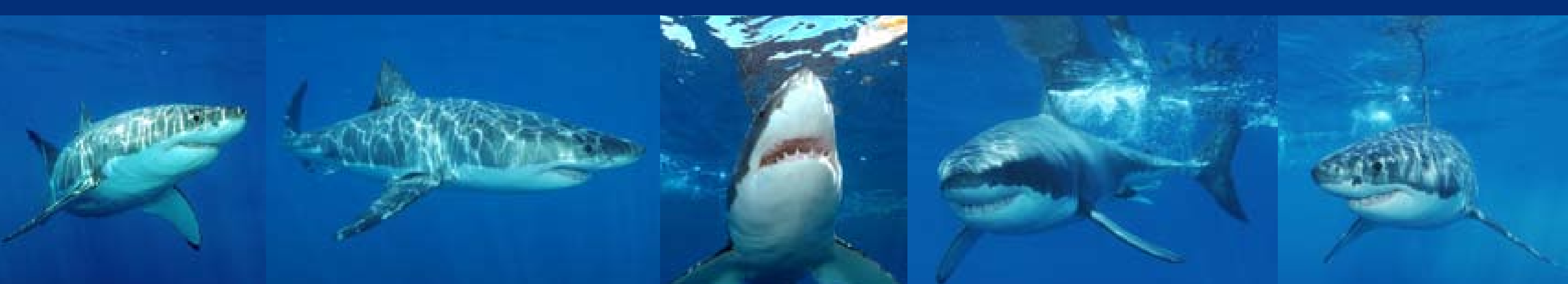
7-10 FEBRUARY 2010



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Joint Institute for Marine and Atmospheric Research- School of Ocean and Earth Science and Technology

I would like to extend a warm welcome to all of you that have traveled to Hawaii to attend the International White Shark Symposium. This event will be the largest ever gathering of white shark researchers, presenting exciting new findings from around the globe. Our understanding of this magnificent apex predator has been hindered by its large size and uncommon occurrence. Through technological advances and sheer perseverance, white sharks are suddenly revealing some aspects of their secret lives. What was once an exceptionally difficult animal to study in the field has now been thoroughly tracked moving between coastal and pelagic habitats. What was once an impossible animal to maintain in captivity has now successfully been put on public display. In fact, I might argue, that after the conclusion of this meeting, the white shark will rank as one of the best known sharks in the world's oceans. These major advances define the purpose of this symposium: a gathering of leading white shark researchers from around the world, to share the latest findings and discuss how they should influence modern research and conservation goals. Be sure to save some energy for the round table discussions at the end of the meeting, since they will cover important current issues. And finally, be assured that this symposium will leave its mark through the production of a dedicated book of the proceedings; a book that promises to be the next reference volume on all of our desks.

Sincerely,

Michael L. Domeier
Chair of the Organizing Committee

Organizing Committee

Michael Domeier
Marine Conservation Science Institute

Alison Kock
Save Our Seas Foundation

John O'Sullivan
Montery Bay Aquarium

Kevin Weng
Pelagic Fisheries Research Program

Quick Look Symposium Schedule

Sunday, February 7

2:00 - 6:00	Registration
5:30 - 7:30	Welcome Reception Sans Souci Room of New Otani Hotel

Monday, February 8

8:00 - noon	Registration
8:45	Welcome and Announcements
9:00 -12:10	Oral Presentations in Imperial Ball Room
12:10 - 1:30	Lunch
1:30 - 5:10	Oral Presentations in Imperial Ball Room
5:30	Poster Session in Sans Souci Room

Tuesday, February 9

9:00 - 1220	Oral Presentations in Imperial Ball Room
12:20 - 1:30	Lunch
1:30 - 5:00	Oral Presentations in Imperial Ball Room
8:00	Movie Night in Imperial Ball Room

Wednesday, February 10

9:00 - 12:20	Oral Presentations in Imperial Ball Room
1:30 - 3:00	Round Table Discussions in Imperial Ball Room
3:00 - 5:00	Round Table Discussions continued in Sans Souci Room (if necessary)

Symposium Schedule

Sunday, February 7

2:00 - 6:00 **Registration**

5:30 - 7:30 **Welcome Reception ~** Sans Souci Room of New Otani Hotel

Monday ~ February 8

8:00 - noon **Registration**

8:45 **Introductions & Announcements**

Mexico

Alison Kock, Moderator

9:00 **A new life history hypothesis for northeastern Pacific white sharks**
*Michael L. **Domeier****

9:30 **The potential use of non lethal techniques to assess the reproductive biology of the white shark, *Carcharodon carcharias.***
*Michael L. Domeier, L. J. Williams and James. A. **Sulikowski***

9:50 **A first examination and description of the northeastern Pacific Shared Offshore Foraging Area (SOFA)**
*Michael L. Domeier, Nicole **Nasby-Lucas** **and Daniel M. Palacios***

10:10 **Comparison of habitat utilization and environmental characteristics of white sharks around the Guadalupe Island and the offshore area in the Eastern Pacific**
*Chi H. **Lam**, Nicole Nasby-Lucas, Dale A. Kiefer and Michael L. Domeier*

10:30 **Break**

10:50 **Movement patterns of the white shark in Guadalupe Island, Mexico**
*Mauricio **Hoyos**-Padilla, Felipe Galvan Magana and Peter Klimley*

11:10 **Evaluation of trophic levels and feeding habitats of white sharks throughout ontogeny based on carbon and nitrogen stable isotope analysis of soft tissues**
*Luis **Malpica-Cruz**, Sharon Z Herzka and Oscar Sosa-Nishizaki*

11:30 **Depth-temperature preferences of the white shark *(Carcharodon carcharias)* in the Gulf of California, Mexico.**
*J. Fernando **Márquez-Farías** and Alejandro Rodríguez*

11:50 **Juvenile white shark *(Carcharodon carcharias)* incidental catch in Baja California, México: on the way to the conservation of the species**
*O. **Santana-Morales**, O. Sosa-Nishizaki, M. A. Escobedo-Olvera, John B. O'Sullivan and E. C. Oñate-González*

12:10 **Lunch**

California

Michael Domeier, Moderator

1:20 **Migration and philopatry of white sharks in the North Eastern Pacific**
*Salvador J. **Jorgensen,** Carol A. Reeb, Taylor K. Chapple, Scot Anderson, Christopher Perle, Sean R. Van Sommeran, Callaghan Fritz-Cope, Adam C. Brown, A. Peter Klimley and Barbara A. Block*

1:50 **Movements and habitat use of juvenile white sharks released from the Monterey Bay Aquarium and tagged in the wild in the Southern California Bight**
*K. **Weng**, J. O'Sullivan, C. Winkler, C. Lowe, S. Jorgensen, M. Ezcurra, C. Farwell and B. Block*

****Presenting authors are indicatd by bold, underlined typeface***

2:10 **The Oceanography of pelagic hot spots for white sharks in the northeastern Pacific**
*Christopher **Perle,** Salvador J. Jorgensen, Taylor K. Chapple, Scot Anderson, Adam C. Brown, A. Peter Klimley and Barbara A. Block*

2:30 **Validation of long-term individual identification and site fidelity of great white sharks, *Carcharodon carcharias*, off California using dorsal fins.**
*Scot D. **Anderson**, Taylor K. Chapple, Salvador J. Jorgensen, A. Peter Klimley and Barbara A. Block*

2:50 **Break**

3:10 **Historic fishery interaction with the white sharks in the Southern California Bight**
*Christopher G. **Lowe**, Gwen D. Goodmanlowe, Mary E. Blasius, Erica T. Jarvis, Tom J. Mason and John B. O'Sullivan*

3:30 **Stable isotope analysis reveals specialists and generalists within California white sharks, 1936-2003**
*Sora **Kim**, M. Tim Tinker, Jim A. Estes and Paul L. Koch*

3:50 **Evaluation of organochlorine contaminants in young-of-year and juvenile white sharks (*Carcharodon carcharias*) from the Southern California Bight**
*Mary Ellen **Blasius**, John B. O'Sullivan and Christopher G. Lowe*

4:10 **Trace Elements and Heavy Metals in the Tissues of Juvenile White Sharks from the Southern California Bight**
*Christopher **Mull**, Christopher Lowe and John O' Sullivan*

Atlantic

4:30 **White shark predation and the implications of increasing pinniped populations in the western North Atlantic**
*Gregory B. **Skomal** and John C. Chisholm*

4:50 **Seasonal Distribution of white sharks in the Northwest Atlantic Ocean**
*Tobey H. **Curtis**, Camilla T. McCandless, John K. Carlson, Harold L. Pratt, Jr., Nancy E. Kohler, George H. Burgess and Gregory B. Skomal*

Poster Session

5:30 **Dorsal fin photo identification of white sharks: a new step-by-step process to enhance accuracy**
*Ryan **Johnson**, Enrico Gennari, Storm van Tonder and Marthan N. Bester*

The potential for aerial surveys of juvenile white sharks in eastern Australia
*Barry D. **Bruce** and Russell W. Bradford*

Towards automated visual identification of great whites using biometric computer vision
*Ioannis Kaloskampis and Tilo **Burghardt***

Beyond The Hype: opportunities & guidelines for effective outreach and education
*Kanesa **Duncan**, Mark Heckman and Judy Lemus*

Assessing the usefulness of operator collected data for monitoring distribution and abundance of great white sharks
*S. **Maduray,** S. Kirkman and M.A. Meyer*

An analysis of South Africa's white shark cage diving industry based on log-book data
*S. **Maduray**, S.P. Kirkman and M.A. Meyer*

First steps to understand the effect of ecotourism on the behavior, distribution and social interaction of white shark *(Carcharodon carcharias)* in the Northeast coast of Isla Guadalupe México
*César **Guerro-Ávila**, Oscar Sosa-Nishizaki and Nadia C. Olivares-Bañuelos*

Real-Time Tracking of Migrating Adult White Shark, Carcharodon carcharias from Guadalupe Island, Mexico
*Ramón **Bonfil**, José L. Castillo-Geniz, Oscar Sosa-Nishizaki, Shannon O'Brien, Barbara Mangold and Arturo Carmona-Torres*

Population dynamics of juvenile and sub-adult Great white sharks around Dyer Island and its in-shore reefs
*Adrian **Hewitt***

White sharks and cephalopod prey: indicators of habitat use?
*Malcolm J. **Smale** and Geremy Cliff*

The international trade in great white shark teeth, and implications for CITES implementation and conservation
*Ernest W. T. **Cooper***

Using stable isotopes to understand the trophic ecology of eastern Pacific white sharks
*Aaron **Carlisle,** Sora Kim, Salvador Jorgensen and Barbara Block*

Tuesday ~ February 9

South Africa

John O'Sullivan, Moderator

9:00 **A review of research on the white shark, *Carcharodon carcharias* (Linnaeus), in southern Africa**
*Sheldon F.J **Dudley***

9:30 **Crittercam reveals novel white shark behaviour**
*Alison **Kock**, Lauren Best, Graham Wilhelm, Mike Shepherd, Mark Thorpe, Karl Laroche and Gregory Marshall*

9:50 **Quantitative analysis of the diet and trophic ecology of the white shark *(Carcharodon carcharias)* in South Africa waters.**
*Nigel E. **Hussey,** Heather McCann, Geremy Cliff, Sheldon F.J. Dudley, Brian J. Fryer and Aaron T. Fisk*

10:10 **Dynamics of predator-prey strategies in white sharks and Cape fur seals at Mossel Bay, South Africa**
*Ryan L. **Johnson,** Marthan N. Bester, Sheldon Dudley, W. Herman Oosthuizen, Michael Meÿer, Deon Kotze, Stephen Swanson and Enrico Gennari*

10:30 **Break**

New Caledonia

10:50 **Ecology of the great white shark, *Carcharodon Carcharias*, in New Caledonia (south Pacific)**
*E. **Clua** and B. Seref*

New Zealand

11:10 **Are winter diving holidays to the tropics the norm for New Zealand great white sharks *(Carcharodon carcharias)*?**
*Clinton **Duffy**, Malcolm P. Francis, Michael J. Manning and Ramon Bonfil*

11:30 **Diving behavior of New Zealand great white sharks *(Carcharodon carcharias)* recorded by popup archival tags**
*Malcom P. **Francis,** Clinton Duffy, Ramon Bonfil and Michael J. Manning*

