenella longirostris	Spinner dolphin	0.1	0
Lagenodelphis hosei	Fraser's dolphin	0.1	0
Pseudorca crassidens	False killer whale	0.1	0
Delphinidae	Unidentified dolphin	0.9	0
Balaenoptera acutorostrata	Minke whale	0.4	25
Sharks			
Rhizoprionodon acutus	Milk	4.6	6
Mustelus mosis	Hardnosed smooth-hound	0.2	50
Halaelurus lineatus	Banded cat	0.1	0
Rhincodon typus	Whale	0.7	57
Squatina africana	African angel	32.9	45
Batoids			
Aetobatus narinari	Spotted eagleray	14.0	80
Myliobatis aquila	Eagleray	3.7	54
Pteromylaeus bovinus	Bullray	37.8	61
Rhinoptera javanica	Flapnose ray	41.1	58
Manta birostris	Manta	52.5	66
Mobula spp.	Devilray	14.2	60
Dasyatidae	Unidentified stingray	6.5	74
Dasyatis chrysonota	Blue stingray	0.8	88
Gymnura natalensis	Backwater butterflyray	49.6	78
Himantura gerrardi	Sharpnose stingray	1.4	93
Himantura uarnak	Honeycomb stingray	1.9	84
Torpedo sinuspercici	Marbled electric ray	0.4	25
Torpediniformes	Electric ray	0.6	100
Rhina ancylostoma	Bowmouth guitarfish	0.1	100
Rhynchobatus djiddensis	Giant guitarfish	122.0	75
Pristis microdon	Largetooth sawfish	0.2	100
Pristis pectinata/zijsron	Smalltooth/ green sawfish	0.9	67
Pristis spp.	Sawfish	1.0	70
Teleosts			
Sphyraena spp.	Barracuda	0.3	
Trachinotus blochii	Snubnose pompano	1.2	
Lichia amia	Garrick	11.5	
Scomberoides spp.	Queenfish	1.8	
Caranx ignobilis	Giant kingfish	0.2	
Carangidae	Unidentified kingfish	0.2	
Thunnus albacares	Yellowfin tuna	4.6	
Euthynnus affinis	Eastern little tuna	2.0	
Katsuwonus pelamis	Skipjack tuna	4.3	
Scomberomorus commerson	King mackerel	0.6	
Scomberomorus plurilineatus	Queen mackerel	0.5	
Scombridae	Unidentified tuna, bonito	1.2	
Rachycentron canadum	Prodigal son	0.9	
Argyrosomus japonicus	Kob	3.2	
Atractoscion aequidens	Geelbek	1.5	
Makaira indica	Black marlin	0.9	
Istiophorus platypterus	Sailfish	0.1	
Elops machnata	Ladyfish (springer)	1.0	
Epinephelus lanceolatus	Brindlebass	0.4	
Epinephelus tukula	Potato bass	0.1	
Sparodon durbanensis	White musselcracker	0.3	
Cymatoceps nasutus	Black musselcracker	0.7	
Oplegnathus spp.	Knifejaw	0.2	
Tripterodon orbis	Spadefish	0.1	
Pomadasys kaakan	Javelin grunter	0.3	
	Unidentified fish	1.0	
Crustaceans			
Panulirus homarus	Crayfish	0.1	

In 1974 the Natal Sharks Board (NSB) - which since its inception in 1964 had had a co-ordinating and supervisory role only - began to take over the servicing and maintenance of nets from independent contractors and municipal employees. By 1982 the NSB was solely responsible for all shark nets on the KZN coast (Davis *et al.* 1989). Nets have, since inception, remained in the water throughout the year, except that from 1975 it became policy to lift some nets temporarily during the annual "sardine run", the winter influx of pilchard into southern KZN waters (Cliff and Dudley 1992a,b). Average meshing frequency was no more than weekly until the early 1970s, but increased to 10 meshings per month by 1974. The frequency has been between 15 and 20 times per month since the late 1970s (Cliff *et al.* 1988).

Total effort, expressed as kilometres of netting, increased from 1.6km in 1952 to a peak of just over 44km in the late 1980s and early 1990s and subsequently decreased to 41km at the end of 1997.

2.4 Markets

The NSB sells certain shark products to defray expenses. Income from such sales is small relative to total expenditures. Products sold from the Board's curio shop include shark teeth - sold either loose or with a jump ring for attachment to a jewellery chain - and entire jaw preparations. In addition, dried fins are stockpiled and sold, usually annually. Initially sales of fins were to local exporters by a tender process but the NSB is now investigating direct export. Fins and teeth from great white sharks *Carcharodon carcharias* are not sold because the species is locally protected. The meat from netted sharks is generally not sufficiently fresh for human consumption. Experimental inclusion of the meat in animal feed has been unsuccessful.

Although there has been an increase in current values with time (Figure 1), these have not kept pace with inflation (Figure 2). The drop in real value in the 1990s is partly due to a ban since 1991 on the sales of white shark jaws and teeth. Fluctuations in revenue are linked to annual catch.

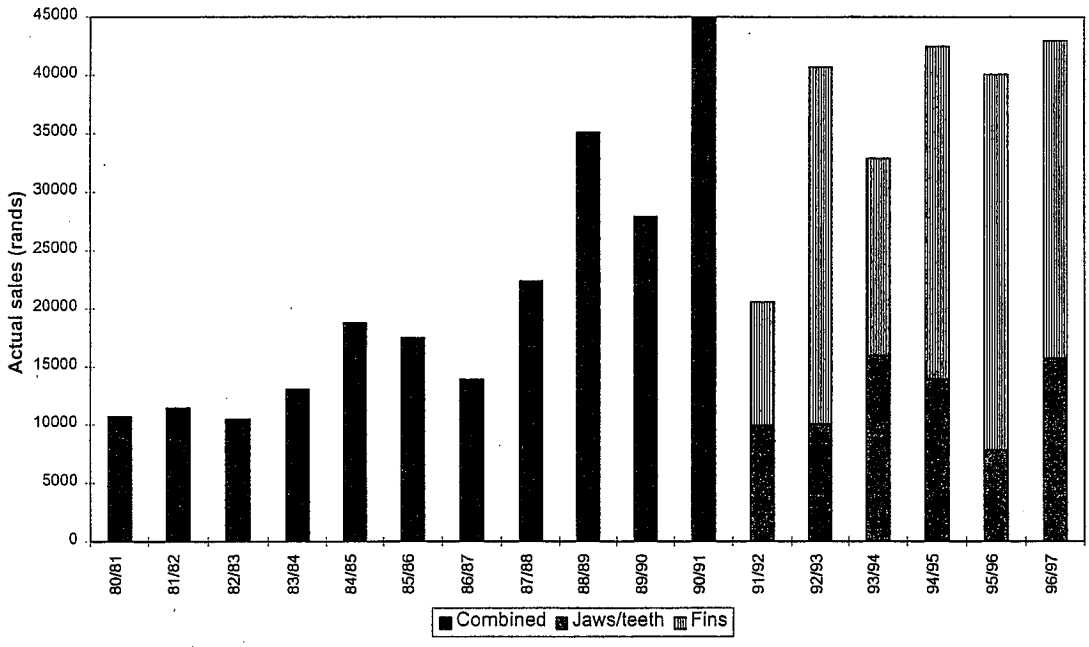
2.5 Economics of the programme

The programme, by nature, is not directly profitable and is almost fully subsidised. In the 1996/97 financial year income was derived from the following sources (approximate figures): subsidy from provincial government of KwaZulu-Natal - R12.4m ($2.8 m), meshing fees paid by coastal local authorities (municipalities etc.) which have protected beaches - R3 m ($0.7m), sundry income, including entrance fees to public shows and sales of shark products - R347 200 ($0.1m). The economic justification for the existence of the programme is that it is integral to the tourism infrastructure of KZN. The annual contribution of tourism to the economy of KZN is at least R6bn ($1.3bn), or 10% of the Gross Geographic Product (J. Seymour, KwaZulu-Natal Tourist Authority, pers. comm.). Not all of this is attributable to coastal tourism, but most of the tourism infrastructure in the province is associated with coastal resorts (Dudley 1998).

2.6 The programme's workforce

Initially the NSB consisted of a board only and had no permanent staff. In 1966 B. Davis, subsequently the NSB's first director, was employed to act as a liaison officer between the NSB and those local authorities which had netted beaches. In 1968 the NSB began to employ its own staff and by 1997 a workforce of some 220 personnel was employed on a full time basis. Of these, 156 are operations staff directly responsible for meshing activities and the remaining 64 provide administrative, financial, logistical, research and public relations support. The research staff includes four scientists.

Figure 1
Sales of products from sharks netted in the KZN programme (current terms)
(1996/97 approximate exchange rate R4.50=$1.00)



2.7 Management objectives

2.7.1 The programme within the context of national fisheries policies

A new Marine Living Resources Bill is set to form the basis for a new Sea Fishery Act. Nine objectives and principles underpin the Bill. Probably the most pertinent of these, with regard to shark control, are the following:

i. the need to conserve marine living resources for both present and future generations

ii. the need to apply precautionary approaches in respect of the management and development of marine living resources

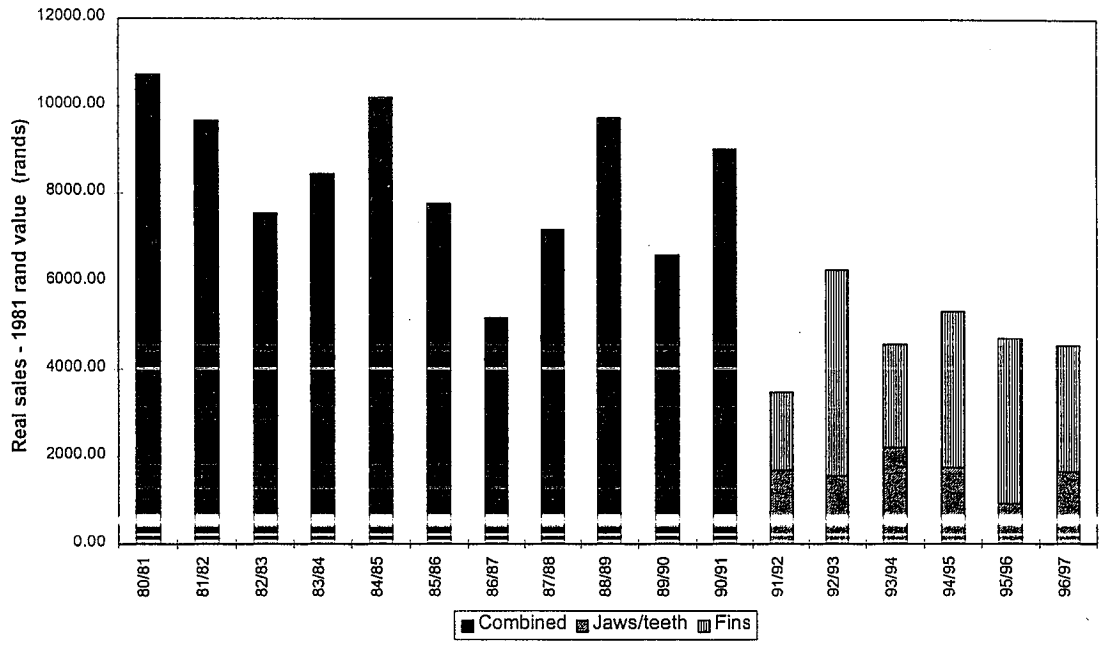
iii. the need to utilise marine living resources to achieve economic growth, human resource development, employment creation and a sound ecological balance consistent with the development objectives of the national government

iv. the need to protect the ecosystem as a whole, including species which are not targeted for exploitation

v. the need to preserve marine biodiversity.

A shark control programme is a unique application of the concept of exploiting marine resources, perhaps equating most closely to angling in that in both cases the basis for exploitation is recreation. The analogy breaks down however, in that shark control is a means to an end rather than an end in itself. The ecological considerations which must be taken into account in the management of shark control are addressed in all of the objectives and principles listed above. It is, however, the achievement of economic growth, human resource development and employment creation by providing a component of the tourism infrastructure of KZN that provides the economic justification for shark control in terms of the Bill.

