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Publication of Fisheries Management and Assessment Papers from World Congress Workshop

Terence I. Walker

Project No. 97/303

FISHERIES RESEARCH & DEVELOPMENT CORPORATION

State Government of Victoria

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Principal Investigator: Terence I. Walker
Marine and Freshwater Resources Institute
PO Box 114 Queenscliff VIC 3225
Telephone: 03 5258 0111
Fax: 03 5258 0270

Objective

Publish a set of high quality internationally reviewed papers on shark fisheries management and assessment in a special issue of the journal Marine and Freshwater Research published in Australia.

Non Technical Summary

The special issue of *Marine and Freshwater Research* entitled 'Shark Fisheries Management and Biology' Biology' (Volume 49, Number 7, 1998, pages 553–767) makes a valuable contribution towards redressing the lack of information worldwide about shark fisheries and their assessment, monitoring and management. The collection of 23 papers in this issue grew out of the Sharks and Man Workshop held in Brisbane on 2 August 1996 as part of the Second World Fisheries Congress. Some of the papers were presented at the workshop but the others were solicited to address some of the gaps in the scientific literature. The issue is unique in that all except two of the papers are sourced from the Southern Hemisphere; 11 are from Australia.

Grouped into four sections, the 23 papers are all relevant to the management of shark fisheries or conservation of sharks. The first section (Shark Fisheries and Management) contains six papers describing national or regional shark fisheries and their management and begins with a review paper addressing some of the broad issues confronting shark fisheries management and shark conservation. The second section (Catch Monitoring and By-catch) comprises five papers describing at-sea-monitoring programs for coastal and offshore fisheries; these papers raise issues such as discarding, by-catch, market grading, shark fishery interactions with mammals, sea birds and turtles and the management of risk associated with interactions between sharks and humans. The third section (Life History and Stock Assessment) comprises seven papers: one provides an important comparison of the productivities of 26 species of shark based on life history parameters, and others address important components of shark biology, such as reproduction, age and growth, and gillnet selectivity, required for stock assessment; one paper applies a stock assessment with risk analysis based on demographic parameters combined with fishing gear selectivity parameters and time series data of catch and catch per unit effort. The fourth section (General Biology) comprises five papers on shark general biology; these include papers on taxonomy and genetic studies relevant to stock delineation, feeding, and liver oils.

Key words: Shark fishery management, shark stock assessment, and shark biology.

Background

There is little information published worldwide on management and assessment of shark fisheries. Through publication of the proceedings of the 'Sharks Down Under Conference' held during 1991 and Australia's experience with research and management of the shark fisheries of southern Australia, Western Australia and northern Australia, Australia has come to be seen as a world leader in the fields shark fisheries research and management.

More recently, two additional workshops on the management of shark fisheries in Australia and in other parts of the world were held in Australia as part of the Second World Fisheries Congress. One was the 'Sharks and Man: Shark Management and Conservation Workshop' held in Brisbane on 2 August 1996 and the other was the 'Life History and Harvest Potential of *Galeorhinus galeus* and Genus *Rhizoprionodon* Workshop' held at the Marine and Freshwater Resources Institute in Queenscliff, Victoria, during 19–23 July 1996. Several of the papers presented at these workshops and others solicited to address some of the gaps in the scientific literature were prepared for publication as a special issue of the internationally reviewed journal *Marine and Freshwater Research* published in Australia.

Need

Sharks have received comparatively little scientific attention in the fields of population dynamics, conservation and fisheries management. The lack of knowledge and basic monitoring of shark harvesting needs to be urgently addressed given the peculiarities of shark biology and the relatively low productivity of shark populations. As the demand for shark fins, meat, cartilage and other products grows, there is widespread concern over increases in shark fishing and the consequences this is having for the populations of sharks in various parts of the world's oceans.

Few countries manage their shark fisheries, and only during the past 2–3 years has there been an international attempt to tackle problems associated with the conservation and management of sharks. This special issue of *Marine and Freshwater Research* makes a valuable contribution towards redressing the lack of information, particularly in terms of describing shark fisheries and their assessment, monitoring and management. The timing of its publication coincides with the endorsement by more than 70 nations of the International Plan of Action for Conservation and management of Sharks developed and approved by the Food and Agriculture Organization of the United Nations (FAO). The information and insights emerging from this issue will contribute to the information base required for implementation of the Plan of Action.

Objective

Publish a set of high quality internationally reviewed papers on shark fisheries management and assessment in a special issue of the journal Marine and Freshwater Research published in Australia.

Benefits

Publication of the special shark issue will provide a valuable source of information for management of the shark fisheries of southern Australia, Western Australia and northern Australia. It will also benefit other countries and international attempts to manage shark taken in fisheries of the high seas. The issue will further enhance Australia's image in the field of shark fisheries research and management.

The flow of benefits are allocated as 55% Commonwealth, 15% Victoria, 10% Tasmania, 10% South Australia, 10% Western Australia, Queensland 5% and New South Wales 5%.

Intellectual Property

No intellectual property has arisen from the project that is likely to lead to significant commercial benefits, patents or licences. Intellectual property associated with information produced from the project will be shared equally by the Fisheries Research and Development Corporation, the Victorian Department of Natural Resources and Environment, and CSIRO Publishing.

Budget

Details of project grant and expenditure are presented in the following table.