Australia

11:50 **Research and conservation efforts on white sharks in Australian waters - current status and future directions**
*Barry D. **Bruce***

12:20 **Lunch**

1:30 **Seasonal size segregation of white sharks, *Carcharodon carcharias,* at the Neptune Islands, South Australia**
*R.L. **Robbins** and D.J. Booth*

1:50 **Identifying juvenile white shark behaviour from electronic tag data**
*Russell W. **Bradford** and Barry D. Bruce*

2:10 **Using long-term catch and movement to determine preferred beach areas by juvenile white shark, *Carcharodon carcharias,* in eastern Australia**
*Jonathan M. **Werry,** Barry Bruce, Wayne Sumpton and Dennis Reid*

2:30 **Break**

Biology

2:50 **The maximum authenticated size of the white shark**
*Jose I. **Castro***

3:10 **Microchemistry of white shark *(Carcharodon carcharias)* vertebrae: a potential tool to age individuals and examine life-history strategies?**
*Heather M. **McCann**, Nigel E. Hussey, Aaron T. Fisk, Sabine P. Wintner, Geremy Cliff, Sheldon F.J. Dudley and Brian J. Fryer*

3:30 **Skeletal anatomy of *Carcharodon carcharias***
*Michael **Gottfried**, Leonard Compagno and Anna Jerve*

Husbandry

3:50 **The Monterey Bay Aquarium's Juvenile White Shark Project: How weaving together partners from the scientific and fishing communities with research, conservation and education messaging created a wildly successful program**
*John B. **O'Sullivan**, Kevin Weng, Chuck Winkler, Christopher G. Lowe, Salvador Jorgensen, Oscar Sosa-Nishizaki, Manny Ezcurra, Barbara Block and Angela Hains*

4:20 **Routine metabolic rate of young-of-the-year white sharks *(Carcharodon carcharias)* transported to the Monterey Bay Aquarium**
*Juan M. **Ezcurra**, Christopher G. Lowe, Henry F. Mollet, Lara Ferry-Graham and John B. O'Sullivan*

4:40 **Captive feeding and growth of young-of-the-year white sharks *(Carcharodon carcharias)* at the Monterey Bay Aquarium**
*Juan M. **Ezcurra**, Christopher G. Lowe, Henry F. Mollet, Lara Ferry-Graham and John B. O'Sullivan*

Movie Night

8:00 **White Shark Café ~ *A film by Sean Aronson***

Wednesday ~ February 10

Monitoring, Management and Conservation

Barry Bruce, Moderator

9:00 **Protecting whites sharks in the Gulf of the Farallones National Marine Sanctuary**
*Irina **Kogan**, Sage Tezak and Maria C. Brown*

9:20 **White shark, a protected species in Guadalupe Island Biosphere Reserve; management and monitoring**
*Nadia Citlali **Olivares Bañuelos***

9:40 **A first estimate of white shark, *Carcharodon carcharias*, abundance off central California using photo-identity marking**
*Taylor K. **Chapple**, Salvador J. Jorgensen, Scot D. Anderson, Paul E. Kanive, A. Peter Klimley, Louis W. Botsford and Barbara A. Block*

10:00 **Estimating the white shark, *Carcharodon carcharias*, population in Guadalupe Island, Mexico, based on mark-recapture data**
*O. E. **Sosa-Nishizaki**, E. Morales-Bojórquez, M. Domeier and N. Nasby-Lucas*

10:20 **Break**

10:40 **White sharks as ambassadors for conservation**
*Randy **Hamilton** and Jim Covel*

11:00 **Shark Spotters: A pioneering shark safety programme in Cape Town, South Africa**
*Alison **Kock**, Sarah Titley, Wally Petersen, Monwabisi Sikweyiya, Patrick Davids, Sakhile Tsotsobe and Gregg Oelofse*

11:20 **Not another brochure! Maximising the shark conservation outcomes of commmunity awareness and education programs**
Chris ***Ball***

11:40 **Application of molecular genetics for conservation of the great white shark, *Carcharodon carcharias*, L.1758**
Chrysoula ***Gubili,*** *Madalena Branco, Clinton Duffy, Geremy Cliff, Sabine Wintner, Mahoood Shivji, Demian Chapman, Barry Bruce, John Stevens, Alison Kock, Ryan Johnson, Herman W. Oosthuizen, Mike Meÿer, Jane E. Sarginson, Andrew P. Martin, David W. Sims, Catherine S. Jones and Leslie R. Noble*

12:00 **Lunch**

Round Table Discussions

1:00 **Research Ethics**
Moderator, John O'Sullivan

2:00 **Shark Tourism**
Moderator, Michael Domeier

3:00 **Shark Attack Response**
Moderator, Alison Kock

4:00 **Adjourn**

7:00 **Banquet**

ABSTRACTS

Abstracts are alphabetical by senior author; presenting authors are indicated by bold typeface.

Scot D. **Anderson**[1], Taylor K. Chapple[2], Salvador J. Jorgensen[3], A. Peter Klimley[2] and Barbara A. Block[3]
[1]*P.O. Box 390, Inverness, CA 94937*
[2]*University of California Davis, One Shields Ave, Davis, CA 95616*
[3]*Hopkins Marine Station of Stanford University, 120 Oceanview Blvd., Pacific Grove, CA 93950*

Validation of long-term individual identification and site fidelity of great white sharks, *Carcharodon carcharias*, off California using dorsal fins

Mark-recapture techniques are one type of method used to estimate great white shark (*Carcharodon carcharias*) populations, which lack adequate fisheries data. These Mark-recapture frameworks are based on the assumptions that marks are conserved over long time periods and animals are present at the sampling location over the entire duration of the study. Though these assumptions have been demonstrated to be valid across short time scales for white shark populations, long-term studies of population trends are dependent on these assumptions being valid across longer periods. We use 22 years of photographic data from aggregation sites in central California to validate the use of dorsal fin morphology as long-term individual identifiers. We identified 5 individuals that were present between 16-22 years with little change in their dorsal fins. Applying dorsal fin mark-recapture techniques to 22 years of photographic data found support for the assumption that white sharks exhibit strong yearly site-fidelity to coastal aggregation sites. Validation of these assumptions up to 22 years supports the use of mark-recapture frameworks for white sharks over longer time-series.

Chris **Ball**
P.O. Box 60, Macclesfield, S.A. 5153, Australia

Not another brochure! Maximizing the shark conservation benefits of community awareness and education programs

Traditional community awareness and education methods such as brochures, posters, websites and forums are, on their own, of limited benefit in achieving shark conservation outcomes. Research from the health promotion field clearly shows that changes in behaviour do not generally result from being better informed. Behaviour change – in this case becoming involved in actions that lead to a reduction in the threats faced by sharks – requires both the opportunity to take action and the capacity to do so. Research also shows that information received from people we know and trust has far more credibility than that received from other sources and is therefore far more likely to influence our beliefs and attitudes. The Shark Watch project in South Australia is an example of how this research can be incorporated into community awareness and education programs to achieve conservation outcomes. It involves users of the marine environment reporting sightings of white sharks and other threatened shark species through a network of well known and respected volunteer local contacts. This approach proved so successful in a previous project that reports are still being received 3 years after funding for the project ended. The Shark Watch community awareness and education component utilises the above network to distribute information, thereby increasing the acceptance of that information. A community campaigning component is also being established to provide opportunities and support for community members to advocate for shark conservation measures such as legislative protection, reduced shark fishery quotas, and a ban on shark fin exports. This presentation will explain how the above research findings and the lessons learned from the earlier program have been incorporated into Shark Watch, the processes used to establish it, and early outcomes from the process. An opportunity for questions and discussion will also be provided.

Mary Ellen **Blasius**[1]; John B. O'Sullivan[2]; Christopher G. Lowe[3]
[1]*California State Univ. Long Beach, Institute of Integrated Research for Materials, Environments, and Society, CA 90840*
[2]*Monterey Bay Aquarium, Monterey, CA 93940*
[3]*California State Univ. Long Beach, Dept. of Marine Biology, CA 90840*

Evaluation of organochlorine contaminants in young-of-year and juvenile white sharks (*Carcharodon carcharias*) from the Southern California Bight

As a top predator, white sharks () occupy one of the highest levels in the oceanic food web giving this species great potential for biomagnification of organochlorines (OCs). Liver and muscle (red and white) samples from incidentally caught young-of-year (YOY) and juvenile white sharks were analyzed for organochlorines (polychlorinated biphenyls, DDT, HCHs, hexachlorobenzene and chlordanes). OC concentrations were the highest in liver samples (n = 16) with total DDT (∑DDT) Having the highest levels of all the OCs (68.31 $\pm$ 70.98 µg/g, lipid weight (lw); mean $\pm$ SD), followed by total PCBs (∑PCBs; 17.94 $\pm$ 11.67 µg/g, lw) and total CHLs (∑CHL; 1.51 $\pm$ 0.79 µg/g, lw). These are the highest levels of OCs reported in elasmobranchs to our knowledge. Average white shark DDT:PCB ratio ranged from 3.62 to 6.59 indicating that they accumulate higher DDT loads than PCBs, which corresponds to the DDT signature found in the SCB. YOYs feed heavily on benthic fishes, which may come from contaminated areas, but it is unlikely they could accumulate pollutant loads of this magnitude solely from their diet. Pinnipeds in the SCB have also been found to have high contaminant loads and high DDT to PCB ratios (6.87) in their blubber. Since adult white sharks are known to feed on SCB pinnipeds, it is possible that high DDT:PCB ratios observed in young-of-the-year white sharks are attributed to maternal offloading on these contaminants to their offspring. Despite the high level of contaminants found in YOY white sharks, nothing is known about the long-term physiological effects or impacts to growth and survivorship.

Ramón **Bonfil**[1, 2], José L.. Castillo-Geniz[3], Oscar Sosa-Nishizaki[4], Shannon O'Brien[5], Barbara Mangold[6], Arturo Carmona-Torres[4]
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[2]*NABU, Naturschutzbund Deutschland e.V., Leif Miller, Invalidenstraße 112, 10115, Berlin, Germany*
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[4]*Departamento de Oceanografia, CICESE. Ensenada B.C., Mexico*
[5]*School of Fisheries, University of Washington. Seattle, WA*

Real-Time Tracking of Migrating Adult White Shark, *Carcharodon carcharias* from Guadalupe Island, Mexico

Despite recent advances in electronic tagging, real-time tracks of migrating great white sharks, *Carcharodon carcharias*, remain rare. Due to the difficulty and risk of deploying real-time satellite transmitters on live sharks, previous studies have only acquired data from juvenile white sharks. Here we report on the first real-time satellite tracking of a great white shark in the North Pacific Ocean. A 5.1 m total length adult female Carcharodon carcharias was tagged with a SPOT tag in Guadalupe Island, Baja California, Mexico on October 16, 2006. This shark was intermittently tracked for a total of 288 days and a grand total of 7,100 km. The shark remained in the vicinity of the tagging site, the NE coast of Guadalupe Island, for a few days after tagging. For the next three and a half months the shark moved between the east and west coasts of the island, but spent significantly more time off the north east coast. At the beginning of February, the shark moved suddenly and decisively away from Guadalupe Island to embark on a ca. 3,900 km westward migration. This clear directional movement took the adult female on an arc-shaped route to a distinct region northeast of the Hawaiian Islands. During the next four months the shark roamed an adjacent ca. 600 km-wide region following a bee-line pattern. The latter area of the North Pacific to where this adult female moved is previously unknown as a focal area for this species. Time at temperature data were intermittently transmitted by the tag and are also presented.