Figure 2
Sales of products from sharks netted in the KZN programme (real terms)



Pending the promulgation of the new Act, living marine resources in South Africa are protected by the Sea Fishery Act of 1988. In terms of the Act the NSB is required to possess permits (a) to use and be in possession of gill nets, (b) catch and be in possession of great white sharks; and (c) catch (incidentally) and be in possession of dolphins. In addition, the NSB is required in terms of the KwaZulu-Natal Nature Conservation Ordinance of 1974 to have a permit to capture, by means of shark nets only, and be in possession of, any marine turtle.

A draft Marine Fisheries Policy for South Africa, dated May 1997, proposes that central government, in serving the principle of sustainable utilisation, should consider devolving research responsibility to a number of institutions, including the NSB.

2.7.2 Objectives for the management of the shark control programme

The major objective of a shark control programme - minimising the risk of shark attack - differs from the objectives of "conventional" fisheries. Another unusual feature of the programme is that the managers are also the prosecutors of the fishery and thus it is in management's direct interest to achieve a second objective - minimising operating costs. A third and more conventional management objective is to minimise environmental impact. A fourth objective is to use the opportunity afforded by the capture of sharks and other animals to conduct biological research.

The primary objective was set because of the negative economic impact of shark attack (Davies 1961). As early as 1907 a shark barrier was built on Durban's beachfront "to ensure that there was safe bathing and as a protection from shark attack" (Davies 1964). At the time of the introduction of shark nets in 1952 there seems to have been no consideration of the ecological consequences of shark control. At its inception in 1964 the NSB was charged "with the duty of approving, controlling and initiating measures for safeguarding bathers against shark attack" (Natal Ordinance No. 10 of 1964). There has subsequently been a gradual change in philosophy such that mortalities of marine organisms - including sharks - are minimised (Cliff and Dudley 1992a), yet without compromising

bather safety unduly. Symbolic of this was a change in name from the Natal Anti-shark Measures Board to the Natal Sharks Board.

There has been a degree of compromise in combining objectives one, three and four, notably the tagging (where possible) and releasing of all sharks found alive in the nets. Released sharks constitute about 15% of the total shark catch. The NSB argues, however, that the nets achieve their protective function primarily by maintaining local shark numbers at a considerably lower level than in the pristine state and that the occasional release of a potentially dangerous shark will have a negligible effect on their numbers. Also, the release of sharks takes place at first light when there are few bathers in the water and it is believed that the released animals tend to move into deeper water (Cliff and Dudley 1992a).

2.7.3 Discussion

The management objectives at the "fishery level" are clear but they are by no means prescriptive in terms of setting management policy, i.e. the manner whereby they should be achieved. Stakeholders include the provincial government (the major funder), coastal municipalities and other local authorities with protected beaches, the tourist industry, recreational users of the sea, environmentalists, conservationists and members of any fishery which might be affected directly, or indirectly, by a reduction in numbers of large sharks. The majority of stakeholders appear satisfied with the objective setting process in that they all influence, directly or indirectly, the process. Indeed, shark control would not exist if it were not for public demand. Dissatisfaction at perceived or real environmental impact has been expressed, however, by environmentalists, conservationists and recreational anglers. The response of the NSB has been to research these impacts to determine their severity and to seek methods of reducing them. Dissatisfaction has also been expressed by certain local authorities whose shark nets have been removed on economic grounds because of low bather numbers.

2.8 Management policies and the policy setting process

2.8.1 Identification and evaluation of policies

Policy options for the provision of safe bathing may be divided broadly into either providing a physical barrier between sharks and bathers or reducing locally the numbers of potentially dangerous sharks, thereby reducing the likelihood of an encounter between sharks and bathers. The NSB has adopted the latter. Physical barriers ("shark fences") were used in the early part of the century (Durban) as well as in the late 1950s and early 1960s (various municipalities). Long term maintenance of these unsightly structures in heavy surf conditions proved expensive and impractical.

By the time the NSB came into existence in 1964 there were already several net installations in existence in addition to that at Durban which had been established in 1952. These installations were maintained by contracted commercial fishermen or by municipal employees. Initially the role of the NSB was supervisory but in 1974 the decision was taken to gradually assume direct responsibility for the maintenance of all net installations. This process was completed in 1982. Reasons for the decision included (1) ensuring a consistently high level of service by means of using trained staff, (2) achieving a reduction in costs replacing with a single NSB meshing team two or more contractors/municipal teams which were servicing adjacent beaches and (3) improved collection of biological and environmental data, including a high level of accuracy in the identification of species in the field, and the retrieval of dead sharks and other animals for dissection.

The nets are maintained in fixed localities throughout the year. Although the use of nets was inspired by a similar practice in Sydney, NSW, the two programmes differ markedly in the quantity of gear deployed per beach and the length of time the gear is in the water. In NSW a "roster" system" is used, with nets being moved from beach to beach. There appears to be no documented explanation for

the Durban City Council's decision to deploy nets at each beach on a permanent basis. Davies (1961) suggested that the use in NSW of supplementary beach patrols when bathing densities were high may have been a factor, and that the higher turbidity of KZN waters would preclude a similar practise, but Dudley (1997) argued that as this is dependent upon human vigilance it is unlikely to explain why the NSW meshing programme has succeeded over a 50 year period despite a relatively low level of fishing effort.

Decisions on the number of nets to deploy per beach were made on the intuitive basis of "beach coverage". Fewer nets were deployed off a beach situated in a "natural curve of the coastline" (Wallett 1973, p.17), because of the physical restriction on a shark's approach to that beach from the sides, than at a beach on a straight Section of coastline. Also, if shallow water inshore dictated that the nets be set further offshore than normal, more nets were set. Wallett's stated relationship between coastline topography and number of nets is difficult to test objectively because most of KZN's netted beaches are defined by Cooper (1991a,b, 1994) as embayments, albeit poorly developed.

The increase in the frequency with which nets are serviced - from approximately weekly until the late 1970s to the present frequency of about 20 times per month - has led to a substantial decrease in undetected captures which used to result from sharks decomposing and falling out of the nets. Similarly, the survival rate of captured animals has increased, though operating costs also increased.

In the 1960s and 1970s most requests for new net installations were granted, the exception being those for areas regarded as particularly environmentally sensitive. More recently, with the increase in environmental awareness, such requests are treated more conservatively and new installations are seldom established. Coupled with this are the recently introduced policies of effort reduction and catch and bycatch reduction. Effort reduction includes the complete removal of net installations at under-utilised beaches and, where possible, a reduction in the size of other installations. In a comparison of the shark control programmes of KZN, Queensland and NSW, Dudley (1997) concluded that there is a case for reducing the number of nets used per beach in KZN. Catch and bycatch reduction could be achieved by effort reduction but also by modifying the existing nets (e.g. increased mesh size, use of passive or active dolphin repellents) and/or through the use of alternative gear such as the baited drumlines used in Queensland. These options have been, or are being, researched.

2.8.2 Policies adopted

i. A single type of gear - a large-mesh anchored gill net - is used.

ii. Each beach is permanently netted except during the "sardine run" when some net installations are temporarily removed.

iii. The nets are serviced at first light about 20 times per month. All live animals are released. Sharks and some rays are tagged. Dead animals are retrieved and used for research.

iv. Fins, teeth and jaws from dead sharks are sold to offset expenses.

v. Requests for new net installations are treated conservatively.

vi. The NSB is engaged in ongoing research into effort and bycatch reduction.

The policies have been effective in achieving a reduction in risk of shark attack. At Durban the rate of attack resulting in a fatality or a serious injury dropped from 0.58/y⁻ to zero with the introduction of nets, and at KZN's other meshed beaches the decline was from 1.08 to 0.10 (91% reduction). Effort reduction, i.e. a reduction in the number of nets per installation, has not yet reached the point where it has resulted in cost reduction. An exception was the permanent removal of two installations which

resulted in one boat unit being taken off the water. Mortalities have been reduced through the policies of releasing all live animals and lifting nets during the sardine run, but could be reduced further with modified and/or alternative gear. The general research objective is being achieved, NSB scientists having published almost 50 peer-reviewed articles in the last decade.

2.9 Gears used

The nets are described in Section 2.2. Their original design was adaptated from those which had been found to be effective in the NSW programme. The mesh size of 50.8cm bar exhibits a peak relative selectivity to sharks (all netted species combined, excluding hammerheads) of about 215cm precaudal length (Dudley 1995). The relative selectivity to sharks of 160cm precaudal length (the size taken as being that of the smallest potentially dangerous shark) is 81%, whereas the selectivity of a 70cm mesh net to the same animal is only 25% (Dudley 1995). Thus, although the larger mesh would take a smaller bycatch, the potential increase in risk to bathers is considered unacceptable.

Drumlines, each consisting of a baited hook suspended from an anchored drum, are an alternative method of capture to nets. The advantage of drumlines is that they take a far smaller non-shark bycatch than nets and are more selective in terms of shark species caught. They have been used since inception in the Queensland programme but are not used by the NSB. Criticisms of drumlines include that they (i) may attract sharks; (ii) are only functional while baits are on the hooks and the baits are subject to scavenging; and (iii), do not offer the partial physical barrier effect of nets. Despite these concerns, drumlines have proven successful in the Queensland programme and experiments with drumlines are under way in KZN.

2.10 Biological regulations

The KZN programme is governed by the national and provincial regulations described in Section 2.7.1. In addition, self-imposed regulations include the release of all live animals, the tagging of live sharks and some batoids and the retention of dead animals for biological research and sale of certain parts.

2.11 Expansion/reduction of the programme

The NSB is reluctant to expand the programme within KZN waters. Catches appear to be sustainable - with the possible exception of the humpback dolphin (*Sousa plumbea*) - but obviously unlimited expansion of the programme would change this. No new installation would be established without first inviting public comment. It is likely that any new installations would have to be self-funded.

The NSB monitors bather numbers at netted beaches and makes recommendations to the KZN government with regard to the removal of nets from under-utilised beaches. All but one of the beaches protected by the NSB fall within KZN, the exception being a beach which lies two kilometres beyond the border with the Eastern Cape Province. The NSB does accept contract work in other parts of the world, but prefers to install passive barrier nets where possible rather than shark-catching gear.

2.12 Discussion

The policy setting progress has been successful in terms of achieving the primary objective of the programme, namely a major reduction in risk of shark attack. Probably the major weakness is that there has historically been little opportunity for the public to comment on the process. Also, there is no regular internal policy review process, the development of policy being somewhat *ad hoc*. Both these weaknesses require consideration.

3. THE MANAGEMENT PROCESS

3.1 Provision of resource management advice

Unlike commercial fisheries, in which research and management are usually conducted by one or more government agencies and the fishing activities themselves by the private sector, in the case of the KZN shark control programme the NSB is responsible for all three functions. The research department of the NSB monitors trends in catch data. Its mandate is to recommend research projects to improve understanding of the biology of the netted species and the ecological effects of the programme. It also recommends and supervises projects to reduct catch (including bycatch) and effort. The NSB has a board, appointed by the provincial government, which meets monthly, *inter alia* to approve policy, and an executive management which ensures the implementation of policy. Actual implementation is done by the operations staff. Because the entire process is internal it has advantages in data capture, communication between researchers, management and operations staff (meshing teams) etc. A potential disadvantage for the process is lack of transparency (see Section 3.4).

3.2 Fishery statistics

The nets are meshed at first light about 20 days per month. Upon completion, each meshing team reports by radio the day's catch and bycatch, by species, to the NSB research department. Other data reported include physical conditions at the nets and sightings of cetaceans. Once the dead sharks have been dissected in the NSB laboratory, biological information is recorded.

There were considerable problems with the accuracy of the data - particularly with regard to species identification but also with regard to total catch figures - until the late 1970s. Since then the quality of data is considered to be good and the officer in charge of each meshing team takes periodic retraining in species identification. The identification of all animals brought to the NSB laboratory is checked by research staff and is seldom found to be incorrect.