Budget item	1997/98 $
Project grant	
Salaries and oncosts	0
Operating expenses	9000
Travelling expenses	0
Capital items	0
Total	9000
Expenditure	
Salaries and oncosts	0
Operating expenses	9000
Travelling expenses	0
Capital items	0
Total	9000

Staff

Terry Walker, Program Leader, Modelling and Data Management, devoted 5% of his time during 1997/98 to preparation of the special issue.

Further Development

The special issue is automatically distributed to libraries and individuals subscribing to *Marine and Freshwater Research*. In addition, the special issue has been publicised

internationally by the journal, by the American Elasmobranch Society and through the international periodical *Shark News* published by the IUCN Shark Specialist Group. Complementary copies of the special issue made available by the journal *Marine and Freshwater Research* have been distributed to all members of SharkFAG, SIRLC and SharkMAC and to leading shark researchers and managers in Argentina, Australia, Brazil, Canada, France, Italy, Japan, Mexico, New Zealand, The Netherlands, South Africa, Trinidad and Tobago, Uruguay, USA, and UK.

Acknowledgments

The support of the Australian Fisheries Research and Development Corporation (FRDC Project 97/303) for this publication is acknowledged, and the authors, reviewers and the editor of *Marine and Freshwater Research,* Ann Grant, are thanked for their efforts.

Summary of Shark Special Issue

The special issue of the journal Marine and Freshwater Research published in Australia is entitled 'Shark Fisheries Management and Biology' and now appears in print as Volume 49, Issue 7 for 1998, pages 553–767. The special issue consists of a brief introduction and 23 papers relevant to the relevant to the management of shark fisheries and conservation of sharks.

The full introduction and the abstracts of the 23 papers are reproduced in the following. The introduction provides an overview of the scope and value of the papers. The issue represents one of the very few issues ever published on shark fisheries management and is unique in that 21 of the 23 papers were sourced from the Southern Hemisphere. Of the 23 papers 11 are from Australia.

Shark Fisheries Management and Biology: Introduction

Terence I. Walker

Marine and Freshwater Resources Institute
PO Box 114, Queenscliff, Victoria, Australia 3225

Sharks and other chondrichthyans are mostly caught as by-catch in the world's fisheries targeting teleost species. In the past, much of the shark catch has been discarded without record but there are trends of greater utilization and targeting of sharks. The relatively few species of shark compared with teleosts and invertebrates and the historically low value of shark products has meant that sharks have received comparatively little scientific attention in the fields of population dynamics, conservation and fisheries management.

The lack of knowledge and basic monitoring of shark harvesting needs to be urgently addressed given the peculiarities of shark biology and the relatively low productivity of shark populations. As the demand for shark fins, meat, cartilage and other products grows, there is widespread concern over increases in shark fishing and the consequences this is having for the populations of sharks in various parts of the world's oceans.

Few countries manage their shark fisheries, and only during the past 2–3 years has there been an international attempt to tackle problems associated with the conservation and management of sharks. At the request of the Convention on International Trade of Endangered Species of Wild Fauna and Flora (CITES) and through a consultation process coordinated by the Food and Agriculture Organization of the United Nations (FAO), an 'International Plan of Action for Conservation and Management of Sharks' has been developed. Implementation of the Plan of Action by individual nations is voluntary, but it is designed to be consistent with the FAO Code of Conduct for Responsible Fisheries and the rules of international law.

This special issue of *Marine and Freshwater Research* makes a valuable contribution towards redressing the lack of information, particularly in terms of describing shark fisheries and their assessment, monitoring and management. The timing of its publication coincides with the endorsement of the International Plan of Action by 70 nations through FAO, and the information and insights emerging from this issue will contribute to the information base required for implementation of the Plan of Action.

The collection of papers in this issue grew out of the Sharks and Man Workshop held in Brisbane on 2 August 1996 as part of the Second World Fisheries Congress. Several of the papers were presented at the workshop but the others were solicited to address some of the gaps in the scientific literature. The issue is unique in that all except two of the papers are sourced from the Southern Hemisphere.

Grouped into four sections, the 23 papers are all relevant to the conservation of sharks and management of shark fisheries. The first section (Shark Fisheries and Management) contains six papers describing national or regional shark fisheries and their management and begins with a review paper addressing some of the broad issues confronting shark fisheries management and shark conservation. The second section (Catch Monitoring and By-catch) comprises five papers describing at-sea-monitoring programmes for coastal and offshore fisheries; these papers raise issues such as discarding, by-catch, market grading, shark fishery interactions with mammals, sea birds and turtles and the management of risk associated with interactions between sharks and humans. The third section (Life History and Stock Assessment) comprises seven papers: one provides an important comparison of the productivities of 26 species of shark based on life history parameters, and others address important components of shark biology, such as reproduction, age and growth, and gillnet selectivity, required for stock assessment; one paper applies a stock assessment with risk analysis based on demographic parameters combined with fishing gear selectivity parameters and time series data of catch and catch per unit effort. The fourth section (General Biology) comprises five papers on shark general biology; these include papers on taxonomy and genetic studies relevant to stock delineation, feeding, and liver oils.

The support of the Australian Fisheries Research and Development Corporation (FRDC Project 97/303) for this publication is acknowledged, and the authors, reviewers and the editor of *Marine and Freshwater Research*, Ann Grant, are thanked for their efforts and patience.