Russell W. **Bradford** and Barry D. Bruce
CSIRO Marine and Atmospheric Research, GPO Box 1538. Hobart Tasmania 7008. Australia

Identifying juvenile white shark behaviour from electronic tag data

Juvenile white sharks (1.7 - 2.8 m) are seasonally resident in the Port Stephens area of central NSW from mid August to early January, one of only two known nursery areas for the species in eastern Australia. Sharks reside at a second known nursery area in coastal waters of eastern Bass Strait, 900 km south, from January to April and return north during the May-June period. When resident at the Port Stephens site, sharks are highly visible in the near-shore surf zone where interactions with recreational fishers and beach users are frequently reported. We used data from the deployment of 20 SPLASH and 7 PSAT tags (6 of which were returned for full data download) on 25 JWS to identify the spatial extent of the Port Stephens aggregation and their behaviour. The Port Stephens nursery area is highly focussed along a 60 km stretch of coastline with sharks occupying areas from the near-shore surf zone out to adjacent waters of the mid-shelf in depths of 120 - 140 m waters, 10-15 km from shore and covering a geographic area of approximately 1000 sq km. We used Mean First Depth (MFD) analyses to define behavioural signatures and provide an indication of habitat use when sharks were resident at, and when travelling between, the Port Stephens and the Bass Strait nursery areas. These analyses identify a suite of behaviours for sharks ranging from shallow water bottom oriented swimming behaviour consistent with surf zone habitat use, diel behaviour in deeper waters, continental slope (400-600 m) and open ocean excursions with dives to nearly 1000 m. By coupling high resolution archival data from returned PSAT tags with data of lower spatial resolution, provided by SPLASH tags, we are gaining a unique insight into the behaviour and distribution of juvenile white sharks in eastern Australia.

Barry D. **Bruce**
CSIRO Marine and Atmospheric Research, GPO Box 1538. Hobart Tasmania 7008. Australia

Research and conservation efforts on white sharks in Australian waters - current status and future directions

Research on white sharks in Australian waters dates back to the 1970s. However it was the advent of protection in the mid-late 1990s that stimulated research activities linked to the implementation of a National Recovery Plan. Considerable research has since been undertaken focussed on movement patterns and habitat use by adult and sub-adult white sharks and more recently, juveniles. White sharks are widely but not evenly distributed in Australian waters and movements have been documented across their Australasian range from South Australia to Exmouth in NW Western Australia as well as east to central Qld and across the Tasman Sea to New Zealand. Seasonal site fidelity, directed long distance travel between a limited number of areas of short term occupancy (days-weeks), coupled with nearshore/continental shelf/slope movements are common features of white spatial ecology in Australian waters. All life history stages (≥ 1.75 m) have been observed to travel over 1000s of km including offshore excursions and dives up to 1000 m. Although offshore excursions have included crossings of the Tasman Sea, there has thus far been no evidence of the similar extensive use of open ocean habitats observed in areas of the eastern Pacific. Despite this growing body of information, there remain significant gaps in knowledge of why certain areas are favoured as occupancy sites by different life history stages, the geographic extent of such areas and the timing of ontogenetic changes in the species habitat requirements. Population sub-structuring between eastern and western Australia cannot be ruled out and this may have implications for the impact of regional and site specific threats on the overall population. There is still no estimate of the total size of the Australian white shark population and no adequate measure of population trend or status. This lack of information makes it difficult to assess the effectiveness of actions to conserve the species. Recent developments in long-life electronic tag technologies, the deployment of coastal observing infrastructure and increasing opportunities in genetic research as well as integration of multiple data sets offer considerable scope for assessing population status. This paper reviews research and conservation efforts on white sharks in Australian waters and identifies directions for the future.

Barry D. **Bruce** and Russell W. Bradford
CSIRO Marine and Atmospheric Research, GPO Box 1538. Hobart Tasmania 7008. Australia

The potential for aerial surveys of juvenile white sharks in eastern Australia

Estimating trends in abundance for species such as white sharks remains a difficult task but one of paramount importance for assessing the efficacy of conservation actions directed towards the species. A number of studies are emerging using tag-resighting techniques (where tags are either applied or using natural marks) but there are few opportunities available for directly counting abundance. Aerial surveys have been used to estimate abundances of various marine animals, notably mammals, with applications on sharks generally limited to whale and basking sharks that spend considerable amounts of time at the surface in some areas. Juvenile white sharks (JWS) aggregate at two known nursery areas in eastern Australia and travel between these on a seasonal basis. Shark activity at one of the sites (Port Stephens, central New South Wales) is restricted to beach areas along a 60 km stretch of coast. Sharks at this site are regularly observed in the surf zone, within 100s of metres from shore, in water depths of 1-5 m. This behaviour makes them ideal candidates for aerial surveys. In October 2009, we trialled a series of flights over 100 km of coast in this region. Three flights registered 31 white sharks (30 juveniles) in the region at a mean rate of 3.2 sharks per 10 linear-coast kilometres of beach. Shark distribution based on flight observations matched the areas of near-shore shark activity based on satellite tracking data. This indicated that the aggregation footprint was captured by the satellite tracking and fell within the aerial survey zone. The restricted depth where sharks occurred, over a featureless sand substrate, provided a high degree of confidence in sighting sharks present. This site offers unique opportunities for estimating abundances of JWS and comparing these over time as an index of population status.

Aaron **Carlisle**[1], Sora Kim[2], Salvador Jorgensen[1] and Barbara Block[1]
[1] *Hopkins Marine Station of Stanford University, 120 Oceanview Blvd, Pacific Grove, CA 93950*
[2] *University of California Santa Cruz, 1156 High Street, Santa Cruz, CA 95064*

Using stable isotopes to understand the trophic ecology of eastern Pacific white sharks

White sharks (*Carcharodon carcharias*) are wide-ranging apex predators that utilize a large geographic area of the eastern Pacific Ocean. While they are primarily distributed along the coast during the fall and winter, they exhibit a regular offshore migration to oceanic habitats during the spring and summer. Although there are several theories regarding the function of this offshore migration, the purpose of this migration remains unclear. Because tissues integrate the isotopic signature of prey items over relatively long periods of time, stable isotope analysis (SIA) can provide valuable information about recent trophic history of consumers. Applied to white sharks, SIA has the potential to help elucidate what sharks are doing during these offshore periods and improve our understanding of white shark trophic ecology. To date 36 individual white sharks have been biopsied during tagging operations being conducted by the Tagging of Pacific Pelagics program (TOPP) at South Farallon Island and Pt. Reyes in central California. Biopsies include two clearly differentiated tissues: subdermal tissue and underlying white muscle. Amino acid and histological analysis is being conducted to determine the composition of the subdermal layer. Analysis is ongoing, but preliminary data indicate that values of $\delta^{15}N$ and $\delta^{13}C$ in the subdermal layer are significantly enriched relative to white muscle. Carbon and nitrogen values in subdermal tissue are similar to those reported for organisms found in coastal California while white muscle values are similar to those reported for organisms found in the offshore environments of Hawaii and the Central Pacific. This suggests that subdermal tissue reflects an onshore signal while white muscle has a slower turnover rate and reflects an offshore signal. Our preliminary results indicate that SIA can be used to help us understand white shark foraging during these offshore periods and improve our overall understanding of white shark trophic ecology.

Castro, Jose I.
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The maximum authenticated size of the white shark

The maximum size of the white shark is often given as 6.4 m (21 ft) based on a specimen from Cojímar, Cuba taken around 1943. The measurement comes from Bigelow and Schroeder (1948), who had received it as a personal communication from Luis Howell-Rivero from Havana, Cuba. This measurement appears to be anecdotal. Randall (1987) analyzed the data on vertebrae from the Cojímar shark, and determined that a vertebra of such size would belong to a 5-m shark. New photographs of the fabled Cojímar shark obtained from persons present at the shark's landing also cast doubt on the reported size. A handwritten note on the back of one photograph reads (translated from Spanish) that the "monster" weighed 7,125 lb., its liver weighed 1005 lb., and it measured 19.5 feet, thus two feet less than the Howell-Rivero length. The weights are the same as those given by Guitart and Milera (1974). The Randall analysis, these photographs, and the lack of specimens between the Cojímar shark and the next largest authenticated specimens do cast doubt on Howell-Rivero's measurement. A similar exaggeration occurred with a tiger shark reported by Howell-Rivero to Bigelow and Schroeder (1948: 269). The largest white shark believed to have been measured reliably is a 6-m specimen from Ledge Point, Western Australia caught on 22 March1984. The jaws of this specimen are currently in Gordon Hubbell's collection in Gainesville, Florida. As Randall (1987: 168) said: "Undoubtedly Carcharodon carcharias exceeds 6.1 m in length, but as yet there is no authenticated record of such a size."

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A first estimate of white shark, *Carcharodon carcharias*, abundance off central California using photo-identity marking

The catastrophic decline of apex predators such as large sharks in the global oceans underscores the need for careful assessment and monitoring of the remaining populations. Three genetically distinct populations of white sharks, *Carcharodon carcharias*, have recently been described in Australia/New Zealand, South Africa and the northeastern Pacific. Abundance estimates for Australian and South African populations suffer from low precision because of low recapture rates from conventional tagging. There is no abundance estimate in the northeastern Pacific, which is mostly comprised of aggregation sites in central California and Guadalupe Island, Mexico. We used photo identification of dorsal fins in a sequential Bayesian mark-recapture algorithm aimed at assessing white shark abundance off central California. We collected 321 photographs identifying 131 unique individuals. The model abundance off central California is estimated to be 251 individuals ([197,360] 2.5% and 97.5% quantile), an order of magnitude smaller than populations of other large marine and terrestrial predators currently protected internationally. This model quantifies the abundance with as much as a 90% increase in precision over previous methods used at other locations. Our methods can be readily expanded to include juvenile and young of the year sharks and sharks from other locations, over extended time-series, to monitor the status, population trends and protection needs of these globally distributed predators.

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Ecology of the Great White Shark, *Carcharodon carcharias*, in New Caledonia (South Pacific)

In spite of its evident presence, at least seasonally, no specific study was ever conducted in New Caledonia about the ecology of the Great White Shark, *Carcharodon carcharias*. Thirteen occurences were validated between 1971 and the end of 2008, mainly relying on sightings and catches by fishermen, and visual identifications by divers. In 50% of the cases, the animals' length was assessed as inferior to 4 meters. For the first time in New Caleodnia, a fatal attack on human was attributed (after analysis of the data) to a Great White Shark in October 2007. This large shark seems to be present in Caledonian waters mainly during winter time, between May and November. Its presence could be linked to the Humpback Whales, that come and stay in New Caledonian waters for mating and giving birth around the same period. However, some of the sightings and a recent fatal attack on a young surfer on the Western coast of the mainland in March 2009, suggests (if the species identification is confirmed again) that the seasonal slot should be significantly extended, probably suggesting a presence all year long. A tagging programme in New Caledonia is planned, in collaboration with New Zealander and Australian researchers, that should provide critical informations at a regional scale for improving and insuring the suitable management of this speCIes.

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The International Trade in Great White Shark Teeth, and Implications for CITES Implementation and Conservation

The teeth of the great white shark, *Carcharodon carcharias*, have a high monetary value, much more so than other shark species. There is an international market for individual teeth and very large specimens may sell for more than $1000 US each. Hence, there is ample incentive for their trade. At the thirteenth meeting of the Conference of the Parties of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) in October 2004, the Parties voted to include C. carcharias on Appendix II of the Convention. As a result, any subsequent legal international trade in this species (including any parts and pieces such as teeth) has required the issuance of CITES export and (where applicable) re-export permits. However, a review of the UNEP-WCMC CITES Trade Database found that only four shipments of a total of 33 *C. carcharias teeth* had been recorded for the years 2005-2007 (inclusive). Yet on any given day there are typically a greater number of teeth offered for sale and worldwide shipping on a single US based Internet auction site. A review of Internet sites indicates that C. carcharias teeth are readily available for sale and are being traded internationally without CITES permits. The volume of teeth offered for sale suggests that the conservation benefits of the CITES listing of C. carcharias may be compromised and steps need to be taken to improve compliance with and enforcement of the Convention.

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Seasonal distribution of white sharks in the western North Atlantic Ocean

Despite recent advances in field research on white sharks (*Carcharodon carcharias*) in several regions around the world, opportunistic capture and sighting records remain the primary source of information on this species in the North Atlantic Ocean. This is due to their sparse distribution and the apparent absence of discrete coastal aggregation sites in this hemisphere. Few studies have attempted quantitative analyses of available data to describe seasonal distribution, population structure, habitat use, and relative abundance. This study builds upon previously published data combined with recent unpublished records and presents a synthesis of over 550 confirmed white shark records compiled over a 210-year period (1800-2009). This is the largest white shark dataset yet compiled for the western North Atlantic. Descriptive statistics and GIS analyses were employed to quantify the seasonal distribution of various sub-components of the population. White sharks range widely along the Atlantic coast of North America, from Newfoundland to the Gulf of Mexico and Caribbean Sea (18-51 °N latitude). All size classes (total length range: 1.2-6.4 m) were present in continental shelf waters in every month of the year, occurring over a temperature range of 11-28 °C. Median latitude of white shark occurrence varied seasonally, with sharks moving to higher latitudes during the summer months. Core areas of high shark density also varied seasonally, with high density between Massachusetts and New Jersey during summer, and off Florida's east coast during winter. In recent years, white sharks have been increasingly associated with marine mammal aggregation sites, providing new opportunities for focused study. White sharks are currently prohibited from commercial and recreational harvest in the region, but the level of bycatch in various fisheries remains uncertain. Although the frequency of white shark encounters has increased in recent years, the current status of white sharks in the western North Atlantic is unknown.