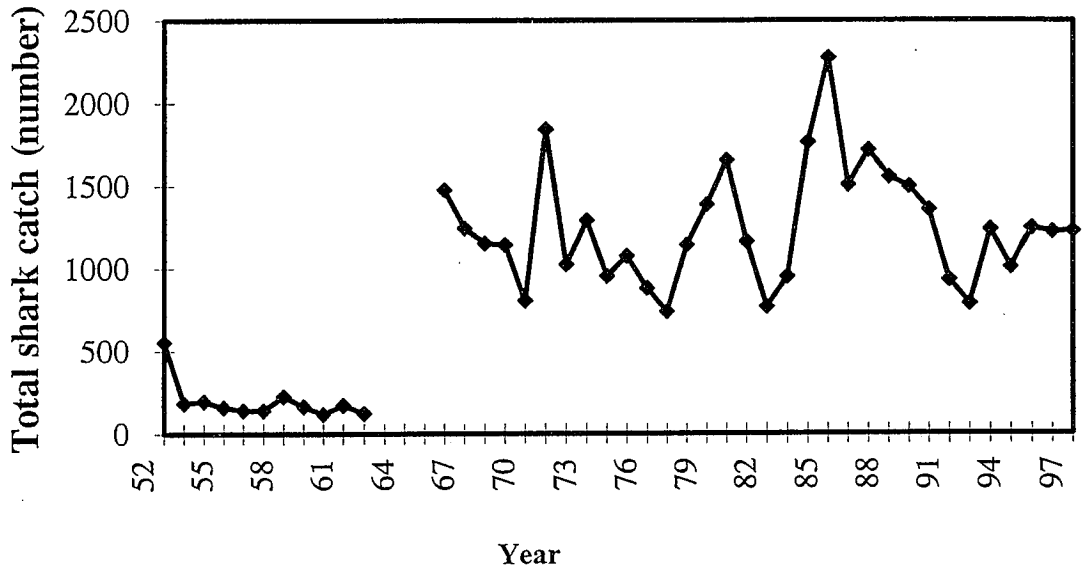
Data are stored on computer using Borland's dBase III+™. The intention is to convert to Microsoft Access™ during 1998. Monthly catch reports are supplied to local authorities which have netted beaches and annual catch reports are submitted to the Chief Directorate; Sea Fisheries. Most requests for data come from researchers working on the KZN coast who require physical environmental data. These requests are generally granted and a preparation fee is levied at the discretion of the NSB chief executive.

3.3 Stock assessment

The NSB programme is characterised by having size-selective fishing gear (gill nets) deployed in fixed localities. Thus a very small part of the geographical range of each shark species is sampled, and always in the same places. Also, there are no other fishery-independent data for most of the shark species caught. This renders the data collected by the programme of some value for stock assessment purposes. Total shark catch is shown in Figure 3.

There have been few attempts at stock assessment. Holden (1977) used a De Lury method of regressing the log of CPUE on accumulated effort to analyse early CPUE data from the first two KZN net installations to be established. Dudley and Cliff (1993a) attempted something similar using Leslie's method as described by Ricker (1975), to estimate by how much shark numbers were reduced by netting in the 1960s. More recently, OLRAC cc, a firm of fisheries consultants, was asked to analyse the catch and effort database to determine whether it would be possible to predict the amount by which shark numbers (and hence risk of shark attack) may increase if effort were reduced.

Figure 3
Total shark catch taken in the KZN shark control programme



3.4 Sustainability of the resource

The shark control operation constitutes a multispecies shark fishery whose dynamics are not fully understood but the catch seems to be sustainable (Dudley and Cliff 1993a, b). Although landings weight data are incomplete for the early years of the fishery, the numbers of sharks caught indicate that the annual catch has fluctuated about a level of 100t since the 1960s (Dudley 1998). (The catch was lower in the 1950s but there was only one net installation, at Durban, during that decade.) Although the shark catch rate (number of sharks per unit effort) declined steeply in the early years of netting, there has been no evident trend for more than two decades. It may be that the apparent sustainability of the KZN catch is because the nets initially caught the "resident" sharks and now only harvest migrants which encounter the gear (Wallett 1983).

3.5 Discussion

Management requires information pertaining to the sustainability of the catch (including bycatch) and methods of reducing operating costs, catch and bycatch without risking bather safety. In the absence of fishery-independent data, catch and effort data from the programme are likely to continue to be the only means of monitoring the sustainability of the shark catch. Independent census data are used, however, as a means of assessing stocks of the bycatch species of bottlenose dolphin (*Tursiops truncatus*) and humpback dolphin (*Sousa plumbea*). Operating costs and catches could both be reduced through a major reduction in fishing effort (number of nets per beach). A comparison of the shark control programmes of Queensland, NSW and KZN suggests that there is scope for such a reduction in the KZN programme (Dudley 1997). Research efforts to quantify the relationship between fishing effort and degree of bather protection have so far been unsuccessful making specific recommendations about effort reduction difficult. OLRAC has proposed the development of a convection model to simulate shark movement around the nets, and the use of sonic tags to track sharks in order to validate the model. Insufficient funds have precluded this investigation todate.

Research into the use of drumlines as a means of reducing bycatch is yielding promising results, yet the introduction of drumlines would not necessarily reduce costs. If the biological advice is that drumlines be introduced and this is a more expensive policy to implement, the decision would rest on the availability of funds. However, the over-riding factor involved in decisions on possible management actions is, in terms of the NSB's mandate, the provision of protection from shark attack.

3.6 Evaluation of the management process

The executive meets weekly and reports to the board monthly. The executive staff also meet weekly with senior representatives of their respective departments. Thus internal communication is well established.

Although there are strengths when research, management and implementation are all functions of a single organisation, there are also potential weaknesses in terms of complacency and lack of accountability. To safeguard against this, the NSB is subject to external evaluation. It is part of the portfolio of, and answerable to, the provincial Department of Economic Affairs and Tourism. Its financial affairs are audited by the Auditor General of the Province of KwaZulu-Natal. Catch and bycatch data are submitted annually to the Chief Directorate; Sea Fisheries, Cape Town of the national Department of Environment Affairs and Tourism. The NSB is also accountable in terms of service delivery to the coastal local authorities which have protected beaches. Monthly summaries of catch statistics are provided to these authorities and to the provincial government. The NSB is also required to furnish information in response to questions raised by members of the national or provincial parliaments. Trends in catches are published by scientists from the NSB and other institutions. Various environmental monitoring organisations keep themselves informed about the activities of the organisation and the NSB is regularly subject to public, print and electronic media scrutiny.

3.7 Management success

3.7.1 Success of the shark control programme

The programme has been extremely successful in terms of reducing the frequency of shark attack (see Section 2.8.2). There has been no fatality at a netted beach since the first beach was netted in 1952, and only three serious injuries, the last in 1980.

3.7.2 Environmental costs

It is believed that a reduction in numbers of large sharks is the primary mechanism whereby the nets have succeeded in reducing the frequency of shark attacks on the coast of KZN, (Dudley 1997 and references therein). Catch rates of most shark species declined initially but have shown either no trend, or, in the case of the tiger and spotted ragged-tooth shark, an increasing trend, since the mid-1970s (Dudley 1997, Dudley and Cliff 1993a, b). The nets also take a bycatch of dolphins, sea turtles, batoids and teleosts. Turtle and teleost stocks do not appear to be threatened by net mortalities (Dudley and Cliff 1993a, Hughes 1989), but there is concern about the sustainability of the humpback dolphin (Cockcroft 1990). Reflectors of dolphin sonar are being tested as a means of reducing dolphin catches and tests of "pingers" (sound-emitting devices) are imminent (V.M. Peddemors, Natal Sharks Board, pers. comm.). Catch rates of certain batoids may have declined despite a high release rate, but the quality of early data is poor (Dudley and Cliff 1993a). All live animals, including sharks, are released. An assertion that shark netting resulted in a proliferation of small sharks through reduced predation was re-examined by Dudley and Cliff (1993a) and considered to be exaggerated.

3.7.3 Profitability of the programme

The programme creates wealth indirectly through its part in the valuable coastal tourism industry in KwaZulu-Natal. No formal cost-benefit analysis has been done but the existence of the programme is regarded by government and industry as essential. Evidence of this is that the programme is funded from these sources.

3.8 Management costs

Total cost of the NSB operation in 1996/97 was R16.2 m ($3.6m), making it the most expensive of the three major shark control programmes. There is, however, a combination of constraints on potential cost reduction which is unique to this programme:

i. There is no umbrella organisation which could potentially provide boat and equipment storage facilities or supervision.

ii. The process of surf-launching requires a minimum crew of five per boat.

iii. Accommodation is provided for the crew.

If the organisation were to revert only to maintenaining shark nets, costs could be reduced by a considerable margin, with or without a reduction in the quantity of gear deployed per beach. But the NSB offers a multi-faceted service in addition to the basic maintenance of shark nets. Among these services are:

i. NSB field officers are trained so that captured animals are accurately identified, live sharks and some batoids are tagged and released and physical oceanographic data are collected.

ii. Resources are provided to transport captured sharks and other animals to the NSB headquarters for dissection and the resulting data are published.

iii. Four biologists are employed to ensure a steady output of both basic and applied research on sharks and cetaceans.

iv. The NSB maintains the South African Shark Attack File, which is a component of the International Shark Attack File. The NSB also advises countries with shark attack problems.

v. NSB research staff sit on various provincial and national committees which address matters ranging from coastal zone policy development to the management of commercial shark fisheries.

vi. As one of the few institutions conducting marine biological research in KZN, the NSB is frequently asked to advise on issues related to the marine environment.

vii. Maintening a public "edutainment" facility, consisting of a modern audio-visual presentation in a large auditorium, a shark dissection accompanied by live commentary, static displays and even a curio shop offering high quality products. In the financial year 1996/97, 30 000 school children and 29 000 tourists visited this facility.

viii. Film companies regularly include the NSB in documentaries referring to sharks and/or to KZN tourism and members of the organisation are interviewed by journalists and writers. The NSB uses these opportunities to convey its philosophy of providing safe bathing in an environmentally sustainable manner and to convey a respect of, and appreciation for, sharks, rather than fear and hatred.

ix. The NSB is on 24 hour call as part of the Aquatic Rescue Co-ordinating Committee, which is responsible for both freshwater and nearshore marine rescue. The NSB is also a member of the Sea Patrol Co-ordinating Committee and South African Search and Rescue.

Many of these services are either non-profit or have intangible financial benefits and it is not easy to identify specific cost-recovery and the cost-effectiveness of management. The operation, although undoubtedly expensive, has resulted in the NSB being regarded as a KZN flagship organisation with an international reputation for shark attack prevention and shark research.

4. QUEENSLAND SHARK CONTROL PROGRAMME (QSCP)

4.1 Introduction

The emphasis of the analysis and summary of the QSCP is from the perspective of swimmer protection. The shark "fishery" in this instance is a by-product of a swimmer protection programme installed at popular swimming beaches close to centres of human population. While it is accepted that swimmers at present are not "totally" protected from shark attack on QSCP controlled beaches, the probability of attack is low. This fact is borne out by the history of the programme where there has been no substantiated death due to shark attack on any beach under QSCP control since its inception over 34 years ago. Due to legal and moral responsibilities, fine tuning of gear-types or gear placement must be for the primary purpose of lowering the risk of shark attack on swimmers. The secondary concern of the programme is the reduction of incidental capture of bycatch species, including harmless shark species, which has been an ongoing process within the programme over a number of years. Thus, the shark control "fishery" is not commercially oriented and is fully state-subsidised, for the purpose of reducing the risk of shark attack on humans. Economically, the justification is enhancement of coastal tourism.

4.2 The resource

4.2.1 Species composition of programme

The objective of a "public safety" shark control programme is to catch those shark species and sizes which are potentially dangerous to man. In Queensland this was determined as sharks over two metres in length, and initially a bounty was paid to QSCP contractors for shark of this size or larger. Since the beginning of the programme the QSCP shark nets have been constructed of 20 inch (50cm) mesh which means they are most effective for the larger species. The major categories of shark that were historically considered dangerous to man are the tiger shark (10% of the total sharks recorded), white pointer or great white shark (8%), and the whaler sharks (75%). The latter category is a multi-species grouping which has only been reliably differentiated into species since 1992.