Can shark resources be harvested sustainably?
A question revisited with a review of shark fisheries

Terence I. Walker

Marine and Freshwater Resources Institute
PO Box 114, Queenscliff, Victoria, Australia 3225

Sharks and other chondrichthyans are often described as long lived, slow growing and producing few offspring. These biological characteristics, together with the common assumption that recruitment is directly related to stock, and pessimistic stock prognoses obtained from application of demographic analysis, have led to doubts that sharks can be harvested sustainably. Developed over the past 40 or so years from studies of only a few shark species, these doubts have been reinforced by declining catch rates in industrial, artisanal and recreational fisheries and in fishing programmes designed to reduce the risk of sharks attacking humans at bathing beaches. However, more recent studies and application of modelling techniques allowing for density-dependent responses to the effects of stock reduction indicate that shark stocks can be harvested sustainably and, if carefully managed, can provide very stable fisheries. It is now understood that some species (such as *Galeorhinus galeus*, *Carcharhinus plumbeus*, *Carcharodon carcharias* and several species of dogfish) have low productivity, whereas other species (such as *Mustelus antarcticus*, *Rhizoprionodon terraenovae*, *Sphyrna tiburo* and *Prionace glauca*) have higher productivity. This paper reviews the use of shark products, the effects of fishing on shark populations of the world, and recent developments in assessment of shark fishery stocks. [References: 157]

Elasmobranch exploitation in Africa

M. Kroese[A] and W. H. H. Sauer[B]

[A]*Sea Fisheries Research Institute, Private Bag X2, Rogge Bay 8012, South Africa*
[B]*Department of Ichthyology and Fisheries Science, Rhodes University, PO Box 94, Grahamstown, 6140, South Africa*

The impact of fisheries on elasmobranchs in Africa is not well documented. Available data suggest that there are no large shark fishing nations (> 10000 t year^{-1}), reported landings for 1994 being around 39000 t. This value is believed to be a underestimate, because of a lack of data on catches and landings from the various different fishing methods and the large number of nations fishing in African waters. Existing data are mostly linked to industrial fisheries, although the artisanal sector could be responsible for substantial catches. Landed by-catch and discard rates of elasmobranchs are unknown for most commercial fisheries targeting teleosts. Limited data sources allowed only crude estimates of catch. The artisanal fishery is calculated to land a minimum of 20000 t of sharks, whereas the industrial trawl sector is likely to catch 23000 t. A conservative estimate for the African continent and the surrounding islands is similar to ~95000 t. The quality of catch-and-effort data for both commercial and subsistence fisheries on the African continent needs to be improved, and the by-catch issue should be investigated through trained onboard observers. [References: 25]

New Zealand shark fisheries: development, size and management

Malcolm P. Francis

National Institute of Water and Atmospheric Research Ltd, 301 Bay Parade, Greta Point, Wellington, New Zealand

New Zealand's shark fisheries have increased steadily since 1975 to reach 17000–19000 t per year. Commercial fisheries catch mainly spiny dogfish (*Squalus acanthias*), school shark (*Galeorhinus galeus*), skates (*Raja nasuta* and *R. innominata*), ghost sharks (*Hydrolagus novaezealandiae* and *Hydrolagus* sp.), rig (*Mustelus lenticulatus*) and elephantfish (*Callorhinchus milii*). School shark, rig and elephantfish fisheries have long histories, and catches are limited by Individual Transferable Quotas. Fisheries for spiny dogfish, skates and ghost sharks have only developed since 1979. Spiny dogfish and skate landings are partially regulated by total quotas. Other sharks are prohibited target species. Blue (*Prionace glauca*), porbeagle (*Lamna nasus*) and mako (*Isurus oxyrinchus*) sharks are taken as by-catch of the tuna longline fishery. There is a small recreational catch of spiny dogfish, school shark, rig, mako shark and blue shark. Historically important Maori fisheries for spiny dogfish, school shark and rig are now minor. A beach netting programme has operated off Dunedin beaches since 1969 to protect swimmers from shark attacks. Fisheries management measures include commercial quotas, prohibitions on target fishing many species, recreational bag limits, limits on set-net length, mesh size and soak time, and closure of many inshore waters to set-netting, trawling and Danish seining. [References: 50]

Keeping the fish in 'fish and chips':
research and management of the Western Australian shark fishery

Colin A. Simpfendorfer

Western Australian Marine Research Laboratories, PO Box 20, North Beach, WA 6020, Australia

The shark fishery in the southern half of Western Australia fishery began in 1941 and developed slowly until the mid 1970s when the fishery began to expand rapidly. A management plan incorporating limited entry, gear specifications and effort controls was introduced in 1988 in response to concerns about the status of the stocks. Research has focused on the assessment of stocks, and has involved the collection of catch-and-effort data since 1975, and tactical research projects to gather data on biology; this has allowed the implementation of stock assessment, modelling and forecasting techniques. The fishing industry is involved in the development of the research projects and in the decision-making process of management. This, together with regular reporting of research results, assists in maintaining industry support and acceptance of results. A potential disadvantage of the involvement of industry is the delay in implementation that may be caused by the complexity of the system of consultation or by the conflict between regulation of the fishery and the present livelihood of fishers. However, this is minimized by the creation of clear quantitative targets for management. [References: 18]

Shark fisheries in Argentina

Gustavo E. Chiaramonte

División Ictiología, Museo Argentino de Ciencias Naturales "Bernardino Rivadavia"
Av. Angel Gallardo 470, Buenos Aires, 1405 Buenos Aires, Argentina