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A new life history hypothesis for northeastern Pacific white sharks

A review of studies focused on white sharks (*Carcharodon carcharias*) in the northeastern Pacific, together with new data have allowed for a revised regional hypothesis for the life history of this species. The understanding of this species reproductive seasonality was advanced through direct observations of adult males with seminal fluid running from calcified claspers. Current evidence suggests that white sharks in the northeastern Pacific begin their life in the nearshore, shallow waters of the Southern California Bight and Baja California. During their first winter they may migrate to the warmer waters of coastal Baja California. As the juveniles grow they gain the ability to remain in cooler water, exploiting deeper depths and migrating north of Point Conception. As they continue to grow, their diet changes from one dominated by fish and invertebrates, to one dominated by marine mammals. As white sharks approach maturity they begin annual (in the case of males) and bi-annual (in the case of females) migrations to between a distant Shared Offshore Foraging Area and adult aggregation sites, presumably for the purpose of mating. After an approximately 18 month gestation period, pregnant females return the southern California/Baja California nursery area to give birth between May and July, before then returning to an adult aggregation site.

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The potential use of non lethal techniques to assess the reproductive biology of the white shark, *Carcharodon carcharias*

Existing information on the reproductive biology of elasmobranchs is largely based on post-mortem gross examination of morphological changes in reproductive organs and accessory structures. For example, past studies have used structural modifications in male claspers and ovary weight in females, while others have utilized the gonadosomatic index (GSI) to help assess the reproductive biology in this group of fish. While this information has proven valuable in obtaining life history information, collecting pertinent data requires that specimens be sacrificed. The logistics of capturing and killing large sharks for data collection is already problematic, but it is complicated further if these elasmobranchs are classified as endangered or threatened. In recent years, circulating concentrations of plasma steroid hormones, such as 17-δestradiol (E_2) and testosterone (T), have been used with gross morphological changes to evaluate the events associated with reproductive cycles and sexual maturity in several elasmobranch species. The results from these studies indicate that the physiological and morphological processes central to elasmobranch reproductive biology are intimately associated with steroid hormones. Based on this information, we are using steroid hormone concentrations as biochemical markers to gauge both sexual maturity and the reproductive cycle of white sharks by non lethal means. That is, instead of sacrificing and dissecting white sharks in order to gauge their reproductive status, we can now simply take a blood sample to obtain the same information. The data provided from this study represents the first us of E_2, in females, and T, in males, as reproductive endpoints in this species.

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A first examination and description of the northeastern Pacific Shared Offshore Foraging Area (SOFA)

White sharks of the northeastern Pacific aggregate at specific sites along the North American west coast, near San Francisco, California and Guadalupe Island, Mexico. Shark migrations from from both of these sites have been analyzed using pop-up satellite tags and real-time tracking SPOT tags. Sharks from both of these areas have been shown to migrate to a similar offshore region spending up to five months in the middle of the Pacific Ocean in an area termed the Shared Offshore Foraging Area (SOFA). Horizontal track positions and vertical behavior data have been documented using pop-up satellite tags from both aggregation sites. Tracking data from SPOT tags from sharks from both aggregation sites show similar migration destinations for sharks from each region. Near real-time SPOT tag data was used to position a research vessel in the vicinity of white sharks so that an attempt could be made to describe this offshore habitat. Strip surveys were conducted to quantify marine birds, mammals and other life as the ship ventured through the SOFA. The abundance of life diminished as we tracked sharks further from shore, revealing a region nearly devoid of fish, birds and mammals, however, squid were abundant. This study is the first attempt to describe the SOFA habitat and potential white shark prey species.

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A review of research on the white shark, *Carcharodon carcharias* (Linnaeus), in southern Africa

Research on the white shark, *Carcharodon carcharias* (Linnaeus), in southern African waters has spanned more than 150 years. Peer-reviewed publications, supplemented by published workshop proceedings, postgraduate theses and selected books or book chapters, total nearly 70. The bulk of the output (52 publications) has been produced in the past two decades, with 37 publications since the turn of the century. Approximately one third of the output has included data or samples from animals caught in nets set to reduce the risk of shark bites at the tourist beaches of KwaZulu-Natal, South Africa, and another third has centred on animals associated with island-based colonies of Cape fur seals, *Arctocephalus pusillus pusillus* (Schreber), in the Western Cape. Research topics facilitated by access to specimens from the nets have included age and growth, stomach content analysis, morphology, genetics and parasitology. No adult females and very few mature males have been caught, however, so there has been little research on reproductive biology. A long-term time series of catch and effort data has enabled an assessment of population status, and a first attempt at a population estimate has been made using tag-recapture data. In the Western Cape, predator-prey interactions between white sharks and seals have been examined by means of visual observation and electronic tagging. Tracking technology and photographic identification have been used to describe fine scale and long range movements, as well as site fidelity. The development of ecotourism based on cage diving, with associated provisioning, has led to research into the potential for sharks to be conditioned and for there to be consequences either for local ecosystems or for human safety. Future research priorities include (i) the continued use of genetic techniques and tracking technology to further investigate movements and global population structure, (ii) investigation of the possibility that a nursery area may exist in Eastern Cape waters and (iii) use of photo identification databases to obtain population estimates of sharks visiting the islands.

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Are winter diving holidays to the tropics the norm for New Zealand great white sharks *(Carcharodon carcharias)*?

Between 2005 and 2009, 25 great white sharks were tagged with popup satellite tags around New Zealand, mainly at offshore island seal colonies. Nineteen of the tags have reported useful data, and four have been recovered, thus providing information on spatial distribution and migration routes. Most sharks performed major migrations of the order of 3,000 km to tropical islands in a broad arc north of New Zealand, or the Great Barrier Reef, Australia. New data from recent tag recoveries will be presented, and used to provide a picture of the large-scale spatial ecology of this species in the south-west Pacific Ocean.

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Beyond The Hype: opportunities & guidelines for effective outreach and education

One of the most important aspects of scientific research is the communication of research findings to broad audiences. In the case of organisms like the white shark, this is especially important – public interest is generally high, but misconceptions and fear often interfere with learning and ultimately with policy- and decision- making. Here we present guidelines for effective educational outreach that is grounded in educational research and learning theory – we argue that effective outreach programs are authentic, aligned, multidisciplinary, flexible, culturally relevant and communicative. We highlight examples that use white shark research to conduct place-based outreach – grounded in local issues, tied to products with real scientific use and linked to techniques, tools and strategies employed by research scientists. When constructed with these guidelines in mind, outreach efforts can be benefit both educators and scientists. We also share opportunities and entry points for outreach and scientist-educator partnerships in the Pacific, such as the National Marine Educator's Association's OCEANIA chapter, the Hawaii Institute of Marine Biology, the UH Sea Grant Center for Marine Science Education and the National Science Foundation funded Centers for Ocean Science Education Excellence.

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Captive Feeding and Growth of Young-of-the-Year White Sharks *(Carcharodon carcharias)* at the Monterey Bay Aquarium

The Monterey Bay Aquarium developed a program with the support of colleagues from Stanford University, California State University Long Beach and the Southern California Marine Institute to display young-of-the-year white sharks (*Carcharodon carcharias*), culminating in the display of five white sharks in the 3.8 million liter

Outer Bay exhibit between 2004 and 2009. The Outer Bay exhibit displays a variety of pelagic fishes including yellowfin tuna (*Thunnus albacares*), dolphinfish (*Coryphaena hippurus*), and scalloped hammerhead sharks (*Sphyrna lewini*) and is maintained at 20°C. Four of the white sharks fed consistently while on display (70—198 days), eating mostly king salmon (*Onchorhynchus tshawytscha*), Pacific mackerel (*Scomber japonica*) and sablefish (*Anoplopoma fimbria*) at a mean daily ration of 747 $\pm$ 46 grams or 1.62 $\pm$ 0.15 % body mass day^{-1} (mean $\pm$ SE). One shark did not feed regularly and was released after 11 days. Daily ration peaked between 3.1—3.5 % body mass day^{-1}, which is among the highest reported for any shark species. The captive white sharks grew in mass at a rate of 71.6 $\pm$ 8.2 kg yr^{-1} (mean $\pm$ SE) yielding a mean gross conversion of 27.1 $\pm$ 3.8 %. They grew at a mean rate of 60.2 $\pm$ 13.7 cm yr^{-1}, approximately twice the growth rate estimated from a von Bertalanffy growth function for white sharks. A simplified bioenergetics model determined parameter estimates for consumption, growth and metabolism. This model determined that 26.8 $\pm$ 2.9 % (mean $\pm$ SE) of energy intake was invested into somatic growth and 46.2 $\pm$ 2.9 % of energy was consumed by metabolism. Young-of-the-year white sharks showed high growth capacity at optimal conditions in captivity; however, what the energetic demands are of white sharks in the wild remain unknown.

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Routine Metabolic Rate of Young-of-the-Year White Sharks *(Carcharodon carcharias)* transported to the Monterey Bay Aquarium

In 2002 the Monterey Bay Aquarium started a project to display young-of-the-year white sharks (*Carcharodon carcharias*) in the 3.8 million liter Outer Bay exhibit, and to conduct field research on the movement patterns of this highly active predator in the southern California bight. We describe a pelagic fish transport tank used to bring young-of-the-year white sharks to the Monterey Bay Aquarium between 2004 and 2009. It allowed the first direct measurements of oxygen consumption rates (MO_2) of free swimming white sharks during transports, ranging in duration between 5—7.5 hours. We recorded MO_2 data during five transports of four individual white sharks (137—161 cm total length (TL) and 22.6—36.2 kg body mass) at water temperature ranging between 15.2—17.9°C. The white sharks in this study showed physiological signs of quickly acclimating to the transport tank, as seen by the trend of decreasing MO_2 values over time. The routine metabolic rate (RMR) calculated from sixteen MO_2 measurements for all five sharks was 246 $\pm$ 13 mg O_2 kg^{-1} hr^{-1} (mean $\pm$ SE), which is among the highest reported for any shark species. In addition, this RMR provides valuable information used to model energy budgets and growth capacity for young-of-the-year white sharks.

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Application of Molecular Genetics for Conservation of the Great White Shark, *Carcharodon carcharias,* L. 1758

Although a species capable of long distance dispersal, *Carcharodon carcharias* exhibits philopatric behaviour, with females known to return to natal sites. However, intractability and rarity mean knowledge of its population dynamics remain limited. Direct observation, by tagging or photographic tracking, often lack, respectively, repeatability and objectivity, but advances in molecular genetics and genomic analysis provide indirect assessments of population connectivity, substructuring and dispersal. In this study, various genetic markers were successfully used to study the population structure of *C. carcharias*. Development of a new marker and the largest sample panel so far assembled for population genetic analyses has given the highest resolution of white shark population structure to-date. Concordance of direct (photographic identification) and indirect (molecular tools) methods of individual identification was assessed to validate proposed white shark local movements. Female mating strategies were investigated and set in the context of a global phylogeographic study of the white shark, utilizing 304 individuals caught worldwide. For the first time multiple paternity was documented in Lamniform species, conforming to the typical mating pattern of elasmobranchs studied to date. Finally, the presence of matrilineal clades among oceans was revealed, markers, supporting the hypothesis of female philopatry with gene flow mediated by both sexes. These findings are essential to the management of white shark populations, a species that has already been classified as 'Vulnerable' by the IUCN.

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Diving behaviour of New Zealand great white sharks *(Carcharodon carcharias)* recorded by popup archival tags

Between 2005 and 2009, 25 great white sharks were tagged with popup satellite tags around New Zealand. Nineteen of the tags have reported useful data, including four which have been recovered, thus providing high resolution archival information on depth and temperature. We analysed these datasets to characterise depth-related behaviour patterns while in the vicinity of seal colonies and while crossing open oceans to subtropical and tropical regions. The sharks exhibited considerable plasticity, staying mostly in shallow water less than 50 m deep while patrolling around seal colonies, but switching between surface swimming and deep diving while crossing oceans. During ocean migrations, all sharks dived periodically to depths greater than 500 m, down to a maximum of 1,000 m. New data from recent tag recoveries will be presented, and used to provide a picture of the vertical distribution of this species in the south-west Pacific Ocean.