The current species list (Tables 3 and 4) differentiates the bull whaler shark or Zambezi shark (*Carcharhinus leucas*). This shark was included in the general "whaler" category prior to 1992-3. The Zambezi shark is of particular concern as it occurs at all protected areas along the Queensland coast, is an inshore estuarine species that is highly aggressive and feeds in relatively shallow turbid waters.

4.2.2 Distribution of programme

In September 1962 protective measures consisting of a combination of shark nets and baited drumlines were introduced at the following centres:

i. Gold Coast (28°S, southern extent of QSCP)
ii. Sunshine Coast
iii. Cairns (17°S, northern extent of QSCP)

In December 1963 the programme was extended to include:

iv. Townsville

v. Mackay

The programme was further extended to include the following centres:

vi. Rockhampton (Capricorn Coast) - July 1969
vii. Bundaberg - October 1973
viii. Rainbow Beach - 1974
ix. Tannum Sands - October 1983
x. Point Lookout - July 1984

Since 1996 the programme could only be extended if local councils pay the costs involved. Currently there are 72 beaches protected, with drumlines or a combination of nets and drumlines maintained by the QSCP, at 10 "controlled" areas along 2000km of tropical and sub-tropical coast.

Table 3
QSCP shark species list (since 1992): General

QSCP logbooks*	Species	Current QSCP common name
	Pristiophorus sp. B	Tropical sawshark
	Unidentified *Heterodontidae*	Unidentified Port Jackson
	Heterodontus galeatus	Crested Port Jackson
	Heterodontus portusjacksoni	Port Jackson
	Chiloscyllium punctatum	Grey carpet shark
0.03%	*Brachaelurus waddi*	Blind shark
	Unidentified *Orectolobidae*	Unidentified wobbegong
	Eucrossorhinus dasyopogon	Tasselled wobbegong
	Orectolobus maculatus	Spotted wobbegong
	Orectolobus ornatus	Banded wobbegong
0.72%	*Stegostoma fasciatum*	Zebra shark
3.23%	*Nebrius ferrugineus*	Tawny shark
0.01%	*Rhiniodon typus*	Whale shark
0.08%	*Carcharias taurus*	Grey nurse shark
	Unidentified *Alopiidae*	Unidentified thresher shark
	Alopias vulpinus	Thresher shark
0.65%	*Carcharodon carcharias*	Great white shark
0.04%	*Isurus oxyrinchus*	Mako
	Lamna nasus	Porbeagle
0.01%	*Galeorhinus galeus*	School shark
	Mustelus sp. B	Gummy shark
0.01%	*Hemigaleus microstoma*	Weasel shark
	Hemipristis elongata	Fossil shark
22.81%	*Galeocerdo cuvier*	Tiger shark
0.77%	*Negaprion acutidens*	Sharptooth shark
0.74%	*Prionace glauca*	Blue shark
0.44%	*Triaenodon obesus*	Whitetip reef shark
6.57%	Unidentified *Sphyrnidae*	Unidentified hammerhead
1.08%	*Sphyrna lewini*	Scalloped hammerhead
	Sphyrna mokarran	Great hammerhead
	Eusphyra blochii	Winged hammerhead
0.31%	Unidentified *Squalomorphea*	Unidentified shark

* The reported incidence of species in QSCP logbooks since 1992, as a percentage of the total number of sharks taken. All species in the list are considered as possible captures of the programme although many are unlikely.

Table 4
QSCP shark species list (since 1992): Whaler sharks

QSCP logbooks*	Species	Current QSCP common name
46.77%	Unidentified *Carcharhinus* spp	Unidentified whaler shark
	Carcharhinus altimus	Bignose whaler
0.03%	*Carcharhinus amblyrhynchoides*	Graceful whaler
	Carcharhinus amblyrhynchos	Grey reef whaler
0.51%	*Carcharhinus amboinensis*	Pigeye whaler
	Carcharhinus brachyurus	Bronze whaler
3.87%	*Carcharhinus brevipinna*	Longnose whaler
0.21%	*Carcharhinus cautus*	Mangrove whaler
	Carcharhinus dussumieri	Spot-tail shark
	Carcharhinus falciformis	Silky whaler
	Carcharhinus fitzroyensis	Creek whaler
	Carcharhinus galapagensis	Galapagos whaler
9.12%	*Carcharhinus leucas*	Bull whaler
	Carcharhinus tilstoni	Australian blacktip whaler
	Carcharhinus limbatus	Blacktip whaler
0.03%	*Carcharhinus macloti*	Hardnose whaler
	Carcharhinus melanopterus	Blacktip reef whaler
0.87%	*Carcharhinus obscurus*	Dusky whaler
0.46%	*Carcharhinus plumbeus*	Sandbar whaler
0.64%	*Carcharhinus sorrah*	Spot-tail whaler
	Carcharhinus albimarginatus	Silver tip whaler
	Carcharhinus longimanus	Oceanic whitetip whaler

* The reported incidence of whaler species in QSCP logbooks since 1992, as a percentage of the total number of sharks taken. All species in the list are considered as possible captures by the programme although many are unlikely.

4.2.3 Associated species either as bycatch or discards

The QSCP database records the capture of non-shark species and the number "released alive". The percentages of bycatch released alive over the 1992-1995 period (Gribble *et al.* submitted) was:

i. 100% of whales
ii. 17% of dugong
iii. 13% of dolphins
iv. 87% of sea turtles (90% of the endangered loggerhead turtle).

Rays and harmless sharks such as the whale shark, milkshark, angelshark, Port Jackson shark and wobbegongs are also released alive if possible. It has always been the practice of the QSCP to release bycatch species and in 1992 the QSCP formed volunteer rapid-response marine mammal rescue teams to improve survival of dolphins, dugong or sea turtles entangled in nets.

The major category of bycatch was "rays" at 40% of the total catch (including sharks) recorded in the full 34 year database. Since 1992 the ray category has been differentiated into species (Table 5). As with the shark species list, these rays could potentially be caught by the QSCP although some would be unlikely. Other species incidentally captured by the QSCP over 34 years are dolphins (2% of the total catch), dugong (2%), sea turtles (16%), and a variety of large fish (see Table 6). Only since 1996 have these been listed by species in the database and species identification by contractors is now the subject of ongoing training.

Table 5
Possible species composition of QSCP "ray" category

Species	Current QSCP common name
Unidentified *Pristidae*	Sawfish (ray)
Pristis zijsron	Green sawfish
Pristis clavata	Queensland sawfish
Anoxypristis cuspidata	Narrow sawfish
Rhynchobatus djiddensis	White-spotted guitarfish
Rhina ancylostoma	Bowmouth guitarfish
Unidentified *Rhinobatidae*	Unidentified shovelnose ray
Aptychotrema rostrata	Eastern shovelnose ray
Rhinobatus typus	Giant shovelnose ray
Trygonorrhina sp. A	Fiddler ray
Torpedo macneilli	Torpedo
Hypnos monopterygium	Numbfish
Unidentified *Dasyatidae*	Unidentified stingrays
Gymnura australis	Butterfly ray
Unidentified *Urolophidae*	Unidentified stingaree
Unidentified *Myliobatidae*	Unidentified eagle rays
Myliobatus australis	Bull ray
Aetobatus narinari	White-spotted eagle ray
Rhinoptera neglecta	Cownose ray
Unidentified *Mobulidae*	Unidentified devilrays
Mobula eregoodootenkee	Pygmy devilray
Manta birostris	Manta ray

Table 6
Incidental bycatch species caught by the QSCP

QSCP logbook*	Common name	QSCP logbook*	Common name
2.53%	Dolphin (sp. not recorded)	0.02%	Crocodile
0.35%	Irrawaddy dolphin	0.08%	Unidentified fish
1.04%	Dugong	0.10%	Kingfish (Y-Tail)
2.73%	Green turtle	0.02%	Lobster
0.35%	Leatherback turtle	0.10%	Mackerel
3.47%	Loggerhead turtle	0.30%	Marlin
18.26%	Turtle (sp. not recorded)	0.03%	Mud crab
0.05%	Barramundi	0.03%	Puffer fish
0.02%	Black kingfish	0.10%	Snapper
3.18%	Blue groper	0.13%	Swordfish
0.02%	Bonita	0.03%	Toadfish
0.05%	Catfish	2.13%	Tuna
0.30%	Cod	0.30%	Whale
0.02%	Conger eel	64.25%	Ray (see Table 5)
0.02%	Crayfish		

*The reported incidence of species in QSCP logbooks since 1992 as a percentage of the total bycatch.

4.3 Development and current status of the programme

4.3.1 Catching methods

The QSCP uses a mixed gear strategy for local reduction of large shark numbers. A combination of baited drumlines and nets have been used since the inception of the programme and drumlines are now the dominant mode of shark population control. This is in contrast to the other two major shark control programmes, the Natal Sharks Board and the NSW Protective Beach Meshing Programme, which use nets exclusively. A mixed gear strategy allows the QSCP flexibility in gear placement. Dreamlines can be deployed in areas that are not suitable for nets and vice versa. Flexibility is also possible in response to environmental concerns. For example, the replacement of nets with drumlines at Bundaberg in 1982 was carried out after concern was expressed for the safety of breeding sea turtles at a near-by rookery.

In 1997 the QSCP deployed a total of 30 shark nets and 340 baited drumlines. Drumlines were deployed at four protected areas and a combination of nets plus drumlines deployed at the other six areas. Each protected area consists of a number of beaches and at each beach the normal amount of gear deployed would be between one and two nets and/or up to six drumlines. Each net is 186m long; consequently any one beach will have a maximum of 372m of net set though the majority of beaches have less. QSCP shark nets are not designed as barriers but as a fishing device to reduce the shark numbers.

Each set of fishing gear is serviced every second day unless weather conditions render this impossible. The gear is removed from the water at least once every 21 days for repairs, cleaning or replacement. A complete replacement set of equipment is kept at each location for backup use.

4.3.2 Fleet characteristics, evolution of the fleet and fishing effort

The evolution of the programme has been linked to the expansion of Queensland's coastal tourist industry. Submissions were made periodically by local councils or community groups to the Queensland State Government for a shark control programme to be established at particular beaches. This usually followed a well publicised shark attack or incident. The Government of the day would then direct the QSCP to set an appropriate number of nets and drumlines and to call for tenders for a local contractor to service the gear. The vessels specified in QSCP contracts are high speed catamarans not less than seven metres in length. Small vessels are used in some inshore areas. All vessels comply with relevant Queensland Marine Safety Standards. Currently there are 10 contract districts each with a boat.

4.3.3 Economics of the programme

The programme is a fully subsidised, non-profit, state government operation run as a public safety measure. The QSCP however makes a positive contribution to the coastal tourist industry of Queensland and to marine tourist in general. Queensland's premier beaches are advertised, with justification, as being "fatality free" in regard to sharks. The effect of this contribution could be measured in millions of dollars over the 34 years of the programme's operation. The alternative would be continual shark "scares" with resultant of tourist bookings cancellations. The tourist industry in Queensland is the second largest industry in the state and generates significant income, particularly foreign exchange income, which is taxed both at the federal and state level. QSCP policy is that no shark products will be sold from the programme. The programme enjoys considerable support from industry groups involved in Queensland tourism, as well as from public safety organisations such as the Surf Life Saving Association.

4.3.4 The programme's workforce

The organisation and overall management of the QSCP is centralised in Brisbane but service delivery is devolved to local districts and contracted to locals who are in charge of daily servicing of the programme's shark nets and/or drumlines. Each shark control district has a liaison officer (Queensland Boating & Fisheries Patrol) who supervises the contractor and liaises with a local community focus group. These focus groups have representatives of client groups such as local councils, Queensland Surf Lifesaving Association, life guards, community interest groups and conservation groups, and provide community feedback to the district and Brisbane QSCP. Head office staff is limited to one or two employees. There are 10 local district "shark" liaison officers, who also fulfil other normal QB&FP duties, and usually a single contractor per district although he may have an assistant. Therefore between 22 and 30 individuals are involved in the "fishery".