In the Argentine Sea there are about 35 species of sharks. Three species are subjected to directed fishing: the smoothhound *Mustelus schmitti*, the school shark *Galeorhinus galeus* and the copper shark *Carcharhinus brachyurus*. Other species of elasmobranchs with commercial importance are the angel shark *Squatina* spp. and several species of skates and rays. The rise in chondrichthyan declared landings registered from 1988 to 1996 is due to the increase in landings of smoothhound and rays. The most important directed shark fishery in the South-West Atlantic is the Necochea gill-net fishery for school shark, which is carried out by the coastal fleet; details are given of the ships and the gill-nets used in this area. The length frequencies of the catches by gill-nets are presented for the school shark; fishing effort (length (km) of net in the water per ship per day) and CPUE (number of sharks per fishing effort) were found not to be good indicators of population trends in the school shark fishery. [References: 60]

The Mexican artisanal shark fishery in the Gulf of Mexico: towards a regulated fishery

J. L. Castillo-Geniz[A], J. F. Marquez-Farias [AD], M. C. Rodriguez de la Cruz[B], E. Cortes[C] and A. Cid del Prado[A]

[A]*Programa Tiburón Instituto Nacional de la Pesca, SEMARNAP, Pitágoras # 1320, 4° Piso, Col. Santa Cruz Atoyac CP 03310, DF, México*
[B]*instituto Tecnologico del Mar Guaymas, Km, 4 carretera Varadero Nacional, sector Las Playitas, Apdo Postal 563, CP 85480, Guaymas, Sonara, Mexico*
[C]*Center for Shark Research MOTE Marine Laboratory 1600 Ken Thompson Parkway Sarasota, Florida 34236 USA*
Present address: Institute for Fisheries Resource Ecology, Florida State University, Panama City Laboratory, 3500 Delwood Beach Road, Panama City, FL 32408–7403 USA
[D]*Present address: Instituto Nacional de la Pesca, SEMARNAP Programa Tiburón, Centro Regional de Investigaciones Pesqueras, Calle 20 No. 605 Sur Guaymas, Son. 85400 México*

Artisanal shark fisheries have been an important source of food and employment in Mexico for many years. In the Gulf of Mexico, this multispecies fishery is based on the seasonal abundance of several shark and teleost species. To obtain fishery and biological information needed to manage the fishery and conserve shark stocks, intensive monitoring of artisanal shark landings was undertaken from November 1993 to December 1994. The State of Campeche had the highest landings and effort. October 1994 had the highest monthly catch per unit effort for all species and areas combined (27.2 sharks per trip). *Rhizoprionodon terraenovae* (46%), *Sphyrna tiburo* (15%), and *Carcharhinus limbatus* (11%) accounted for most of the landings numerically, and the highest catch per unit effort for *C. limbatus* occurred late in the year as a result of increased landings attributable to an annual southward migration from USA to Mexican waters. The high proportion of neonate and juvenile sharks in gill-net catches from shallow coastal waters suggests that the main shark nursery areas are under heavy fishing pressure. In light of the heavy exploitation of shark resources, the Mexican

National Fisheries Institute recommends a number of precautionary actions to avoid the collapse of this fishery. [References: 23]

Pelagic elasmobranchs caught by longliners off southern Brazil during 1974-97: an overview

A. F. Amorim, C. A. Arfelli and L. Fagundes

Centro de Pesquisa Pesqueira Marinha, Instituto de Pesca, Bartolomeu de Gusmão 192 11030-906 - Santos São Paulo, Brazil. email: ipescapm@eu.ansp.br

From 1974 to 1997 elasmobranchs caught by longliners based in Santos City Sao Paulo State, Brazil, have been identified and the biology of some of the species has been studied. The fleet has fished since 1968, and in 1996 comprised 16 boats operating in the area 17-35 degrees S, 27-52 degrees W. Since 1977 yields of sharks have shown an increasing trend, reaching similar to 60% of the longline total catch in 1993. Blue shark (Prionace glauca) was the main species and responsible for about 30% of the total catch of the Santos longliners. The 33 shark and 2 ray species identified belonged to the following families and genera: Alopiidae (*Alopias*), Carcharhinidae (*Carcharhinus*, *Galeocerdo*, *Prionace*) Hexanchidae (*Heptranchias*, *Hexanchus*), Lamnidae (*Isurus*, *Lamna*), Megachasmidae (*Megachasma*), Odontaspididae (*Carcharias*, *Odontaspis*), Pseudocarchariidae (*Pseudocarcharias*), Rhincodontidae (*Rhincodon*), Sphyrnidae (*Sphyrna*), Squalidae (*Squaliolus*, *Etmopterus*, *Isistius*), Dasyatidae (*Dasyatis*) and Mobulidae (*Mobula*). Abundance, reproduction and other biological aspects of some of the species are presented. [References: 74]

Incidental catch associated with swordfish longline fisheries in the south-west Atlantic Ocean

Yamandú H. Marín, Federico Brum, Luis C. Barea and Julia F. Chocca

Instituto Nacional de Pesca, Constituyente 1497, Montevideo, CP 11200 Uruguay
email: ymarin@inape.gov.uy