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Skeletal Anatomy of *Carcharodon carcharias*

Many basic aspects of white shark anatomy are poorly known, and in many cases the limited information that is available is inaccurate. This includes the incomplete and often erroneous descriptions of the skeletal anatomy of this iconic species, which compromises attempts to resolve controversial issues regarding the interrelationships of white sharks with other lamnids and their fossil relatives. To address this situation, we recently completed a detailed study describing the white shark skeleton. Several wet-preserved skeletons were prepared from specimens in the collections of the Iziko South African Museum and KwaZulu-Natal Sharks Board (the use of carefully prepared wet-preserved material avoids the problems of distortion that occur when cartilaginous shark skeletons are kept as dried specimens, a factor that contributed to earlier inaccurate accounts). Distinctive features of white shark cranial and branchial anatomy include a blunt tripartite rostrum with a small rostral node, greatly enlarged nasal capsules, very large stapedial fenestra in the suborbital shelf, massive palatoquadrate and Meckel's cartilages with a "double" jaw joint that permits a shifting point of articulation, and a complex

branchial skeleton with the gills supported by prominently developed semicircular extrabranchial cartilages. Postcranially, the pectoral fins are massive and braced by large scapulocoracoid elements. The centra are strongly calcified, and show a transition from mono- to diplospondyly in the trunk region. Total vertebral counts range from ca. 170 to ca. 190, including very small centra that extend out to the dorsal tip of the strongly heterocercal caudal fin. Areas of particular skeletal robustness and structural reinforcement in these very large sharks are located at the bases of the pectoral fins and contiguous regions of the scapulocoracoids, along the caudal peduncle, and on the haemal spines associated with the more anterior caudal centra.

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First steps to understand the effect of ecotourism on the behavior, distribution and social interaction of white shark *(Carcharodon carcharias)* in the Northeast coast of Isla Guadalupe México

Guadalupe Island, in the Mexican Pacific, has become an important cage diving spot for observation of white sharks. This activity started since 2000 in the northeastern coast of the island, where touristic boats chum and use hand bait to attract the sharks close to the cages. However, this activities rise the concern of the local abalone fishermen, that fish by hookah diving and argument that there has been a change in shark behavior. In order to improve their management system and to solve this problem, the Guadalupe Island Biosphere Reserve started a research program to understand the potential effect of cage diving activities on white shark behavior, and to set the bases for following the white shark population that visits the reserve through time. We will present results from our preliminary search of a methodology of easy application, after trying land observations for studying behavior, and line transects, on sea stationary shark counts and photo identification for measuring the population. Also, results from fisherman interviews for understanding their interaction with the white shark, and their vision as a risk for their community.

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Conservation and Education Value of Having a White Shark on Exhibit

From 2002 to 2009, the Monterey Bay Aquarium (MBA), Monterey , California has embarked on an initiative to collect young of year white shark, *Carcharodon carcharias*, and place them on public display. To date, five white sharks have been successfully exhibited for a total of 575 days and collectively seen by over two and a half million people. This presentation will include information on the conservation and education value of having a charismatic top level predator on public display, the impact on aquarium visitors, impacts on attendance and value in terms of how this effort seeks to portray the white shark as an ambassador for the conservation of other oceanic species, including itself.

Adrian **Hewitt**
White Shark Projects

Population dynamics of juvenile and sub-adult Great white sharks around Dyer Island and its in-shore reefs

Seasonal occurrence, residency patterns and sex ratio of white sharks, *Carcharodon carcharias* were studied at two locations, Dyer Island and Jouberts Dam in Gansbaai, Western Cape, South Africa. Using digital photographs taken of their dorsal fins 303 white sharks were identified between April 2008 and November 2009, 160 (52.8 %) of which were subsequently re-sighted between one and 25 times. White sharks are found primarily in the surrounding waters of Dyer Island during the winter months, and transition inshore to a nearby shallow reef system, Jouberts Dam during the summer months. Male and females ranged between 1.5 to 4.0 m with the average size observed being larger in winter (2.7 m) than summer (2.3 m). Females were observed more frequently than males throughout the year, with a highly skewed ratio of females in summer (9:1 F:M). Conversely, male sightings peaked mid-winter (3:2 F:M), but were consistently low for the remainder of the year.

Five males and 1 individual of unknown sex (3.75 %) were re-sighted at the island the following winter season. Ten females, 1 male and 1 shark of unknown sex (7.5 %) were re-sighted inshore the following season. None of these individuals were re-sighted at the other grounds, being indicative of seasonal site fidelity. Fifty four (33.75 % total identified) sharks were identified at both locations 13 were male, 38 females and 3 of unknown sex (24, 70.4 and 5.6 % respectively). Four individuals were observed during all four seasons but not consistently throughout. One juvenile female was continuously re-sighted (20 times) for the longest consecutive period May to October 2009. The evidence presented here shows a much higher degree of site residency than previously documented for the area. The observed transient and semi-resident individuals infer a population of young of the year, adolescent and sub-adult white sharks. This suggests that Dyer Island and its associated inshore reef habitat are a potential nursery area for Carcharodon carcharias.

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Movement patterns of the white shark in Guadalupe Island, Mexico

Guadalupe Island is an important white shark (*Carcharodon carcharias*) aggregation site in the eastern Pacific. The present thesis focuses on the behavior of white sharks at Guadalupe Island and provides information that will help in the development of future management and conservation plans for this species in Mexico. Acoustic telemetry techniques provided preliminary data on the movement patterns and swimming depths of juveniles and adults white sharks ranging from 1.8 m TL to 5 m TL. These data have revealed the following: 1) horizontal movements are similar in the juveniles staying close to shore during all day; 2) adults move farther during the day while searching for prey and stay close to shore at night; 3) the rate of movement of adults exceeded that of the juveniles due to their capacity to maintain an optimal physiological operating temperature; 4) there is an exponential relation between total length and habitat range possibly related to their size and the distribution of their prey; 5) depth and temperature records indicate a number of interesting behaviors, including a strong diurnal pattern, and behavioral differences across age classes, possibly due to different thermoregulation capabilities and prey preferences; 6) ten potential preys were identified for juveniles and four for the adults; 7) the first well-documented record of ten predation events by white sharks on pinnipeds on the island; 8) we recorded the maximum difference between the internal temperature of the stomach of a white shark and the surrounding water (16 °C) in the world, confirming the hypothesis of thermoregulation in this species; 9) temporary social structures are formed with a dominance hierarchy based on size during predation events; similarly sized sharks can dissuade the competitor from eating its prey through displays (exaggerated swimming style) before a direct attack.

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Quantitative analysis of the diet and trophic ecology of the white shark (*Carcharodon carcharias*) in South African waters

Understanding the diet and trophic ecology of keystone predators is critical for effective ecosystem management, but analysis is generally restricted by their low abundance, threatened status and hence available data. To address this knowledge gap for the white shark (*Carcharodon carcharias*), we examined archived stomach content data (n = 225) and undertook stable isotope analysis ($\delta^{5}N$ and $\delta^{3}C$) of muscle and liver tissue (n = 21) of sharks sampled from KwaZulu-Natal, South Africa. Summarised stomach content (SC) data indentified an ontogenetic transition in diet; an increase in mammalian prey and a corresponding decrease in teleost and elasmobranch prey with increasing size class of shark. Multivariate analysis of SC data by size was marginally significant highlighting a high degree of overlap of the principal prey groups across the four size classes. Trophic level calculated from SC data ranged from 4.5 ± 0.3 (size class 1) to 4.8 ± 0.1 (size class 4) with no significant trend

observed. In contrast, there was a significant increase in $\delta^{15}N$ of muscle tissue with size of shark, with a non-linear regression providing the best fit to the data. Sharks >200 cm PCL had highly variable $\delta^{15}N$ muscle tissue values (min. 14.7, max. 16.8) indicating multiple feeding strategies. For $\delta^{13}C$, most animals >150 cm PCL were within the latitudinal range of values expected for the coastal waters of Cape Town to KwaZulu-Natal. The two smallest animals (124 and 134 cm PCL) had depleted $\delta^{13}C$ values relative to all other sharks except the largest individual. As these sharks are likely newborn animals this may suggest interference of the maternal signature and may indicate that large individuals switch forage base. Liver tissue $\delta^{15}N$ and $\delta^{13}C$ values of individual sharks will be compared to corresponding muscle tissue to examine seasonal shifts in diet/forage base.

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Dorsal fin photo identification of white sharks: a new step-by-step process to enhance accuracy

White shark (Carcharodon carcharias) is an apex predator and therefore able to influence the structure of the entire ecosystems through direct and indirect effects. In South Africa, a major threat to this species is the lack of data on the population status of white sharks, particularly in its main centre of abundance – the southern coast. This renders it impossible to gauge the effectiveness of current protection and monitor and respond to new and existing threats

Long-term information on the population status and composition of this vulnerable species is restricted to the capture of sharks in the Natal Sharks Board east coast bather protection nets. A non-invasive alternative method of collecting long term data on the relative and absolute trends in population numbers and their composition is through photographic identification of white sharks. Analysis of mark-recapture data can be used to obtain ecological data such as abundance estimates, survival, recruitment and thus population growth rates over time.

Our study evaluated the persistence of various marks on the dorsal fins (pigmentation, scars, notches) and their size relative to dorsal fin height to determine the viability of using a multi-feature analysis of the dorsal fin to identify individual sharks. Subsequently we present (a) a five star photograph rating system and (b) a categorical presence - absence based filtering system to facilitate analysis and management of large databases.

Between 2001 and 2005, a total of 3315 photographs were taken of white shark dorsal fins. Implementing our rating system, a total of 1728 (52.1%) and 362 (10.9%) photographs gained four and five star ratings respectively and thus were deemed usable. Using these photographs, we determined the presence of white and black dorsal fin pigmentation patterns as the most persistent features, whilst dorsal fin notches were semi permanent, yet vulnerable to change slowly over time. Large deformities were acquired infrequently by a few individuals over time. Overall, marks varied in frequency, with white pigmentation existing 20% (LHS) and 21% (RHS) of fins, and black pigmentation on 29% (LHS) and 24% (RHS) of fins. Significant notches (greater than a 3:100 depth to dorsal fin height ratio) were identified on the top (17.2%), middle (13.8%) and bottom (13.8%) regions of fins trailing edge. Large deformities to the fin existed on 7% of fins. Using this combination of marks, changes in fins was able to be documented over time, thereby ensuring minimal sharks were lost from our catalogue. During the study 208 different
white sharks were identified within Mossel Bay.

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Dynamics of predator-prey strategies in white sharks and Cape fur seals at Mossel Bay, South Africa

Active and passive acoustic telemetry and direct observations were used to describe the predatory relationship between white sharks and Cape fur seals at Seal Island, Mossel Bay. White sharks patrol hunt for Cape fur seals traversing between Seal Island and offshore feeding grounds. Traversing seals dive when close to Seal Island to reduce encounter probability; other adopted strategies include grouping and increasing traversing frequency in the twilight period and possibly at night. Incoming seals form smaller groups and approach from diverse bearings, whereas outbound seals use more predictable pathways but reduce individual vulnerability by exiting in larger groups. White shark patrolling is concentrated close to the seaward side of the island where the probability of encountering traversing seals is the greatest. Ontogenetic shifts in shark behaviour were evident. White sharks over 325 cm TL displayed a near crepuscular hunting pattern, whilst sharks less than 276 cm did not display this diel patrolling pattern, spent less time patrolling Seal Island and patrolled a more general area. All successful attacks by actively tracked sharks occurred during twilight or early night, a previously non-described behavioural phenomenon. We suggest anthropogenic light pollution and/or bioluminance may create an environmental where sharks can utilise scotopic, or possibly mesopic, vision at night time to capture seals. Feeding frequency for a 420 cm female that was tracked for 345.8 hours was 0.277 seals·day^{-1}, whereas a 350 cm female did not consume seals during 110.1 hours of tracking. Successful attacks twice resulted in the larger shark ceasing to hunt seals in subsequent days, possibly indicating satiation.