Staff participation is encouraged through devolving responsibility for day-to-day shark control to the district teams of the shark liaison officer and shark contractor. Annual workshops ensure exchange of techniques and knowledge and maintain consistency of client service between the districts. Central leadership, vision and team cohesion is provided from the head-office management team. Changing client attitudes and needs of the programme are reflected in regular staff training programmes.

4.4 Management objectives

4.4.1 The programme within the context of national fisheries policies

The QSCP could be defined as an inshore fishery and hence comes under Queensland state jurisdiction and the Queensland Fisheries Act (1994), in part, covers the actions of the QSCP. The most pertinent Section of the Act is the requirement for ecologically sustainable development of the fishery. This requirement is also reflected in national fisheries policies. As the QSCP does not sell product it is not covered by the Queensland Fish Management Authority and is exempt from the Authority's licensing regulations.

A number of other policies and/or pieces of legislation affect the activities of the QSCP, the most important being the Queensland Nature Conservation Act (1992) and in particular the Cetacean Management Plan and the Dugong Management Plan. Currently the QSCP is exempt from these management plans. Again the plans reflect national policies on nature conservation and on the protection of endangered species.

There is an overlap of jurisdictions between the state and federal governments because a number of the QSCP controlled beaches are within the Great Barrier Reef Marine Park world heritage area which is administered by a federal authority, the Great Barrier Reef Marine Park Authority (GBRMPA). Historically the inshore areas have been controlled by the state but in 1996 the responsibility of GBRMPA was expanded into these areas. The effect, if any, of this change of jurisdiction on the QSCP is unknown.

4.4.2 Objectives for the management of the shark control programme

Objectives of a shark control programme differ markedly from those of "normal" fisheries in that they are intended to:

i. minimising the risk of shark attack on humans,
ii. minimising the environmental impact of the programme, and
iii. minimising operating costs of the programme.

These priorities were reinforced at the 1996 ministerial Committee of Enquiry review. Profit is not a motivation as the programme is fully state subsidised but it is financially accountable to the government of the day.

The ongoing management of the QSCP must exhibit two levels of ethical decision making and behaviour. Any changes in the number or placement of shark nets and/or drumlines must be made against a background of the potential risk of such actions to human life, and, while maintaining acceptable levels of swimmer safety, there is an ethical need to reduce unnecessary mortality of bycatch species.

4.4.3 Discussion

There has been a clear and enduring direction given by the management objectives of the QSCP over the years. Even amongst the most vocal conservation groups the concept of protecting human life is considered a powerful argument in favour of maintaining a shark control programme. Management policies, however, are subject to changing community standards and client needs. A permanent feature of the QSCP is client focus groups in each of the programme's 10 controlled districts to provide a venue for local groups to determine a community consensus with regard to shark control. The perception of these needs can diverge, particularly between tourist development and conservation interests. All interest groups have the opportunity to discuss issues and to provide advice to the QSCP. Shark control, and particularly mortality of non-shark species, can be strongly emotive issues and a high degree of diplomacy and judgement is required in dealing with them. Focus groups provide the continuing community feedback the QSCP needs to balance these sometimes conflicting views to determine policies appropriate to the local area. That the QSCP has survived for 34 years is testimony to the balance it has maintained between conflicting client needs and to its dedication to the programme's primary objective of protecting human life.

5. MANAGEMENT POLICIES AND THE POLICY SETTING PROCESS

5.1 Identification and evaluation of policies

The Queensland Department of Primary Industries (QDPI) Fisheries Group, consists of a policy unit, research unit, and an enforcement unit; the latter being the Queensland Boating & Fishing Patrol (QB&FP) which administers the QSCP. The QSCP directly contributes to the overall QDPI policy of "community and client service", and to the policy of "industry development" as it enhances the economic viability of the coastal tourist industry of Queensland. QDPI's policy document "Priorities Towards 2000" specifically states that part of the role of the QB&FP (through the QSCP) is to ensure the ongoing effectiveness of the shark control programme on bathing beaches in Queensland. This has been a consistent state government policy through a number of changes of government.

To attain its objectives the QSCP has developed a number of operational policies and policy options:

i. A policy of mixed gear, drumlines plus nets, for the local reduction of large dangerous sharks at bathing beaches.

ii. A policy of minimising bycatch and of maximising the survival of incidental captures that are released, particularly vulnerable and endangered species caught.

iii. A policy of not selling shark products that result from the programme.

iv. A policy of reducing, or changing, the type of shark control gear at any beach, based on scientific advice as to the potential risk to swimmers. The approach is not inflexible but human safety is the highest priority.

v. A policy of local shark contractors rather than full-time staff. This has proven to be cost-effective and puts resources back into the local communities.

vi. A policy of open consultation with local communities through local focus groups and with concerned organisations through an annual contractors conference.

5.2 Policies adopted

Since its inception the QSCP has pioneered the combined use of nets and drumlines for shark control. The use of the mixed gear results in a marked reduction in the incidental capture of non-target species such as dolphins, dugong and sea turtles. The QSCP has a firm policy of reducing both initial capture and subsequent mortality of non-target species in shark control gear. This policy is delivered through contract provisions requiring constant checking of nets and drumlines, training of contractors and QSCP personnel in methods of live release of large marine animals and the formation of rapid response marine mammal rescue teams. Further, the QSCP pioneered the use of sonic "whale alarms" on shark control nets to reduce the accidental entanglement of migrating humpback whales. The QSCP is currently evaluating the use of "dolphin alarms" for a similar purpose. Both devices work by alerting cetaceans to the presence of possible obstructions. There is also currently research into more turtle-friendly hooks for the drumlines. These innovations allow the QSCP to maintain its beach safety standards while reducing its environmental impact, and consequently to enhance Queensland's reputation as an eco-tourist destination.

In 1996 the policy concerning the reduction or changing of the type of shark control gear was examined by a ministerial Committee of Enquiry. Their major recommendation based on the historic comparison of nets with drumlines was to extend the policy of replacing nets with drumlines in sensitive areas. Removal of nets over the summer months (jelly-fish "stinger" season) was put to the community focus groups for approval. The committee agreed with the basic policy of human safety being the highest priority.

The policy of open consultation is supported by the provision of summary shark catch data to the respective focus groups as a normal part of the service delivery. Both the local focus group meetings and the annual contractor conferences provide venues for a full disclosure of the shark catch and bycatch, broken down by area and species. Specialised analysis of these catch data can, and has, been requested at these forums and results are then reported back at subsequent meetings. The feedback from this consultation process allows the QSCP an independent check on its operation and enables it to include client needs in ongoing and future planning.

5.3 Resource access

The QSCP uses competitive public tendering of private-sector shark contractors. The contractor supplies his own boat and pays his own operating expenses (including insurance) but the nets and drumlines are bulk ordered and supplied by the programme. This ensures that the QSCP remains a lean, efficient cost-effective programme yet maintains a consistently high standard of beach safety.

There are stringent quality requirements written into all QSCP contracts. The contractor must meet certain minimum standards in the number of checks per week of the shark control gear, the maintenance of nets and drumlines, procedures for release of bycatch species and accurate catch/effort data collection. The quality control provisions of each contract also call for at least two random inspections per month by officers of the QB&FP. Furthermore, all elements of the purchasing

and management of the programme are covered by the QDPI's quality assurance requirements. Again, the quality of client service provided by QSCP contracts is ultimately measured by the safety of swimmers within the contract area.

5.4 Gear types

Shark nets - arrangement and operation: The nets are set adjacent to beaches according to prevailing tides and currents. The distance the nets are placed offshore is assessed individually and is governed by the topographical features of the area. Nets are 186m in length, have three sections and a mesh size of 50cm. They are marked by pink A3 Polyform floats and are anchored to the sea bed using Danforth or CQR anchors.

Drumlines - arrangement and operation: This fishing method uses bait to attract a shark and hence, although unmanned, constitutes an active fishing operation. The efficiency of the gear depends on the ability to attract and embed a hook into the shark. The drumline float provides high impact resistance to "shock" the hook into the animal if the bait is taken (a "strike"). A 14/0 shark hook is suspended from a pink A3 polyform buoy using a two metre length of five millimetre galvanised chain trace. The depth at which the hook is suspended (or "set") is adjusted to suit local conditions and is baited with fresh sea mullet which is a naturally occurring food source for sharks. The hook, trace and float are anchored to the seabed using either a Danforth or CQR anchor and 12mm polypropylene rope three to four times the depth of the water.

5.5 Biological regulations

QSCP management plans since 1992 include the reduction of incidental capture of endangered species (and their live release if taken accidentally) as a priority, and a Code of Practice with regard to capture and release of such species has been incorporated into QSCP contracts. Procedures for the safe release of large marine animals from QSCP nets and drumlines have been documented and distributed to officers in all QSCP areas.

Large sharks are not released alive but are discarded at least six miles to sea. No product may be sold from the sharks taken by the programme, hence the QSCP does not come under the CITES convention. Currently the QSCP co-operates with a number of external research projects, principally looking into the movement and feeding patterns of loggerhead turtles. Contractors now tag and release turtles caught in QSCP gear. Dolphin carcasses from the southern region are made available to the University of Queensland and from the northern region they are shipped to researchers at James Cook University, Townsville. Dugong carcasses are to be turned over to the indigenous community in Cairns on a trial basis.

5.6 Expansion/reduction of the programme

Future expansion of the programme is to be on a user-pays basis. Local councils currently make a financial contribution to any extension of the service to protect developing tourist beaches. This procedure will be applied to any future expansion of existing areas or to new areas where the local community requests the introduction of shark control. There is also the possibility of a reduction in the programme if there is a change of federal government policy banning the taking of protected species for any purpose within the Great Barrier Reef world heritage area.

5.7 Discussion

The challenge in involving community focus groups in advising on management policy is first in the process of initially nominating appropriate groups or candidates to represent the community, and second in ensuring that these representatives attend the majority of meetings. Less

populated QSCP districts have had both these problems. In highly populated districts, the reverse situation may occur. Any advisory committee with a reasonably high public profile can be seen as a potential political platform by narrow interest or single issue groups. Thus media exposure may become more important than providing relevant advice to the QSCP. Attempts have been made to hijack the agenda of some focus groups and unduly influence QSCP policy. The strength of the process is that others in the community can have their say, both on the local focus group and as a consensus of all the focus groups state-wide.

6. THE MANAGEMENT PLANNING PROCESS

6.1 Planning

A management planning and review process for the QSCP occurs annually and is usually finalised after the annual contractors conference which deals with projected budgets, equipment purchases and changes to operating procedures. A second tier review process occurs when individual contracts come up for renewal. Changes in contractual requirements, such as the type of gear to be serviced (added drumlines or reduced number of nets) are negotiated at this time. Contracts are usually for six years and are let by competitive tender. A third tier of review has been through a ministerial Committee of Enquiry which has subjected the programme to a detailed critical examination at irregular intervals.

The ongoing management of the QSCP must consider two ethical issues:

i. any changes in the number or placement of shark nets and/or drumlines must be made against a background of the potential risk of such actions to human life, and,

ii. while maintaining acceptable levels of swimmer safety, there is an ethical need to reduce unnecessary capture of non-target species.

The consistently high swimmer safety record maintained by the QSCP at controlled beaches speaks for itself, as does the ongoing reduction in the mortality of bycatch species.

6.2 Provision of resource management advice

Although provision of resource management advice is not the primary role of the QSCP, regular summaries of shark catch data for each "controlled" district are provided to the respective community focus group as a normal part of the service delivery to the client groups. Both the local focus group meetings and the annual contractor workshops provide venues for a full disclosure of the shark catch and bycatch of the QSCP, broken down by area and species. Specialised analysis of these catch data can be, and has been, requested at these forums, the results of which are reported back at subsequent meetings.

A number of scientific articles, based on the QSCP database, have been published and papers delivered at both national and international conferences. Because of the politically sensitive nature of shark control, QSCP has always had a policy of an open and accountable delivery of service. The best example of this policy is that the three major scientific articles summarising the catch of the QSCP were written by a totally independent conservationist (Dr R. Paterson) who was given free access to the QSCP data over a period of 20 years.