This paper describes the composition of the harvest by species of two vessels operating with two different pelagic longline systems aimed at swordfish (*Xiphias gladius*). Four zones were surveyed in the Uruguayan EEZ and international waters in the south-western Atlantic. Data were collected by observers on board who recorded the number of individuals in each of the species caught. In all, 50 species were caught, of which 15 were cartilaginous fish, 27 were teleosts and eight were 'non-fish' species (birds, mammals and turtles). The most abundant species were blue shark (*Prionace glauca*) (43%), swordfish (27%) and albacore tuna (*Thunnus alalunga*) (9%). The abundances of blue shark and of swordfish differed significantly between the two rigging systems and among the four zones. The catch was classified into three marketing groups: primary marketing (swordfish and high-price tuna), secondary marketing (non-target species but marketable) and discards (with no commercial value). In terms of numbers, the first two groups represented between 91% and 72% of the species collected. This percentage may vary if the catch is analysed by weight, as only part of the carcass and shark fins are used. [References: 10]

By-catch of sharks in Patagonian coastal trawl fisheries

Silvina Van Der Molen[AB], Guillermo Caille[AB] and Raúl González[AC]

[A]Patagonian Coastal Zone Management Plan, Fundacion Patagonia Natural Marco A. Zar 770 Puerto Madryn, Chubut, Argentina
[B]Universidad Nacional de la Patagonia, Belgrano 504 (9100) trelew, Chubut, Argentina
[C]Instituto de Biología Marina y Pesquera Almirante Storni, Avda Costanera s/n (8520), San Antonio Oeste, Rio Negro, Argentina

In coastal Patagonia, Argentina, an unknown number of species of sharks are frequently caught in bottom-trawl nets. Between 1993 and 1996, 454 trawls by Patagonian coastal fisheries (41°-51°S) were analysed; 264 included sharks. Of the seven species of sharks caught, the most frequent was the smoothhound *Mustelus schmitti*, mainly in Bahía Engaño (off Chubut). The argentine angel shark (*Squatina argentina*) and the tope (*Galeorhinus galeus*) were common in the north of Patagonia, the piked dogfish (*Squalus acanthias*) in the central zone, and the narrowmouthed catshark *Schroederichthys bivius* in the south. The broadnose sevengill shark (*Notorhynchus cepedianus*) was rarely caught. A single basking shark (*Cetorhinus maximus*) was caught in San Matias Gulf (off Río Negro). Although undesirable, the by-catch of sharks is growing as a result of the increase in the fishing activities of the region, and the sustainability of the shark populations in Patagonian coasts is a matter of concern. [References: 32]

Effect of the Queensland Shark Control Program on non-target species: whale, dugong, turtle and dolphin: a review

N. A. Gribble, G. McPherson and B. Lane[A].

Northern Fisheries Centre, PO Box 5396, Cairns, Qld 4870 Australia.
[A]Queensland Shark Control Program, Mineral House, George St, Brisbane, Qld 4000, Australia.

The Queensland Shark Control Program (QSCP) has recorded a long-term annual mortality of 0.1 humpback whale, 2 'small whales' (species uncertain), 20 dugong, <78 turtles (species and number released uncertain), and <19 dolphin (species and number released uncertain). Available population estimates suggest that the historic impact of the QSCP would have been negligible on whales, 0.5% per year of the dugong population in the southern Great Barrier Reef, minor on green and loggerhead turtle populations, and unknown but probably minor on leatherback turtles and dolphin populations. In response to improved methods between 1992 and 1995 the average yearly mortality fell to 0 humpback whales, 4 dugong, 3 loggerhead turtles (11 turtles in total), and 10 dolphin (species uncertain); this suggests no impact on whales, 0.1% per year of the dugong population of the southern Great Barrier Reef, 1.6% of the yearly indigenous harvest of green turtles in eastern Australia, and 0.2% per year of the loggerhead turtle population in Queensland. Lack of population estimates and species identification precluded impact calculations for dolphin. The number of rare, vulnerable and endangered marine animals killed in the QSCP gear each year is in tens rather than thousands and the effect of this incidental mortality on their populations is probably minor. [References: 26]

Shark control: experimental fishing with baited drumlines

S. F. J. Dudley[A], R. C. Haestier[A], K. R. Cox[A] and M. Murray[B]

[A]Natal Sharks Board Private Bag 2 Umhlanga Rocks 4320 South Africa. email: dudley@shark.co.za
[B]department of Statistics, Faculty of Science, University of Natal, Durban 4041, South Africa.

Protective gill-nets (shark nets) have been successful in reducing the frequency of shark attacks on the coast of KwaZulu-Natal (KZN), South Africa, since 1952. This is achieved primarily through a local reduction in numbers of large sharks. Yet the nets are non-selective in terms of shark species caught and take a by-catch of dolphins, sea turtles, batoids and teleosts. Baited lines, or drumlines, as used in the Queensland shark control programme, were tested as possible alternatives to gill-nets. They demonstrated greater species selectivity for sharks and also a reduced by-catch of non-shark animals. The shark catch included the three species responsible for most shark attacks on the KZN coast, *Carcharhinus leucas*, *Galeocerdo cuvier* and *Carcharodon carcharias*. The probability of the bait being scavenged, or a shark being caught, was modelled in relation to a number of physical environmental factors. Although there was insufficient variability in the effort data for a quantitative comparison of catch rates between nets and drumlines, the results suggested that an optimal solution may be to deploy a combination of nets and drumlines. [References: 27]