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Migration and Philopatry of White Sharks in the North Eastern Pacific

White sharks (*Carcharodon carcharias*) have been identified for international protection, yet effective population assessments and management actions are hindered by lack of knowledge about the geographical extent and size of distinct populations. Reconciling migration patterns and gene flow to define the resolution of discrete population management units is a major challenge, and a vital conservation priority for threatened species such as white sharks. The Tagging of Pacific Pelagics (TOPP) research program has deployed 103 Satellite Archival Tags (PAT), 109 acoustic tags and analyzed 59 mtDNA sequences from white sharks in the central California region. The tags together reveal how eastern Pacific white sharks adhere to a highly predictable migratory cycle where individuals persistently return to the same network of coastal hotspots following distant oceanic migrations, and comprise a population genetically distinct from previously identified phylogenetic clades. We hypothesize that this strong homing behaviour has maintained the separation of a north-eastern Pacific population following a historical introduction from Australia/New Zealand migrants during the late Pleistocene. Concordance between contemporary movement and genetic divergence based on mitochondrial DNA demonstrates a demographically independent management unit not previously recognized. This population's fidelity to discrete and predictable locations offers clear population assessment, monitoring and management options.

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Towards Automated Visual Identification of Great Whites using Biometric Computer Vision

This paper presents an experimental computer vision system which aids the identification of individual Great Whites (*Carcharodon carcharias*) based on digital imagery. We propose a methodology that uses the jagged pattern of the rear (trailing) side of the first dorsal fin as a machine-recognizable biometric identifier for differentiating between individual sharks. The system takes as input high-quality, high-resolution images of a side view of the fin. Note that data of this kind can be routinely acquired during boat trips to the species' natural habitats. After applying histogram equalization to an input image, the software detects the fin area using

the Viola-Jones object recognition framework. The system provides an option to improve on this automated detection by manual, watershed-aided fin segmentation. Subsequently, Lowe's Scale-Invariant Feature Transform (SIFT) is applied to the fin segment yielding a set of biometrically significant, local visual features. These features are filtered using RANSAC and Geometric Histogramming before being matched iteratively against a database of known shark profiles stored as KD-Trees of SIFT descriptors. Ordering by application-tailored distance measures finally produces a ranked list of best matches between the shark in the input image and the entries of the database. Experiments on a small sample database of n=100 individuals were conducted in order to produce a preliminary benchmark that describes the system's performance. Results showed that in 86% of cases the system ranked the correct individual within the top ten of matches, whilst the exact individual could be pinpointed in 46% of cases. Acknowledging the need for further system improvements, we conclude that the experimental prototype presented constitutes a promising step towards a non-invasive biometric tool for an automatic photo identification of individual Great Whites in the field.

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Stable isotope analysis reveals specialists and generalists within California white sharks, 1936-2003

White sharks (*Carcharodon carcharias*) are top-level opportunistic predators capable of hunting marine mammals. To better understand the predatory behavior and movement patterns of white sharks, we must couple dietary and satellite tagging information. We focus on white shark diet using a biogeochemical method, stable isotope analysis. Various lines of evidence such as stomach contents, tooth morphology and coastal observations, suggest white sharks typically feed on pinnipeds off the California coast. However, the complete breadth of white shark diet is unknown. Stable isotope ratios of carbon ($^{13}C/^{12}C$) and nitrogen ($^{15}N/^{14}N$) elucidate feeding patterns in birds, mammals, bony fish, and are gaining use in shark ecology. Carbon isotopes vary at the base of the food web with primary productivity, onshore versus offshore location, and latitude. Nitrogen isotopes are strongly sorted by trophic level, with greater ^{15}N-enricment at higher trophic levels. First, we established vertebrae-to-diet stable isotope discrimination factors for leopard sharks during a controlled experiment. We then applied this information to interpret stable isotope data from 15 white sharks caught off the California coast from 1936 to 2003. White shark vertebrae record diet in concentrically accreted growth bands. The $\delta^{13}C$ and $\delta^{15}N$ values of organic matter extracted from these bands allow us to track a shark's diet over its lifetime. Our results illustrate that the California white shark population has a generalized feeding structure rather than an exclusive focus on pinnipeds. The white shark $\delta^{13}C$ and $\delta^{15}N$ values range widely (4‰ and 7‰, respectively). The data confirm that many individuals undergo an ontogenetic dietary shift, but the extent of this trophic switch varies among individuals. Additionally, isotopic patterns reveal individual specialists and generalists within the California white shark population. These dietary patterns persist even as pinniped populations increased after the passage of the Marine Mammal Protection Act in 1972.

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Crittercam reveals novel white shark behaviour

Crittercam is a non-invasive animal-borne video and data collection system that has successfully been used to study the foraging ecology, feeding behaviour and fine-scale habitat use of large sharks. It provides a rare opportunity to gather data on swimming depth, water temperature, and acceleration, while simultaneously collecting visual images from the shark's perspective of predatory and social behaviour. Between 2004 and

2009, 29 successful Crittercam deployments were made on 27 different white sharks at Seal Island, False Bay, South Africa. The cameras were temporarily attached to the first dorsal fin of male and female sharks ranging in size from 2.5 – 4.0 m. The systems were pre-programmed to release at specific times which varied with each deployment. Upon release the entire Crittercam system, including the fin clamp, released from the shark, floated to the surface and was located using a VHF tracking receiver and transmitter. Successful deployments ranged from 15 - 480 minutes, and a total of 63 hours of video and associated depth, temperature and acceleration data were collected. Sharks exhibited pronounced vertical swimming behaviour between the ocean bottom (25 m +) and surface around the seal colony; this behaviour became less pronounced away from colony, suggesting that it is associated with seal (prey) detection. Only eight brief (< 20 second) interactions were documented between conspecifics, leading to the hypothesis that white sharks display avoidance behaviour at the seal colony. Sharks investigated various animate and inanimate objects throughout the water column including kelp, fish, seals, jellyfish, boats, and debris. We present new investigatory and feeding behaviours, and conclude that white sharks appear to be more opportunistic predators than previously thought, even in the presence of a large 'preferred' prey source such as Cape fur seals.

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Shark Spotters: A pioneering shark safety programme in Cape Town, South Africa

In Cape Town, South Africa white sharks (*Carcharodon carcharias*) are responsible for the majority of bites on recreational water users with the number of bites increasing over recent years. Although relatively rare, shark bites that result in human injury or death threaten existing protective measures through the reluctance of the public to support shark conservation, the possible execution of culling programmes and illegal hunting. Furthermore, shark bites can negatively impact local business and tourism. A unique programme was adopted by Cape Town in 2004 with the aim of finding a balance between white shark conservation and recreational water user safety. This initiative, called Shark Spotters, employs 14 - 28 spotters at 5 - 10 of Cape Town's popular beaches (numbers are season dependent) throughout the year. The shark spotters scan coastal waters for sharks from an elevated platform during daylight hours, seven days a week. A protocol using four informational flags and a shark siren warn water users of the nearby presence of sharks. Upon hearing the warning, water users exit the ocean and wait until the shark spotters give the 'all clear' sign before returning to the water. This proactive measure reduces the risk of a shark bite and the associated negative impacts for both humans and sharks. Daily data is recorded on the number of sharks detected, shark behaviour, sea conditions and the number of water users. During the period November 2004 to June 2009, 530 shark sightings were recorded with the highest number in the southern hemisphere's summer months and at Muizenberg (297) and Fish Hoek (134) beaches. Limitations of the programme include the ability to detect sharks in poor water visibility, human error and operating hours. Despite these limitations the programme has proven to be an effective shark safety system at appropriate beaches. Additional advantages of the programme are job creation and skills development for previously disadvantaged South Africans, environmental education and awareness and data collection that contributes to the knowledge base of white shark coastal occurrence and behaviour.

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Protecting White Sharks in the Gulf of the Farallones National Marine Sanctuary

The Gulf of the Farallones National Marine Sanctuary (GFNMS) offshore San Francisco, California, USA protects the wildlife and habitats of one of the most diverse and bountiful marine environments in the world. White sharks depend on the rich sanctuary ecosystem, aggregating every fall in vicinity of the Farallon Islands to feed on pinnipeds and cetaceans. The high, seasonal concentration of white sharks has resulted in cage diving operations, other wildlife watching operations, filming operations, researchers, and general boaters vying for encounters with the sharks. In order to reduce disturbance to white sharks from interaction with humans, the

GFNMS promulgated regulations in 2009 prohibiting white shark attraction and limiting human approach of white sharks. In order to implement the new regulations, the GFNMS has initiated the White Shark Stewardship Project that includes: 1) Public and boater outreach, 2) Naturalist training, 3) Permitting, 4) School education programs, and 5) Monitoring. The goal of the White Shark Stewardship Project is to protect and conserve the white shark population that utilizes the sanctuary. Outcomes and lessons learned from the first year of implementation will be presented.

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Comparison of habitat utilization and environmental characteristics of white sharks around the Guadalupe Island and the offshore area in the Eastern Pacific

Seven pop-up satellite archival tags were recovered from white sharks tagged off Guadalupe Island, Mexico during the period of 2002-2006. These tags provide valuable high-resolution data of depth, temperature and light at 2-min intervals, allowing the characterization of shark behavior and movement in both the horizontal and vertical contexts. A recent study by Nasby-Lucas et al. (in revision) has detailed the sharks' behavior and environment in the shared offshore foraging area using a subset of this dataset. This talk will focus on the inshore area around the Guadalupe Island and provide a comparative discussion of the habitat and behavioral differences between inshore and offshore area. We will explore the impact of oxygen as a limiting physiological variable, especially when more and more inshore areas of the Eastern Pacific Ocean are shown to be blanketed by a widening layer of hypoxic water. The tag data in combination with auxiliary environmental variables will aid in understanding the different lifestyles of this enigmatic creature between distinct eco-regions. Lastly, we hope to investigate the feasibility of estimating chlorophyll concentration from the light data (Teo et al. 2009) around the Guadalupe Island for potential future field studies.

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Historic fishery interactions with white sharks in the Southern California Bight

The degree to which white sharks (*Carcharodon carcharias*) interact in southern California fisheries is unknown, despite their high public interest, economic value, and recent protection under state, federal, and international regulations. Data on white shark fishery interactions in southern California were mined from news reports, state and federal management agencies, fisher logbooks, and research institutions. Of the 248 records of reported white shark catch between 1936-2007, 73% were young of the year (YOY), followed by juveniles (11%) and adults (7%). YOY sharks were caught in nearshore waters (< 50 m depth) more often than adult sharks, which were mainly caught in offshore waters (> 50 m depth). In addition, the entangling net fisheries (drift gillnets and trammel nets) caught more white sharks (65%) than other fisheries (purse seines, trawls, hook and line; 13%), with a significant decline occurring after the closure of the nearshore gillnet fishery in 1994. Incidental catch rates of YOY and juvenile white sharks have increased since the California nearshore gillnet ban despite decreased effort. This suggests that the white shark population off California is increasing.

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Evaluation of trophic levels and feeding habitats of white sharks throughout ontogeny based on carbon and nitrogen stable isotope analysis of soft tissues

Studies indicate juvenile white sharks have distinct feeding habitats and dietary preferences from adults. Ontogenetic changes in their feeding habits can be related to size and habitat (inshore vs. offshore). To understand their ecological role throughout ontogeny, it is necessary to characterize their feeding habitats and trophic level as a function of size. The fractionation and mixing processes that underlie variations in the relative abundance of stable isotopes ($^{13}C/^{12}C$ and $^{15}N/^{14}N$) in natural systems allow us to estimate trophic level and discriminate among food webs that rely on different primary producers. We evaluated the isotopic composition (_^{13}C and _^{15}N) of blood, plasma and muscle in juvenile and adult (149.5-500 cm TL) white sharks sampled between June and November 2008 in the Mexican Pacific. Sharks were caught as by-catch in fishery camps in Baja California and by direct sampling of live animals off Guadalupe Island. To estimate the time integrated by the isotopic composition of each tissue (the rate of isotopic turnover) for white sharks of different sizes, we coupled literature-based growth rates with estimates of the relative contribution of metabolic turnover and biomass gain to isotopic turnover. We predict the tissues of juveniles should integrate dietary periods of months, while adult tissues may take years to reach isotopic equilibrium to a new diet. Blood and muscle from adults exhibited enrichment in ^{15}N relative to juveniles, suggesting feeding at a higher trophic level. We found a consistent difference in _^{15}N values between tissues with different estimated isotopic turnover rates, which we interpret as strong evidence of an increase in trophic level related to ontogeny. Enriched _^{13}C values in juvenile blood and muscle juveniles might indicate a benthic feeding habitat. Light plasma _^{13}C values compared to adult muscle could be related to recent migration from coastal waters to an offshore pelagic feeding ground.