6.3 Fishery statistics

6.3.1 Methods used for collection of catch and effort data

Consistent inspection procedures provide the key to accurate data collection. All contractors are subject to two random checks per month by officers of the QB&FP Fishing Patrol. Contractors are also obliged to complete daily log sheets which contain the following information:

i. species identification
ii. size/sex (and number of pups if female)
iii. stomach contents
iv. prevailing weather and sea conditions at time of capture
v. photographic records of unusual species, and
vi. samples taken from unusual species (to be used in identification and for stock definition).

Since 1992 all contractors have been issued with copies of the most recent taxonomic publication dealing with the elasmobranchs of Australia. The standard reference book is *Sharks and Rays of Australia* by Peter Last and John Stevens (1994) and represents a summary of the collections of CSIRO, state fisheries organisations and museums from Australian Fishing Zone waters. Prior to 1992 the main reference text used was *Grant's Guide to Fishes* (Grant 1965). Mr E. Grant set up the QSCP in 1962.

The contractor's daily record logbook has been substantially unchanged throughout the 34 year history of the QSCP. Extra information on non-target species has been required since 1992 but the information required on the shark species caught and the abiotic variables measured has remained constant.

6.3.2 Evaluation of the data collection process

Regular reports on the contractor's performance are made by the local liaison officer and an annual training workshop allows for the evaluation of the contractor's ability to identify sharks species and for identifications to be corrected if necessary. Historically the QSCP focused on the taking of large sharks considered dangerous to humans and hence the reporting requirements have concentrated on shark species. The capture of non-shark species has been recorded for the full 34 years of the programme but in less detail. In 1992, following the recommendations of a ministerial Committee of Enquiry review, species identification was expanded and more detail on non-target species captured was included in the catch reports. Therefore prior to 1992 the bycatch data are limited to the general categories of whale, dugong, sea turtle and dolphin. Sea turtles, in particular, began to be reliably separated into species only after Dr Col Limpus (Queensland Department of Environment) addressed the contractors annual meeting in 1992 and distributed identification kits and tagging equipment. In the special case of Point Lookout where the contractor has identified loggerhead turtles as constituting the majority of turtles taken prior to 1992, it is possible to back-estimate the catch of this species at this site over a 16 year period.

Within the database there are three categories of gear; net, drum and unknown. Where capture of non-shark species was recorded but not associated with a gear type it was entered as unknown gear. Similarly in the early records the condition of non-shark species was not recorded hence the database contains categories of alive, dead and unknown. QSCP contractors have always had a general policy of releasing bycatch species alive if possible. This policy has been emphasized since 1992.

6.3.3 Data processing and storage and accessibility

The QSCP shark control catch and effort database has gone through a long period of development. The contractors' daily reports form the basis of the database and are retained as

hardcopy archives. In the early period of the programme these reports were summarised manually and entered into ledgers. Since 1988 the reports have been entered onto a computer database. Initially this database was resident on a PC but this system was limited and unreliable. A series of technical malfunctions, over-writing of previous data and undetected errors in data entry led the QSCP to upgrade the database and its management to a more professional level.

Negotiations in 1994 were successful in moving the shark control database to the control of the Queensland Fisheries Management Authority "QFISH" logbook database system which is the official state fisheries catch/effort logbook database system. The QSCP is still responsible for data collection and data entry but QFISH guarantee data integrity and safety from power shortages or hardware malfunction. The new format, which was fully compatible with AFMA's national fisheries databases and with the research databases of CSIRO, has been developed under contract. This software has since been optimised by the QFISH programmemers for ease of data entry and production of customised reports.

One goal is that over time all data will be re-entered and verified from the contractors' original daily logs. Data verification ensures that contractors' errors are detected and are referred to the consultant shark biologist for correction. All historic records, back to 1962, have been re-entered from summary records and/or original log sheets. However, some originals were lost or damaged over the intervening years. The process of verification continues.

6.3.4 Technical specifications

The Shark Control Information System (SCIS), is used by the QSCP to store catch and effort information provided by the shark contractors, and to prepare financial reports and calculate payments to the contractors. SCIS is a client/server application with the client (PC) side written with CA-OpenRoad™ and running under Microsoft Windows™. The server side is a CA-Ingres™ database running on a dual Sun™ UNIX™ computer, which is maintained by the QFMA. In 1996 SCIS contained over 61 000 catch records dating from 1962. Contract information is confidential and is stored in secure files with limited access. Contractor catch and effort records are stored in a series of relational tables and are generally accessible with a relatively low-level security. All requests for access to the data are referred to the manager of the QSCP who assigns appropriate security levels.

6.4 Stock assessment

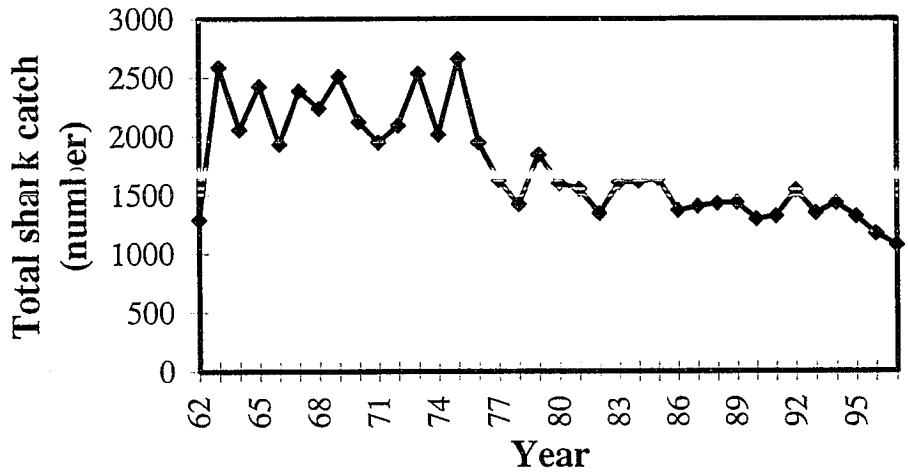
Attempts at stock assessment within the shark control programme have been limited. The current yearly take (since 1992) of all shark species combined is approximately 90 sharks per protected area (Figure 4). It is considered that this rate of removal, spread across 54 species (Tables 3 and 4), would not have a major effect on the stocks. The programme does, however, provide a unique sampling tool, because of its continuity over 34 years in both gear type and location of gear, for assessment of changes through time in stock biomass of selected species of sharks and possibly of bycatch species. As the data are limited mainly to catch and effort information, robust biomass-dynamic production modelling has been attempted, combined with simple time-series analysis of catch and CPUE. The primary indicator of stock abundance has been catch per unit effort (CPUE). Trends in CPUE are monitored for the major species, where these species can be identified unambiguously from the logbook data.

Given the very small number of sharks caught by the QSCP relative to the catch of the commercial shark fishery in adjacent waters, it is unrealistic to believe that the programme would be able to manage stocks. At best the QSCP can monitor the stocks exploited by the Queensland East Coast commercial shark fishery, through the programme's small scale but continuous sampling. As noted previously, the power of this sampling is its continuity over 34 years. Trend analysis of the

species composition and size of shark species caught at 10 points along 2000km of Queensland coast can provide only an indication of the health of the stocks.

In the special case of vulnerable, or endangered, species, whether sharks or bycatch, the responsibility of the QSCP is to reduce captures to a minimum. The great white shark (*Carcharodon carcharias*) and the grey nurse shark (*Carcharias taurus*) are protected or in the process of being given protected species status in Queensland. These species are caught in low numbers and are released alive if possible. The primary function of the QSCP is the protection of human life, and while it removes large dangerous sharks, it does not "target" protected species of shark. As such the programme is within the Australian protected species guidelines.

Figure 4
Total shark catch taken in the Queensland shark control programme



CPUE has remained relatively stable over the past 20 years for all species of shark that can be reliably identified as a single species, including the white shark, and the size of sharks caught has remained reasonably constant too (McPherson *et al.* 1998). These are less than perfect measures of the sustainability of the stocks but they indicate that the small number of sharks taken locally by the QSCP has little effect on the larger population.

There has been a necessary compromise between programme costs and quality of data collection. The contract system, while cost effective, ensures that the shark contractor will be a good fisherman but not necessarily a good shark taxonomist. Training is provided but the result is a knowledgeable lay person, not a trained scientist, and the quality of the species identification may suffer. Furthermore, contractors are self-employed and not public servants. Therefore any research project requiring extra time or effort has to be factored into the original contract or negotiated as a separate short-term contract. In the tendering process contractors must cost their time and the use of their boat and gear. This can make research projects more expensive (i.e. the true cost is not hidden in programme running costs) and more inflexible if changes to methodology are required.

Given the spread of the programme over 2000km of coast it is financially and logistically impossible to bring every shark caught to a central laboratory. A compromise has been to make specimens available to research organisations on request, with the organisation paying for the transport, photographs, teeth and electrophoretic samples to be collected by the contractor for analysis by the programme's scientific advisers.

6.5 Evaluation of the management process

As part of ongoing management evaluation, daily catch/effort logbooks are filled out by each shark control contractor and this information is used for contract evaluation (compliance) purposes. Regular reports on the contractor's performance are also made by the local liaison officer and the annual training workshop allows for the evaluation of the contractor's ability to identify sharks species. Financial reporting, reconciliation and annual auditing are performed by the QDPI corporate services division to Queensland State Government standards. Currently Queensland has a triple A international credit rating.

Two major evaluation reviews of the programme have been carried out by ministerial Committees of Enquiry - in 1992 and again in 1996. The terms of reference for the first review were to investigate and advise on:

i. The roles and responsibilities, inter-communication procedures and contract obligations of the various agencies involved in the Shark Meshing Programme including Boating and Fisheries Patrol, Surf Life Saving Association, Lifeguard, Westpac Rescue Helicopter Services, Department of Transport (Harbours Corporation) and Shark Control Contractors.

ii. The present physical condition, usage, current designs, construction and operational methods including recovery procedures of equipment being used including any changes that may be required.

iii. Alternative mechanisms for providing protection for bathers from shark attack.

iv. The current level of supervision and level of compliance of shark control contractors with their contract conditions including order of work.

Twenty recommendations were accepted by the Government and have been implemented. (See Ănon (1992) for detail.)

A second ministerial Committee of Enquiry in 1996 investigated and advised on the impact of the QSCP on vulnerable and endangered species. In particular, the committee examined the outcomes of the recommendations and initiatives put forward in 1992 (see following Section "Environmental costs").

The QSCP sponsored and organised the "SHARKS and MAN: Shark Management and Conservation" workshop, held under the auspices of the 2nd World Fisheries Congress in Brisbane in 1996. This allowed both international peer review of the programme and a "benchmarking" of the QSCP against similar shark control programmes operating in other parts of the world. The rationale was to bring to Queensland all the recognised experts on shark fisheries, control and conservation to discuss the state of shark stocks and the latest innovations and techniques in bather protection. The twin objectives of the shark control component of the workshop were to explore ways to maintain bather safety while reducing capture of endangered species.

6.6 Success of the shark control programme

Shark control in Queensland was initiated in 1962 in response to public pressure over a number of fatalities caused by shark attack at popular swimming beaches. Since 1962 the QSCP has been spectacularly successful in meeting the needs of beach users in Queensland by reducing the number of fatalities due to shark attack at the controlled beaches to zero.

The major environmental concern with the shark control programme has been the incidental capture of non-shark species. The species perceived to be most at risk are humpback whales, dolphins, dugong and sea-turtles.The Australian humpback whale population is increasing at 12% per

district QSCP liaison officers visiting local schools and community groups as part of the QB&FP's ongoing public education programme.

Research and stock assessment are carried out through partnerships with QDPI Fisheries and with national and international research institutions. In this way the QSCP has been involved in research, development and pioneering use of a number of innovative shark control related methodologies. The cost of the research has been met by a small amount of seed money from the QSCP, external grants and funding gained from external consultancies.