Intrinsic rebound potentials of 26 species of Pacific sharks

Susan E. Smith, David W. Au and Christina Show

Southwest Fisheries Science Centre National Marine Fisheries Service NOAA PO Box 271 La Jolla California 92038–0271 USA email susan.smith@noaa.gov

A demographic technique is used to compare the intrinsic rates of population increase of 26 shark species hypothetically exposed to fishing mortality. These rates (r_{2M}) are used as a measure of the relative ability of different sharks to recover from fishing pressure. The method incorporates concepts of density dependence from standard population modelling and uses female age at maturity, maximum reproductive age, and average fecundity. A compensatory response to population reduction is assumed in pre-adult survival to the extent possible given the constraints of the life-history parameters. 'Rebound' productivity was strongly affected by age at maturity and little affected by maximum age. Species with lowest values ($r_{2M} < 0.04$) tended to be late-maturing medium- to large-sized coastal sharks, whereas those with the highest (> 0.08) were small coastal, early-maturing species. Sharks with mid-range values ($r_{2M} = 0.04–0.07$) were mostly large (> 250 cm maximum size) pelagic species, relatively fast growing and early maturing. Possible selection pressures for these three shark groups, management implications, practical applications for the derived parameter r_{2M},, and recommended areas of research are discussed. [References: 87]

Biology of the ornate angel shark (*Squatina tergocellata*) from the Great Australian Bight

Natalie F. Bridge[AC], Duncan Mackay[A], and Gina Newton[BD]

[A]The Flinders University of South Australia, Bedford Park, SA 5042, Australia
[B]Bureau of Resource Sciences, PO Box E11, Kingston, ACT 2604, Australia
[C]Present address: Marine and Freshwater Resources Institute, PO Box 114, Queenscliff, Vic. 3225, Australia. email: n.bridge@mafri.com.au
[D]Present address:Environment Australia, GPO Box 787, Canberra, ACT 2601, Australia

Ornate angel sharks were sampled from commercial catches from the Great Australian Bight trawl fishery during the period from February 1992 to February 1993. Size structure, reproduction and diet were studied. Both sexes exhibited similar length-weight relationships. Morphological data indicate that the most accurate conversion to total length (TL) would be obtained from the distance between the granular ocelli on the trunk near the pectoral fins. Males reached sexual maturity at a TL of 810–910 mm, females at 1150–1250 mm. The male:female ratio was 1:3 for the *post partum* population and 1:1 for embryos. Both ovaries were functional throughout the year, but the left ovary contained more ovarian follicles than the right. Follicle diameters ranged from 1 to 68 mm; the largest follicle was found during autumn, before ovulation, the smallest during spring, after ovulation. Eighteen near-term embryos from four females were observed during January and February 1993. The number of young per female ranged from 2 to 9. It appears that *S. tergocellata* has a minimum gestation period of 6–12 months and parturition may occur biennially. The most common stomach contents were squid (*Nototodarus gouldi*) and fish (mainly Monacanthidae). [References: 24]

Reproductive biology of the whiskery shark, *Furgaleus macki*, off south-western Australia

Colin A. Simpfendorfer[A] and Phillip Unsworth

Western Australian Marine Research Laboratories, PO Box 20, North Beach, WA 6020, Australia
[A]Present address: Center for Shark Research, Mote Marine Laboratory, 1600 Ken Thompson Parkway, Sarasota, FL 34236, USA. email: clins@mote.org

The whiskery shark, Furgaleus macki, is important in the commercial shark fishery off southern Western Australia. The reproductive biology was studied with the aid of 886 specimens collected by commercial gill-net vessels off south-western Australia between March 1994 and August 1996. The size selectivity of the gill-nets resulted in: only mature and large juvenile specimens being caught. Size at birth was estimated to be 22–27 cm total length. Size (fork length) at maturity was 107 cm for males and 112 cm for females. There is a seasonal reproductive cycle. Mating is most likely to occur from August to September, with females storing spermatozoa until ovulation in late January to early April. Gestation lasts 7–9 months, with parturition from August to October. Litter sizes vary from 4 to 28 (mean 19). There was a significant linear relationship between litter size and maternal length. Mature males mate each year, but females produce litters every second year. Mature non-pregnant females develop large yolky ova from March to October, with development of the ova completed several months before

ovulation. The results are compared with previous records and with data for other species of the family Triakidae that occur off southern Australia. [References: 29]

Reproductive biology of shortnose spiny dogfish, *Squalus megalops*, from the Agulhas Bank, South Africa

G. Watson and M. J. Smale

Port Elizabeth Museum PO Box 13147 Humewood 6013 South Africa

Aspects of the reproductive biology of *Squalus megalops* were investigated in material collected from commercial and research trawl samples from the Agulhas Bank. The largest male measured 572 mm TL and the largest female 782 mm. The size at which 50% of the males in the population were sexually mature was similar to 400 mm; 50% of the females were mature at similar to 500 mm, and 50% were pregnant at similar to 510 mm. Litter size varied from 2 to 4 but only the largest females had the maximum litter size. Reproduction in *S. megalops* is aplacental-viviparous, and the pups are 232-277 mm at birth. The sex ratio of embryos was not significantly different from unity. Trawled dogfish had a sex ratio significantly different from unity, probably because of sampling bias; aggregations were apparently not adequately sampled over their entire distribution. [References: 35]

Age determination and growth of the smalltail shark, *Carcharhinus porosus*, from northern Brazil

Rosangela Lessa[AC] and Marcente Santana[B].