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Assessing the usefulness of operator collected data for monitoring distribution and abundance of great white sharks

Globally there has been a decline in white shark populations due to many external factors. At the same time there is no global estimate of population size. The same holds true for the white shark population in South Africa. Studies have been conducted in the three main areas off the South African coastline where white sharks are concentrated, but a long time series of these data are required robust. Another avenue that can be explored is the use of operator collected data in these areas, to provide comparative trends or indices of distribution and abundance. This study compares distribution and abundance estimated from log book data provided by different operators from the same locations, to determine congruency between the data sets and their potential usefulness for monitoring

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An Analysis of South Africa's White Shark Cage Diving Industry based on log-book data

White shark cage diving (WSCD) ecotourism has been practiced in South Africa since 1991, though the industry only became regulated in 1999. Permit conditions include that trip data be recorded in log books and submitted to the Department of Environmental Affairs. Logbook data include a record of effort (time, duration and location of trips), numbers and source (local or international) of viewers and viewer experience (numbers of sharks observed). Using the logbook data, we investigate the growth of the industry in terms of tourist numbers and effort, and possible effects of this growth on viewing experience at the individual level.

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Depth-temperature preferences of the white shark (*Carcharodon carcharias*) in the Gulf of California, Mexico

Given the extent and importance of commercial fisheries in the Gulf of California (GOC), sporadic occurrence of the white shark *C. carcharias* incidentally caught is well known. However, little is known of the distribution, seasonality, movement patterns, or residence time of the white shark, *C. carcharias* in Gulf of California (GOC). A satellite PAT-Tag was attached to a ~280 cm total length (estimated, sex no available) white shark (C. carcharias) in the vicinity of San Pedro Nolasco Island (eastern central GOC) on November 7, 2004 and the tag was successfully released on April 30, 2005, 166 km southwards. Maximum recorded depths by month were Nov 232 m, Dec 92 m, Jan 104 m, Feb 180 m and March 244 m. The monthly temperature ranges logged by the tag were Nov 13.2-26.4ºC, Dec 18.2-22.7 ºC, Jan 16.2-21.3 ºC, Feb 13.9-20.2ºC and 13.2-22.3ºC during March. Tracking results indicate movements of the white shark into the Upper GOC.

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Microchemistry of white shark *(Carcharodon carcharias)* vertebrae: a potential tool to age individuals and examine life-history strategies?

The microchemistry of calcified structures, such as fish otoliths, is becoming an important tool to elucidate life-history characteristics of marine animals over ontogeny. The corpus calcareum of shark vertebrae grows incrementally preserving a seasonal microchemistry signal (summer /winter) over the lifetime of the animal, similar to fish otoliths. The microchemistry of white shark (*Carcharodon carcharias*) vertebrae may provide an additional ecological tool to understanding individual life history patterns. Here we present baseline elemental concentration profiles for a 5.5 year old male white shark (280.6 cm PCL) sampled from beach protection nets in KwaZulu-Natal, South Africa. We assessed the potential of both a scanning electron microscope (SEM) with energy dispersive X-ray spectroscopy (EDS) and laser ablation inductively coupled mass spectrometry (LA-ICP-MS). The variation of calcium (Ca) across seasonal bands (SEM with EDS) showed that calcification was higher in the opaque bands than in the translucent bands. This suggests that current age estimates from growth ring counts could be validated using Ca concentrations as an indicator of season. A suite of elements (ranging in concentration from a few ppb to 1000s of ppm) were quantified using LA-ICP-MS in continuous transects along the corpus calcareum. Barium levels varied across growth bands suggesting ontogenetic movement between nutrient rich upwelling areas and non-nutrient rich areas. A number of non-essential elements (e.g., uranium, lead) also varied across growth bands and may provide insights into ontogenetic migration and depth profiles of individual sharks. A number of essential elements (zinc, copper...) of the embryonic component of the vertebrae were enriched compared to after birth and increased with age to levels approaching those in the embryonic sections. These preliminary results show that a range of elements have suitable detection limits to aid in determining life-history patterns. Data for male and female white sharks of various sizes and ages will be presented.

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Heavy Metals and Trace Elements in Juvenile White Sharks *(Carcharodon carcharias)* from the Southern California Bight

Evidence suggests that the white shark (*Carcharodon carcharias*) in the eastern north Pacific utilize the southern California bight (SCB) as a nursery ground. Due to the proximity of highly urbanized locations a large amount of anthropogenic contaminants are introduced to the system, and juvenile white sharks are potentially exposed to relatively high levels of trace elements. To assess potential exposure levels, concentrations of 17 elements, including arsenic, selenium, cadmium and mercury were measured from the muscle and liver tissue of juvenile white sharks using inductively coupled plasma mass spectrometry (ICP-MS). Samples were collected from incidental mortalities of juvenile white sharks in the southern California gill net fishery. There was no significant difference in concentration of arsenic, selenium or cadmium between muscle and liver. Average mercury concentrations were significantly higher in muscle (2.74 ± 0.61 μg/g dry weight) than liver (0.42 ± 0.07 μg/g dry weight) ($p<0.05$). Dry weight concentrations of mercury and selenium are comparable to levels in adults of other shark species for which trace elements have been analyzed (*Galeocerdo cuvier; Prionace glauca*) and due to the young age of the sharks suggest a high level of dietary exposure or the potential for maternal offloading during reproduction.

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Use of photo identification to describe a white shark aggregation in the eastern Pacific (Guadalupe Island, Mexico)

White sharks, Carcharodon carcharias, aggregate annually around Guadalupe Island, Mexico. To document and monitor individual white sharks present at the island, a system of photo-identification (photo-ID) was developed which identifies individual sharks by their color patterns. Using this system we have compiled a catalog of 107 white sharks from Guadalupe Island between 2001 and 2008. 81% of the sharks in our catalog have been sighted in at least two years, with 52% of the males and 33% of the females being sighted at the island at least four years. We examined the every-other year residency patterns of sexually mature females and the presumed 18 month gestation cycle for white sharks and found that during this study period 69% of the females exhibited an every other year visitation pattern at least once with some sexually mature females that had previously returned on an every other year cycle being sighted in consecutive years, indicating that females may not get pregnant each year. This data in conjunction with satellite tag tracking data will help to answer important questions on the migratory patterns and life history of this threatened species.

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White shark, a protected species in Guadalupe Island Biosphere Reserve; management and monitoring

White shark, *Carcharodon carcharias*, is part of the pelagic-coastal and oceanic shark assemblages that regularly visit Guadalupe Island Biosphere Reserve, under the Comisión Nacional de Areas Naturales Protegidas (CONANP). In Mexico, white shark is included in the Mexican Official Regulation NOM-059-SEMARNAT-2001, for Environmental Protection of wild native Flora and fauna species of Mexico; and NOM-029-PESC-2007 for Responsible Fishing of Sharks and Rays, along with other shark and ray species vulnerable to overfishing, in a chapter for special protection. Both regulations protect and forbid capture, fishing and killing of any white shark in Mexican waters, because their life history (low reproductive potential, late sexual maturity, slow growth rate and an extended longevity) makes them an extremely vulnerable species. Other management, protection and conservation tools are the Creation Decrees and Management Programs for Natural Protected Areas, where all regulations, management, protection and conservation actions, surveillance and law enforcement are widely described. Internationally, this species also have been included in the Appendix II of CITES which include species not necessarily threatened with extinction but in which trade must be controlled in order to avoid use incompatible with their survival. Due to the presence and abundance of this species in the surrounding waters of the Reserve, and Mexican regulations for its protection and conservation, it has been necessary to implement protection and management measures especially in regards to all the activities that develop around it such as white shark cage diving, photography and filming, and research. These procedures mentioned above have been applied since the decree of the Reserve on 2005, and have been upgraded specifically using the information derived from the white shark observer program on board the tourist vessels that carry out these activities in the Reserve. This program has provided information in regards to white shark surface observations for four years.

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The Monterey Bay Aquarium's Juvenile White Shark Project: How weaving together partners from the scientific and fishing communities with research, conservation and education messaging created a wildly successful program

The Monterey Bay Aquarium has longstanding interests in the exhibit of white sharks, the education of the public regarding the species, its conservation, and in supporting research on this iconic animal. The aquarium's juvenile white shark program has three goals: to better understand the biology of these ocean predators through electronic tagging and sampling (science component); to determine, systematically whether it is possible to keep and display a young white shark (husbandry component); and to develop and disseminate educational and conservation messaging.

Through the combined support of our colleagues we learned more about the lives of juvenile white sharks in the wild in the eastern Pacific. We utilized SPOT and PAT satellite archival tags to observe geographic movements and diurnal temperature and depth preferences of juvenile white sharks. Our program worked closely with commercial fishermen (both in the U.S. and Mexico) and enabled us to understand the principal threats to the species in the eastern Pacific. The data collected by our research team directly supported the husbandry goal by revealing natural behaviors of "wild", "captive" (exhibit) and post "captive" (released) behaviors and habitat preferences, enabling us to maintain healthy white sharks at the aquarium.

The presence of a juvenile white shark in the aquarium's Outer Bay Waters exhibit is the result of the successful integration of our research and husbandry efforts.

Our program continues to explore new avenues into the biology of this ecologically important species, and how ongoing display will continue to improve and contribute to the public's understanding and perception of white sharks and our commitment to their conservation.

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The Oceanography of Pelagic Hot Spots for White Sharks in the Northeastern Pacific

White sharks (*Carcharodon carcharias*) of the northeastern Pacific are known to abandon coastal aggregation sites along the western margin of North America in late winter/early Spring and migrate to pelagic areas with vastly different environmental and ecological characteristics. Owing to its proximity and accessibility to research teams and their vessels, the California Current System (CCS) where white sharks reside in Fall and Winter is well studied; its dynamics, while complex, are far better understood than the remote oceanic habitats white sharks occupy at other times of the year. However, inference of ecological conditions likely to be favorable to white sharks in offshore pelagic habitats can be made from a variety of readily available oceanographic data products. The research presented here combines positional and behavioral characteristics of white sharks derived from electronic tags deployed in the CCS (but carried by sharks into offshore pelagic zones) with satellite and ship based synoptic and climatologic environmental data, such as chlorophyll, primary productivity, geostrophic currents, and others. Contemporaneous and antecedent environmental data are explored as proxies for the development of pelagic food webs significant enough to support (or, conversely, limit) the extended residence of active adult white sharks. Changes in the relative quality of oceanic habitats from the perspective of white sharks might initiate migration back towards coastal aggregations zones. Furthermore, the effects of long term shifts in oceanic conditions due to climate change may be considerable. As this research is ongoing, preliminary results that examine these concepts and the value to conservation and management of this approach will be presented.

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Seasonal sexual and size segregation of white sharks, *Carcharodon carcharias*, at the Neptune Islands, South Australia

The seasonal temporal sexual and size segregation of white sharks *Carcharodon carcharias*, at the Neptune Islands, South Australia, are described in relation to sea surface temperature. Under baited conditions, using chum to attract sharks to the vessel, the sex and size of white sharks were recorded over a three-year period from April 2001 to February 2004. Temporal size segregation was observed between sub-adult and mature sharks, with sex playing an important role in this segregation. There was a high degree of interannual variability in the data with the number of sub-adult males increasing and mature males decreasing over the three years of the study. An overall trend was observed for larger white sharks to be recorded in the winter/spring months (June to September) and smaller sharks in other months. Sea surface temperature appeared to be related to sexual and size segregation in this species. It was found to be negatively related to sub-adult and mature male numbers, while no significant relationships with temperature were found for females of either size grouping, although female abundance tended to cluster toward the higher temperature ranges (15.7 to 18.1° C). Since parturition is thought to occur in spring or summer, it is suggested that females are absent at this time and only return during prime feeding periods or times at which temperatures are elevated in order to increase developmental growth rates of their young. The significantly lower temperatures in 2003 may explain the absence of females in this year. Hypotheses related to temperature regulation in this species are put forward to explain the segregation observed.