7. NSW PROTECTIVE BEACH MESHING PROGRAMME[1]

7.1 Introduction

As noted for the QSCP, the goal of the NSW "public safety" shark control programme is to implement appropriate harvesting strategies to minimise the potential for a shark attack on swimmers at heavily used swimming beaches. Since the beginning of the programme the NSW shark nets have been constructed of 50 to 60cm mesh which means they are most effective for the larger species. The major categories of shark that were caught over the period 1952-1992 were hammerhead sharks (34.2% of the total catch recorded), whaler sharks (23%), tiger shark (3.1%), and the white pointer or great white shark (5%) (Reid and Krogh 1992). Species data are given in Table 7. Because of substantial changes in contracts and reporting requirements, following a review of the programme in 1972, the data are treated as two periods 1950-1972 and 1973-1996. Data collected earlier than 1950 are considered too unreliable for analysis.

Table 7
Shark species identified from the logbook database of the NSW programme

Species	Common name	Comment
Carcharhinus spp.	Whaler (?)	up to ten species
Squatina australis	Australian angel shark	
Sphyrna spp.	Hammerhead (?)	possibly three species
Carcharodon carcharias	White or Great white shark	(protected in NSW)
Heterodontus spp.	Port Jackson shark (?)	possibly two species
Galeocerdo cuvier	Tiger shark	
Notorhynchus cepedianus	Broadnose sevengill shark	
Carcharias taurus	Grey nurse shark	(protected in NSW)
Isurus oxyrinchus	Shortfin mako shark	
Alopias spp.	Thresher shark	possibly two species
Orectolobus spp.	Wobbegong shark	possibly two species

7.2 Regional distribution of programme

The use of systematic netting of sharks off Sydney's beaches was initially recommended in 1929 (Anon 1935) but was only implemented in September 1937, after which netting spread to the beaches of both Newcastle and Wollongong in December 1949 (Collins 1972), and to the Central Coast beaches in January 1987 (Reid and Krogh 1992). Meshing was interrupted by the Second World War from January 1943 to March 1946 (Collins 1972). In 1996, 49 bathing areas were protected along 200km of coastline from Newcastle to Wollongong.

[1] Information verified through D.D. Reid, NSW Fisheries.

7.3 Associated species either as bycatch or discards

Recording of bycatch has been inconsistent throughout the period of meshing and figures presented are probably underestimates of total bycatch. These inconsistencies have arisen through non-systematic under-reporting and/or miss-reporting of catch by untrained contractors, although data collected since 1989 are considered to be more accurate than earlier data (Krogh and Reid 1996). The reported bycatch consisted of non-dangerous sharks (angel sharks, Port Jackson sharks, and wobbegongs), rays, dugong, dolphins, turtles and finfish (Table 8). For the period 1950 to 1993 rays were the most commonly recorded bycatch group, averaging 40 per year, while dolphins averaged 2 per year and turtles 1 per year (Krogh and Reid 1996). Dugong were rarely caught.

Table 8
Bycatch recorded from the NSW meshing programme

Species	Common name
Galeorhinus galeus	School shark
Lamna nasus	Porbeagle shark
Prionace glauca	Blue shark (rarely caught inshore)
Dugong dugon	Dugong
Chelonia mydas	Green turtle
Dermochelys coriacea	Leatherback turtle
Orcinus orca	Killer whale
Various TELEOSTEI	Tuna, jewfish etc.

The ray group consists of skates (species of the family Rajidae), stingrays (Dasyatididae), stingarees (Urolophidae) and various other rays (Mobulidae, Myliobatididae, Rhinobatidae, Rhinopteridae and Rhynchobatidae) (see Table 9). The majority (75%) of the rays recorded were caught in the Newcastle region. Included in the bycatch category are species of shark which were rarely caught or are considered as "harmless" and which were released alive if possible. NSW Fisheries policy is that bycatch species be released alive if possible.

Table 9
Rays recorded from the NSW meshing programme

Species	Common name
Dasyatis kuhlii	Blue spotted stingray
Aptychotrema sp. (?)	Shovelnose ray (3 species)
Rhinobatus typus (?)	"
Rhynchobatus djiddensis (?)	"
Trygonorhina sp.	Fiddler (banjo) ray
Manta birostris (?)	Manta ray
Rhina ancylostoma	Shark ray
Rhinoptera sp.	Cow ray
Myliobatis sp.	Eagle ray

7.4 Development and current status of the programme

7.4.1 The harvesting process

Systematic gill netting is the sole method used to reduce local populations of large sharks. The basic strategy is to remove dangerous sharks from the local bathing area to reduce the probability of a swimmer being attacked. Nets are set overnight seven to thirteen times per month at each beach

using an intermittent "fish-down" tactic (D.D. Reid, NSW Fisheries, pers. comm.). This tactic differs to that of the QSCP and Natal Sharks Board where nets are left in the water on a nearly continuous basis.

7.4.2 Fishing methods

Contractors provide vessels, nets and labour. Current nets have 50-60cm mesh in 150m long panels that are 6m deep. From 1937 until 1946 nets were 305m long (Collins 1972) and then 152m long until 1972. All nets have been bottom set since 1972, but prior to this the setting was not contractually stipulated (Reid and Krogh 1992). In 1983, meshing in the months of June and July was removed from the contracts and in 1989 the months of May and August were also removed (Reid and Krogh 1992). Until 1972, the contract stipulated only the number of overnight "sets" of a 152m net per 4 week period, which varied considerably between areas (Collins 1972). Subsequent to revision of the contracts in 1972-73, effort was standardised for all bathing areas, leading to an increase of some 20% in nominal effort (Reid and Krogh 1992). Each beach must be meshed a minimum of 13 times per month. A net "set" is now specified as one 150m net set overnight for a minimum period of 12 hours on week days. Weekend meshing or "sets" are left in place for a minimum period of 48 hours. A combination of weekday and weekend meshings gives an average 17 net-days per month (D.D. Reid, NSW Fisheries, pers. comm.). Four meshings must be conducted over weekends and no more than 70% of the monthly meshings should be completed per half month. The general practice is to set two nets joined together, thereby effectively having two "sets" on one night with the result that nets are in the water for an average of only nine days per bathing area per month. As there are 49 meshed beaches this would be the equivalent of 150m of net set at each beach for an aggregate of 833 net-days (or 441 days in the water if double nets are used) per month from Newcastle to Wollongong.

All carcasses are discarded at sea (Reid and Krogh 1992); live dangerous sharks are usually shot (M. Krogh, Environment Protection Authority, pers. comm.). Catches are recorded but identification tends to be by taxonomic group rather than to species level (Reid and Krogh 1992).

The coastal shark stocks are also exploited by a limited entry commercial shark fishery and by recreational sport fishing.

As with the QSCP, the Protective Beach Meshing Programme is a fully state-subsidised public safety measure. Shark carcasses cannot sold for profit and no contractor can hold a commercial shark fishing license to avoid conflict of interests.

7.4.3 Economics of the programme

NSW and Queensland have extended coastal tourist seasons, due to their benign climate and premier bathing beaches. The tourist industry is a major economic contributor to each state through taxation and multiplier effects. While there is no direct revenue from the NSW shark control programmes, there is the indirect effect of increasing the revenue created by the coastal tourist industry and by marine tourism in general.

7.4.4 The programme's workforce

The organisation and overall management of the NSW meshing programme is based in NSW Fisheries, Sydney. Service delivery is contracted through local operators who are in charge of daily servicing of the programme's shark nets. At present there are 49 beaches meshed and five contractors.

8. MANAGEMENT OBJECTIVES

The NSW Protective Beach Meshing Programme could be defined as an inshore fishery hence it comes under NSW state jurisdiction. The NSW Fisheries Management Act (1994) and General Regulations (1995) cover shark meshing. The most pertinent Section of the Act is the requirement for ecologically sustainable development of the fishery. This requirement is also reflected in national fisheries policies. The Protective Beach Meshing Programme is covered by special permit issued under the Act, as is the taking of white sharks and grey nurse sharks as these are both protected species in NSW. Negotiations are underway to protect these species nationally.

The objectives of the NSW Protective Beach Meshing Programme are similar to those of the QSCP in that the programme should:

i. minimise the risk of shark attack on humans at popular bathing beaches
ii. minimise the environmental impact of the programme, and
iii. optimise the cost effectiveness of the programme.

An objection to public safety shark control has been that there is a low risk of shark attack in Australia which does not justify the environmental cost of such programmes. One difficulty with this argument is that attack statistics quoted are usually those for the last 30 years i.e. after shark control measures had already been introduced in NSW and Queensland. Ironically, the low risk of shark attack is used both by the managers to measure the success of the various risk reduction programmes and by those who wish to show that they are unnecessary.

Stevens and Last (1994) report that there is a large recreational shark fishery near Sydney and that many of the sharks caught are killed, although tag-and-release is growing in popularity (Pepperell 1992). There is considerable overlap with the NSW beach meshing programme in terms of the species composition of the catch (Stevens 1984) and hence the recreational fishery could be regarded as an additional risk reduction measure, albeit unintentional.

9. MANAGEMENT POLICIES AND THE POLICY SETTING PROCESS

9.1 Identification and evaluation of policies

In New South Wales, fishery resources are generally regarded as common property assets. They belong to all people and are managed by the NSW Fisheries Department who derives its authority from the Fisheries Management Act 1994. The Fisheries Management Act grants powers related to commercial and recreational fishing, aquaculture and fish habitat protection. The objectives of the Act are to conserve, develop and share the fishery resources of the State for the benefit of present and future generations.

The aim of the Department is to conserve and manage the use of the State's fisheries resources within a framework of Ecologically Sustainable Development. This is defined as "using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased". To achieve this goal, NSW Fisheries conducts scientific research to understand fish populations and implements appropriate harvesting strategies to control fishing.

The Protective Beach Meshing Programme uses appropriate harvesting strategies to minimise the potential of shark attacks on swimmers. The NSW Protective Beach Meshing Programme has a similar policy framework to that of the QSCP. These policies have the following features:

i. The programme has human safety as its highest priority.

ii. The Department seeks to selectively cull local populations of large, potentially dangerous sharks adjacent to popular swimming beaches, while maintaining their numbers elsewhere.

iii. The Department seeks to minimise the catch of incidental species (including harmless sharks) and to maximise the survival of released species.

iv. Meshing activities are conducted to ensure minimal impact on the marine environment and local contractors are employed to ensure cost efficiency.

v. NSW Fisheries maintains a catch database to monitor the effect of its management arrangements and the Department welcomes open consultation with other scientists, fishers and local communities regarding the programme.

9.2 Policies adopted

The above policies have been in operation, with minor changes, since 1972, but the overall policy of increasing bather protection by lowering the probability of shark attack has been in operation since 1937. There have been a number of refinements to netting times, locations and strategies to improve the efficiency of meshing operations and reduce bycatch. In recent years, the scientific activities have been improved with more appropriate data management and more accurate analysis and reporting of catch and effort. The use of independent observers aboard meshing vessels to measure catches and identify shark species has greatly improved the monitoring of meshing activities.

Following a review and upgrading of the beach meshing programme in 1972, contracts specified use of nets 150m long by 6m deep with mesh sizes of between 50 and 60cm positioned so that the bottom of the net rested on the seabed. Baited lines (drumlines) were not introduced in case they attracted sharks to beaches (Collins 1972).

In NSW both the white shark and the grey nurse shark are protected species. Deliberate targeting or sale of products from these species is banned and it is policy to release them alive if possible. The NSW Protective Beach Meshing Programme is allowed to take these sharks as bycatch under special permit.

There are no current plans for expansion of the Protective Beach Meshing Programme and the minister in charge of NSW Fisheries stated in late 1996 that there would be no reduction of the programme during his term of office (Holt 1998). There is, however, considerable on-going pressure from conservation groups for removal of nets because of the perceived threat posed to protected species.

The positioning of the nets at 49 beaches along a 200km stretch of coast provides an effective gauntlet to sharks moving parallel to the coast. The catch at the northern end of this array of nets, i.e. Newcastle, is higher than at central or southern beaches, as is the CPUE. This would suggest that there is a gradient in coastal shark abundance, or migration, from north to south. An alternative view is that there is a synergistic effect from the linear array of multiple nets such that the central coast in particular receives a higher degree of protection than beaches at either end (Dudley 1997).

The inclusion of independent observers to validate contractors' reports was necessitated because of concerns raised over the operation of some contractors. For example, claims had been made of buoys being laid with only rope between them rather than nets and conversely of nets being left in the water for extended periods without service.