[A]Laboratorio de Hidrobiologia, Universidade Federal do Maranhão, 65.020-240 Brazil
[B]Departmento de Pesca, Universidade Federal Rural de Pernambuco Dois Irmãos Recife 52171 900 Brazil
[C]Present Address: Departmento de Pesca, Universidade Federal Rural de Pernambuco, Dois Irmãos, Recife, 52.171-900, Brazil. email: Lessa@elogica.com.br

Age and growth of *C. porosus* was estimated from seasonally formed marks in vertebrae of 504 specimens (30.0–101.0 cm total length), and from length-frequency data from 1128 individuals (29.4–120.5 cm). Estimated von Bertalanffy growth parameters were: from observed length-at-age, L_∞125.1 cm, K 0.101 year^{-1} and t_0 –2.89 year; from back-calculated lengths, L_∞ 136.4 cm, K 0.077 year^{-1}, t_0 –3.27 year; and from length-frequency analysis, L_∞ 131.0, K 0.080 and t_0 –3.40. Growth did not differ significantly between sexes. Males and females were mature at 71.0 and 70.0 cm, respectively, corresponding to 6 years old. The largest shark aged from vertebrae was a 12-year-old female (101.0 cm). Growth rates calculated from mean observed lengths were 7.0 cm year(–1) for the first four years and 4.0 cm year^{-1} after maturity. Lee's phenomenon was not apparent. The annulus forms from September to January. Parameters derived from back-calculated lengths were considered to best describe growth. Like most carcharhinids, *C. porosus* follows he general pattern of K-selected species, exhibiting slow growth, late maturity and low fecundity. [References: 32]

Gill-net mesh selectivity of dusky sharks (*Carcharhinus obscurus*) and whiskery sharks (*Furgaleus macki*) from south-western Australia

Colin A. Simpfendorfer[A] and Phillip Unsworth

Western Australian Marine Research Laboratories, PO Box 20, North Beach, WA 6020, Australia
[A]Present address: Center for Shark Research, Mote Marine Laboratory, 1600 Ken Thompson Parkway, Sarasota, FL 34236, USA. email: clins@mote.org

Gill-net mesh selectivity parameters were estimated for *C. obscurus* and *F. macki* from catches of an experimental net composed of seven panels of mesh ranging in size from 12.7 cm to 21.6 cm. A maximum-likelihood model was used to fit a gamma distribution to length data from each of the different-sized meshes. Mesh selectivity parameters for the gilled-only data set were θ_1 =126.90 and θ_2 =20253, and for the data set including gilled and non-gilled sharks θ_1 =130.13 and θ_2 =29237. The advantages of the parameters from each of these data sets are discussed. Mesh-selectivity parameters for *F. macki* were θ_1 =173.70 and θ_2 =26415. The exclusion of data from the two largest mesh sizes, which had much lower catch rates than the other mesh sizes, did not significantly change the parameter estimates. Catch rates from the panels in the experimental net that correspond to those used by the commercial gill-net fishery in south-western Australia were compared and no significant differences were found. [References: 10]

Stock assessment and risk analysis for the school shark (*Galeorhinus galeus*) off southern Australia

André E. Punt and Terence I. Walker.

[A]CSIRO Division of Marine Research GPO Box 1538, Hobart Tas. 7001 Australia.
email: Andre.Punt@marine.csiro.au
[B]Marine and Freshwater Resources Institute, PO Box 114, Queenscliff, Vic. 3225, Australia

A spatially aggregated age- and sex-structured population dynamics model was fitted to standardized catch-rate data from the school shark resource off southern Australia. The model incorporates the peculiarities of shark populations and fisheries, including the pupping process and the selectivity characteristics of gill-nets. Estimates are determined by a Bayesian approach that incorporates prior distributions for virgin biomass, the parameter that determines productivity, and the variation in pup survival. Tests of sensitivity include changing the data series used, varying the value of adult natural mortality, and changing the prior distribution for the productivity parameter. The point estimates of the mature biomass at the start of 1995 range from 13% to 45% of the pre-exploitation equilibrium size, depending on the specifications of the assessment. The results are notably sensitive to the selection of a catch-rate series. Results suggest that the current fishing intensity will lead to further declines in abundance, that a reduction of similar to 20% in fishing mortality would achieve a 0.5 probability of not declining further, and that a reduction of 42% would achieve with a probability of 0.8 the management goal of not being below the 1996 mature biomass at the start of 2011. [References: 41]

Population structure of the Australian gummy shark (*Mustelus antarcticus* Gunther) inferred from allozymes, mitochondrial DNA and vertebrae counts

M. G. Gardner[AB] and R. D. Ward[A]

[A]CSIRO Division of Marine Research GPO Box 1538, Hobart Tas. 7001 Australia.
[B]Present address and address for reprints: Evolutionary Biology Unit, South Australia Museum, North Terrace, Adelaide, SA 5000, Australia . email: Michael.Gardner@flinders.edu.au