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Juvenile white shark (*Carcharodon carcharias*) incidental catch in Baja California, México: on the way to the conservation of the specie

Juveniles white sharks are caught incidentally in Baja California peninsula's waters. These catches occur in the coastal zone by commercial and artisanal fishing, and most of the times are not documented. During 2002-2009, we have documented the incidental catch of 125 white sharks by visiting artisanal fishing camps, being on board of commercial vessels and reviewing log books of amicable fishing captains. White shark size range was 110 to 300 cm of total length, the majority being juveniles, and most of them were caught by artisanal bottom gillnet and commercial drift gill net, targeting bony fishes, during the May to October period. This captures of juveniles in the coast of Baja California indicates that this area might be serving as nursery area to the species during a specific stage of growth, and might be close to the breeding area. In Mexico, since 2001 the great white shark was considered as an endangered species, so it was included in the NOM-059 where it is protected from catching and marketing. Also, in 2007 the NOM-029 came into force and also prohibits the catch of the species. Under these norms, the white shark in Mexico is in safe; however, there is a certain amount of incidental catch of its juveniles, and further research is need to identify the impact of this incidental catch in the eastern Pacific white shark population.

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White shark predation and the implications of increasing pinniped populations in the western North Atlantic

Although the occurrence of the white shark, *Carcharodon carcharias*, is well documented in the North Atlantic, the species is relatively rare and much of what is known about its distribution and movements is based on historical sightings data. The advent of new tagging technology coupled with the existence of white shark "hotspots" near pinniped colonies have allowed researchers to investigate the ecology of this species in the Pacific and Indian Oceans, but its elusive nature in the Atlantic has hampered such studies in this region. However, the number of white shark-pinniped predation events has been rising off the coast of Massachusetts in recent years and, in particular, near Monomoy Island on Cape Cod, which hosts a large growing population of grey seals (Halichoerus grypus). While the perceived increase in shark predation on grey seals can be attributed to several factors, it is feasible that large white sharks, which were thought to primarily scavenge cetaceans in the Atlantic, are exhibiting a dietary shift in response to regional changes in seal abundance. Based on documented changes in white shark populations exhibited in other parts of the world, we anticipate that the number of white shark sightings and seal interactions will continue to rise off the coast of Massachusetts. In early September 2009, this prognosis came to fruition as more than a dozen white sharks ranging in length from 2.5-6.0 m were sighted in close proximity to the grey seal colony on Monomoy Island. This event sparked international media attention

and resulted in the closure of beaches. To examine site fidelity, seasonal movements, and habitat use, five of these sharks were tagged with pop-up satellite archival transmitting tags. This presentation explores the implications of increasing seal populations in this region and presents the first results of PSAT tagging efforts in the North Atlantic.

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White sharks and cephalopod prey: indicators of habitat use?

Stomach contents of white sharks – *(Carcharodon carcharias*) caught in bather-protection nets off the KwaZulu-Natal coast between 1983 and 2008 were examined for prey remains during routine biological necropsies. Of 220 white sharks with prey remains in their stomachs, cephalopod beaks, which are highly digestion-resistant, were found in 24. This sample was split according to predator size to investigate whether these prey remains could be used to test the hypothesis that smaller individuals (<2 m PCL, 2.5 m TL) preyed on coastal prey to a greater extent than larger individuals (>2 m PCL, > 2.5 m TL), which may be a proxy for habitat use. These preliminary results supported the hypothesis in that the cephalopods of small sharks were composed almost exclusively of coastal and benthic species typical of the continental shelf, such as Octopods, Sepiids and coastal pelagic prey such as Loliginid squids. Cephalopod prey of large sharks were dominated by mesopelagic and oceanic prey (e.g. *Ancistrocheirus and Octopoteuths* and Ommastrephidae), with few coastal prey. This suggests that larger sharks are using deeper offshore waters to a greater extent than smaller individuals, supporting tagging research on these apex predators. This study has shown the potential of stomach content analyses to provide an alternative approach to study habitat use by large predators, although we describe some potential pitfalls of such investigations.

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Estimating the white shark, *Carcharodon carcharias,* population in Guadalupe Island, Mexico, based on mark-recapture data

White sharks aggregate off Guadalupe Island during the summer and autumn months, after a long migration to the Shared Offshore Foraging Area (SOFA). The identification of individual white sharks using underwater photographs has demonstrated philopatry of individual sharks to the island. Using this method, over 100 individuals have been identified between 2001 and 2009, however, an estimation of the entire Guadalupe Island population is needed to help the management of this population by Mexican authorities. Using the historic photo-ID database, we develop an estimation based on mark-recapture analysis for the 2002 to 2008 period. We used standard technique as our first approximation, resulting in an estimate of population around 100 sharks. However, we are trying to improve this estimation taking into consideration the difference of the white shark behavior by sex and time of arrival to the island. Our approach is to use a likelihood model based on a binomial distribution in order to minimize bias and maximize the precision of the estimations. Final results will be presented at the symposium.

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Boat strike wound healing in *Carcharodon carcharias*

Wound healing of a 2.5 m female great white shark is documented from Dyer Island, a known hot spot for white shark aggregation off South Africa. The wound was caused by a boat strike and resulted in a severe wound estimated to measure 25 cm long, 30 cm wide and 15 cm deep on the dorsum above the gill slits in front of the first dorsal fin. It was most likely caused by the boat's propeller. The position and depth of the wound was calculated to be close to the vertebral column. The wound healing process was documented and the wound photographed over a two month period while the shark stayed in the vicinity of Dyer Island, where several white shark cage diving companies operate. The shark moved away from Dyer Island after two months but returned approximately a year later, where it was recognised by dorsal fin and underwater body patterning using the extensive photographic data base on this species. The wound had closed and although a scar remained, there was little evidence of long-term damage in that the animal swam and behaved in the normal manner for this species. The rapid healing of this severe wound is compared with other wounds commonly inflicted during intraspecific and interspecific interactions. Boat strikes and wound healing in other taxa is discussed to provide context to this incident.

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Movements and habitat use of juvenile white sharks released from the Monterey Bay Aquarium and tagged in the wild in the Southern California Bight

The white shark, *Carcharodon carcharias,* is under threat from human predation and our knowledge of its biology is limited. Until the project detail here, it had never been maintained in captivity in stable condition and successfully released to the wild. Five white sharks were captured in the Southern California Bight and maintained at the Monterey Bay Aquarium between 2004 and 2009. Durations in captivity ranged from 11 to 198 days. Following their release with satellite tracking devices, the sharks displayed active swimming and diving behaviors and traveled toward Southern California Bight and Baja California nursery grounds. The behavior, habitat preferences, and migratory patterns of all sharks were similar to those of wild white sharks tracked in the region, indicating that captivity did not prevent the animals from resuming normal behavioral patterns. Habitat use and migration in juveniles differed markedly from patterns observed in adult and subadult animals tagged at sites off the US and Mexico. This project represents the first successful husbandry and wild release of the white shark. It improved our understanding of the species' biology and yielded a large increase in public awareness and support for the conservation of sharks and the marine environment.

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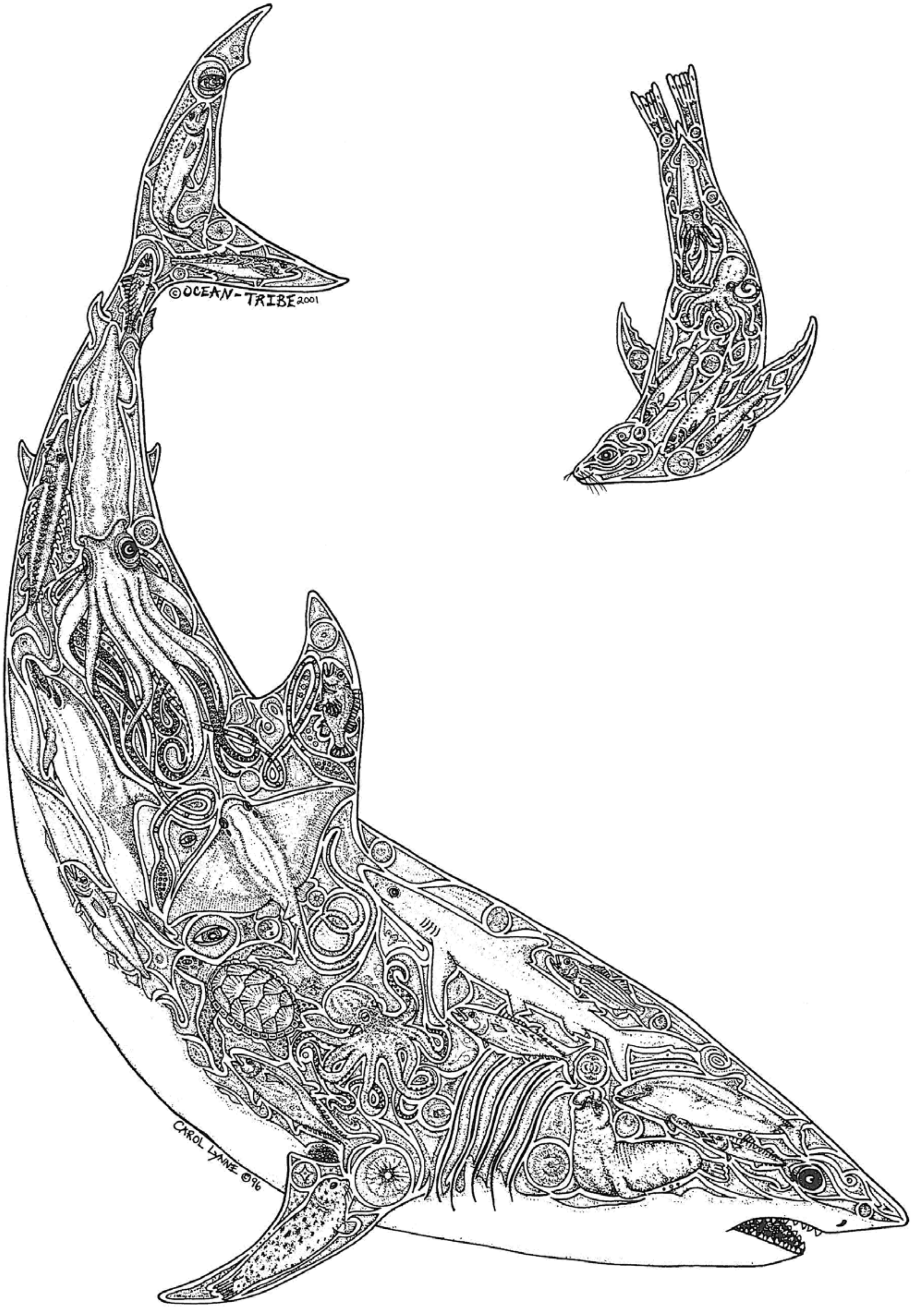
Using long-term catch and movement to determine preferred beach areas by juvenile white shark, *Carcharodon carcharias*, in eastern Australia

Shark control programs (SCPs) on Australia's east coast have recorded the capture of juvenile white sharks, *Carcharodon carcharias*, since their inception in the late 1930's in New South Wales and early 1960's in Queensland. Recent satellite tracking of juvenile *C. carcharias* (1.75 - 2.6 m total length), suggest that they are seasonally resident at a relatively small number of interconnected areas along the east coast of Australia and that they show directed and consistent periods of travel when transiting between these areas. Behaviour at these residency areas often included extended periods within the near-shore surf zone environment whereas travel between areas involves infrequent coastal visits. These differences in behaviour along the east coast suggest that the risk of interaction with SCPs and, ultimately, beach users differ significantly between beach areas. Such differences may also have ramifications for interpreting trends in SCP catches which provide one of the few long term data sets on the species in Australian waters. We examined catches of juvenile *C. carcharias* from 1993-2009

from both shark control programs and compared these to the movements of 13 satellite tracked sharks. Analyses indicated a concordance between beaches of higher catch and areas of site fidelity in tracked sharks, suggesting that data from these areas are more conducive to long term monitoring. Correlations between SCP catches and abiotic factors were also examined to test for cues that may influence the onshore movement of juvenile white sharks both at residency areas and over areas of transit. These data provide the basis for an in-depth investigation of beach habitat characteristics and factors that may influence inshore residency or in-transit beach visits by juvenile *C. carcharias*.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