10. THE MANAGEMENT PLANNING PROCESS

10.1 Provision of resource management advice

A management planning and review process occurs annually, in line with state government auditing requirements, which deals with projected budgets, equipment purchases and changes to operating procedures. A second tier review process occurs when individual contracts come up for renewal. Changes in contractual requirements, such as the number of gear sets, or changes to gear, are negotiated at this time. Contracts are usually for 2 years and are let on a competitive tender basis. There was a major external review of the programme in 1972 and current operational procedures were established in place following the recommendations made by that review.

Providing resource management advice is not the primary role of the NSW Protective Beach Meshing Programme though regular summaries of shark catch data for each meshed area are provided to the State government as a normal part of the service delivery. Specialised analysis of these catch data can be, and has been, requested at public forums, the results of which are reported back to the government or at subsequent public meetings.

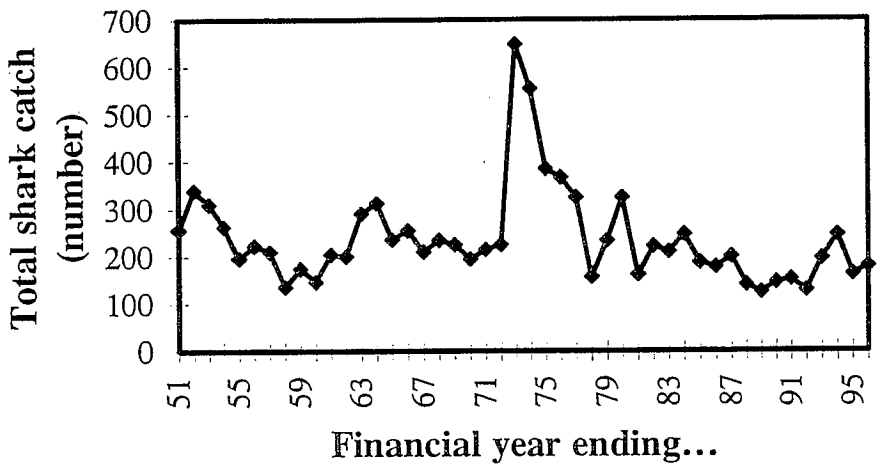
10.2 Fishery statistics

Monthly statistical returns are provided by each contractor and include; the number and species of shark caught (ditto of bycatch), length of shark, gender, condition (alive or dead) and, if female, the number of pups. NSW Fisheries employs part-time observers to go out with the contractors to verify that contracts are fulfilled and that the catch data reported are accurate. Data are archived as hard-copy records of the contractors' returns and are entered onto a computer database held at NSW Fisheries.

10.3 Stock assessment

Total shark catch is shown in Figure 5. Stock abundance can be followed from trends in CPUE, assuming a direct relationship exists between them. Some catch data, grouped by species or species group, are available for the period prior to 1950 (Coppleson 1950), but Coppleson expressed doubts about their accuracy and both Collins (1972) and Reid and Krogh (1992) choose not to use them. Stevens and Paxton (1992) report that more than 1000 sharks were caught in the first year of meshing, 1937-38, although Coppleson (1950) gives a figure of only 517 sharks which may have been for the second year of meshing. Whitley (1940) indicates that 721 "dangerous sharks" were meshed in the first year of the programme but this did not include all sharks caught.

Figure 5
Total shark catch taken in the NSW protective beach meshing programme
(Data supplied by D.D. Reid, NSW Fisheries)



By 1950, the annual catch was 354 sharks (Collins 1972), but this 56 had decreased to an annual average of 162 sharks during 1985-1990 (Reid and Krogh 1992). There was no trend in CPUE between 1951 and 1972, but the changes in gear specifications and net deployment in 1972/3 led to an increase from a pre-1972 mean of 44.6 sharks per 1000 sets to 107.4 sharks per 1000 sets in the 1972/3 season (Reid and Krogh 1992). There was a decline in catch during the 1970s but there was no trend through the 1980s (Reid and Krogh 1992).

Given that the annual number of sharks taken by the NSW meshing programme averaged only 167 fish (spread across at least 10 species) for the last 10 years, it is unlikely that the programme on its own is affecting the sustainability of the shark resource in NSW. The major concerns are over the white shark and grey nurse shark where the CPUE has been declining. Both species are now released alive if caught. In the case of the grey nurse the main cause of its decline has been identified as sport spear-fishing in the early 1970s and in the 1980s (Pollard 1998).

The catch of both sharks and bycatch by the NSW Protective Beach Meshing Programme is the smallest of the three major shark control programmes (KwaZulu-Natal, NSW and Queensland) and is well below the catch of any viable commercial shark fishery. Historically the CPUE of the NSW meshing programme has declined over the duration of the programme. Initially the drop would have been due to a "fishing down" of local shark populations. Subsequently, the slow decline (except in tiger shark) probably reflects a declining abundance of the general shark populations. The small number caught by the NSW meshing programme is unlikely to be the cause of such declines on its own, but continuous low-level sampling can expose underlying trends in the population dynamics of coastal shark species.

10.4 Evaluation of the management process

The NSW Protective Beach Meshing Programme is ultimately responsible to the state government minister in charge of the fisheries portfolio. Evaluation of the programme's management follows normal NSW State Public Service procedures. Due to the high public profile and interest in shark meshing, both from the view of potential shark attack and the incidental capture of endangered species, there is considerable public scrutiny of the activities of the programme.

At Newcastle's meshed beaches there were 11 attacks (four fatal) between 1918 and 1949 (Collins 1972). Since the initiation of meshing in December 1949 (Collins 1972), there have been only two attacks, both at Merewether Beach. A fatality occurred in 1951 and a surfer received minor injuries in 1957 (Coppleson and Goadby 1988). At Sydney's meshed beaches 18 attacks (10 fatal) occurred between 1897 and 1936 (Collins 1972) prior to netting. After nets were installed in September 1937 there were two attacks, one at Cronulla in January 1938, in which the fate of the victim is unknown, and the other a non-fatal attack at Bondi in February 1951 (Collins 1972); Reid and Krogh (1992) report no further attacks after 1951. Coppleson (1950) claims that no attacks occurred at meshed beaches from the time nets were installed until 1950, so the Cronulla incident appears doubtful. Despite its large bather population, shark attacks in the Wollongong area have been "almost unknown" both before and since the installation of nets (Coppleson and Goadby 1988). Overall the success of the programme and its management can be measured by the marked reduction in shark attacks on humans at protected bathing beaches and the elimination of shark fatalities at these beaches since 1951.

The major environmental concern with the Protective Beach Meshing Programme has been the incidental capture of harmless species. The species perceived to be most at risk are protected shark species (great white and grey nurse sharks), "harmless" sharks, dolphins and sea turtles. The catch of this group is relatively small and it is the policy of the programme to release them alive if possible. In some species the percentage of captures released alive is high; for example the angel shark (65%) and Port Jackson shark (95%) (Holt 1998). For other species the catch is extremely low,

e.g. dolphins (2/y) and sea turtles (1/y). Ultimately, the problem is one of value judgements. What is the worth of a human life in terms of the incidental mortality of the bycatch species? This decision is a community responsibility but it is the mandate of the meshing programme to reduce the incidental capture to the lowest level possible while maintaining swimmer safety.

10.5 Management costs

The total annual cost of the Protective Beach Meshing Programme was A$600 000 in 1996 (Holt 1998). This included both the cost of the shark meshing contracts (A$400 000) and an estimation of the cost of managing the contracts (D.D. Reid, NSW Fisheries, pers. comm.). There was no specific allocation of funds for research, although joint projects have been arranged between the programme and universities. One such project has been genetic identification of shark species using electrophoresis of tissue samples supplied by the meshing contractors (pers. Comm., R.W.K. Chan, University of NSW).

11. DUNEDIN (NEW ZEALAND) SHARK CONTROL NETS[2]

Between 1964 and 1968, there were four shark attacks on surfers, swimmers and divers near Dunedin which is on the east coast of the South Island, three of which were fatal. Great white sharks were probably responsible for all four attacks. In late 1969, two shark nets were laid off St Clair and St Kilda Beaches to protect swimmers and surfers. The number of nets was increased to 16 by 1976 (though not all were used at one time), and the programme was extended to include Brighton Beach. By 1992, the number of nets had dropped to eight, six of which were in use at any one time. The netting programme currently covers St Kilda, St Clair and Brighton Beaches, with two nets set permanently at each beach between December and February. Each net is about 100m long, 5.5m high, and has a mesh size of 30cm. Therefore only larger sharks (and other marine animals) are caught. The nets are inspected three times a week.

For the first decade, no accurate records were kept of the numbers and types of shark caught. However, in a letter to the *Otago Daily Times* in 1978, the Secretary of the Otago Water Safety Council stated that the numbers caught each summer were: 1971–72: 16; 1972–73: 6; 1973–74: 29; 1974–75: 14; 1975–76: 62 and 1976–77: 18. The sharks were mainly great white, thresher, sevengill and blue sharks. The numbers of great whites caught in each of three seasons were given as: 1973–74: 2; 1974–75: 7; 1975–76: 5. Accurate catch details were first kept in 1986, and between then and 1991, 72 sharks were reported caught. Half were sevengill sharks, 31% were school sharks and 11% were threshers. Mako and blue sharks made up the remaining 8%. No great white sharks were caught. In the 1995–96 season, 29 sharks were caught, including ten sevengill, eight thresher, five blue and four school sharks, along with one rig and one unidentified shark.

Following the deployment of the nets, shark attacks in the region declined rapidly. There was one attack at St Clair Beach in late summer 1971, after netting had finished for the year, and another at Moeraki (in the region, but never netted) in 1973. There have been no attacks since 1973.

12. SHARK CONTROL IN HAWAII[3]

In an attempt to allay public fears and to reduce the risk of shark attack, the state government of Hawaii spent over $300 000 on shark control programmes between 1959 and 1976. Six control

[2] Extracted from: Francis, M.P. (submitted) New Zealand shark fisheries: development, size and management. Marine and Freshwater Research.

[3] Abstract from: Wetherbee, B.M., C.G. Lowe and G.L. Crow 1994.

programmes of various intensity resulted in the killing of 4668 sharks at an average cost of $182 per shark. The programmes furnished information on diet, reproduction, and distribution of sharks in Hawaii, but research efforts of the programmes had several shortcomings. Analysis of the biological data gathered was not directed toward the tiger shark, *Galeocerdo cuvier* (Peron & Lesueur), which is responsible for most attacks in Hawaii. Reliable estimates of shark populations in Hawaii cannot be made based on catch data from control programmes because of sampling biases. Most of the information gained from the control programmes was not published in review journals and is not readily available to the scientific community. The ability of the control programmes to reduce shark populations and to remove large sharks from coastal waters appears to have been stated with more confidence than is warranted, considering seasonal changes observed in shark abundance and variable fishing effort. Shark control programmes do not appear to have had measurable effects on the rate of shark attacks in Hawaiian waters. Implementation of large-scale control programmes in the future in Hawaii may not be appropriate. Increased understanding of the behavior and biology of target species is necessary for evaluation of the effectiveness of small-scale control efforts, such as selective fishing after an attack. Acoustic telemetry, conventional tagging, and studies on population dynamics concentrating primarily on the tiger shark may be used to obtain data about activity patterns, distribution, and population parameters, providing information useful for reducing the risk of shark attack in Hawaii and elsewhere.

Subsequent to this publication, an update was provided by B.M. Wetherbee, University of Hawaii in October 1997. He noted that there were two fatal attacks in 1991-1992 which led to directed shark fishing in areas where there had been an attack or where sharks were sighted. Over the next few years an estimated 100 tiger sharks were killed by state sponsored and private fishing in the waters around Oahu. This small-scale fishing lasted until 1994 or 1995, by which time the number of attacks, and consequently public demand for action, had dwindled. Recent research has shown that tiger sharks move long distances around the Hawaiian Islands (Holland *et al.* 1997) and hence that localised fishing following an attack is of limited use if the objective is to catch the shark in question. These findings probably contributed to the cessation of shark fishing. The state has heeded a call by fisheries biologists to channel resources into shark research and public education rather than shark control.

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