The gummy shark (*Mustelus antarcticus*) is the main target of southern Australian shark fisheries. Its stock structure was investigated through allozymes (up to 28 loci), mitochondrial DNA (up to 10 restriction enzymes) and vertebrae count. The average heterozygosity per allozyme locus (0.099) and degree of polymorphism (0.255) was high for sharks. Composite mitochondrial DNA haplotype diversity (0.534) and mean nucleotide sequence diversity (0.16%) were also moderately high. Three of the seven polymorphic allozyme loci (*CK-A**, *LDH-1**, *PEP**) and the mtDNA haplotypes showed significant spatial differentiation. Two genetic stocks were identified: one along the southern coast of Australia from Bunbury in Western Australia to Eden in New South Wales and one off northern New South Wales (in the region of Newcastle to Clarence River). There was some evidence for a third stock off Townsville, Queensland. The northern occurrences extend the known geographical range of this species. Vertebrae counts from Eden northwards increased, supporting the conclusion of population heterogeneity off eastern Australia. [References: 43]

The shark genus *Carcharhinus* Blainville, 1816 (Chondrichthyes: Carcharhinidae) in Argentine waters

Gustavo E. Chiaramonte

División Ictiología, Museo Argentino de Ciencias Naturales "Bernardino Rivadavia"
Av. Angel Gallardo 470, Buenos Aires, 1405 Buenos Aires, Argentina. email: gchiaram@mail.retina.ar

The purpose of this contribution is to review the species of the shark genus *Carcharhinus* found along the coast of Argentina. New southern limits for the distribution of the genus are given for the western South Atlantic. The presence of *Carcharhinus leucas* (Valenciennes, 1839) is recorded for the first time on the Province of Buenos Aires coast. New evidence is given which confirms the presence of *Carcharhinus brachyurus* (Günther, 1870) in the area. *Carcharhinus plumbeus* (Nardo, 1827) is known from only a single Argentine record. *Carcharhinus longimanus* (Poey, 1861) has been recorded from oceanic waters offshore of Argentina, but has not been taken from continental shelf waters. [References: 42]

Observations on the diet and feeding habits of the epaulette shark, *Hemiscyllium ocellatum* (Bonnaterre), on Heron Island Reef, Great Barrier Reef, Australia

M. R. Heupel and M. B. Bennett[A]

Department of Anatomical Sciences, University of Queensland, St Lucia, Qld 4072, Australia.
[A]To whom correspondence should be addressed. email: m.bennett@mailbox.uq.edu.au

The diet and feeding habits of the epaulette shark, *Hemiscyllium ocellatum*, were investigated through stomach content analysis. Five groups of prey items were found. The index of relative importance showed worms and crabs, to be of greatest value at 51.3% and 40.1% respectively. The three minor prey groups were shrimps (7.7%), small fishes (0.7%) and amphipods (0.3%). Epaulette sharks tend to be crepuscular, although feeding bouts may occur at any time. They appear to be opportunistic predators, using olfaction and electroreception in prey capture. This species appears to be an important benthic predator in the reef flat environment on Heron Island Reef. [References: 16]

Diet of the Australian sharpnose shark, *Rhizoprionodon taylori*, from northern Queensland

Colin A. Simpfendorfer

Western Australian Marine Research Laboratories, PO Box 20, North Beach, WA 6020, Australia
Present address: Center for Shark Research, Mote Marine Laboratory, 1600 Ken Thompson Parkway, Sarasota, FL 34236, USA. email: clins@mote.org

Stomachs from 433 specimens of *Rhizoprionodon taylori* caught by gill-nets and otter trawls in Cleveland Bay, north Queensland, were examined. At least 5.3% of specimens examined had regurgitated. Of the remaining 410 specimens 59.0% had empty stomachs and only 19.3% contained food items identifiable to the family level. The diet comprised mostly small teleosts from the families Leiognathidae, Clupeidae, Teraponidae and Engraulidae. Penaeid prawns and loliginid squid were also important in the diet. Average weight of individual recently ingested food items was 28.5 g, which represented 2.3% of body weight. The high diversity of potential prey groups, high rate of regurgitation, and high proportion of empty stomachs meant that although a large number of specimens were examined the sample size was probably insufficient to provide a thorough analysis of the diet of *R. taylori* in Cleveland Bay. [References: 23]

Oils rich in docosahexaenoic acid in livers of sharks from temperate Australian waters

Peter D. Nichols, Michael J. Bakes and Nicholas G. Elliott

CSIRO Division of Marine Research GPO Box 1538, Hobart Tas. 7001 Australia. email: Peter.Nichols@marine.csiro.au

The livers from the two main commercially-targeted shark species in southern Australia (*Mustelus antarcticus*, gummy shark; *Galeorhinus galeus*, school shark), together with

Squalus acanthias (white-spotted spurdog), were analysed for oil content and composition, and fatty acid composition. The yield of oil from the liver was 30–64% (wet weight) for *M. antarcticus* and 50–53% (wet weight) for *G. galeus*. Lipid classes were determined by thin-layer chromatography with flame ionization detection, with the major lipid being triacylglycerol (≥95%); other minor lipids were polar lipid, wax ester, sterol (mainly cholesterol) and free fatty acid. Long-chain omega-3 polyunsaturated fatty acids accounted for between 33% and 39% of the total fatty acids in all three species, and docosahexaenoic acid (DHA) concentrations were between 13% and 18%. The liver oils of *M. antarcticus* and *G. galeus* and other shark species may be an attractive source of ω-3 fatty acids, specifically DHA, for direct use and/or for adding further value. [References: 24]