

AES Abstracts Manaus, Brazil June 27 – June 30 from pdfs available on ASIH website. No guarantees for completeness. Symbols got mangled as I had to use MS Word as intermediate step to prepare this pdf. June 18, 2003 HFM.

AES Symposium: Elasmobranch Populations. Friday June 27, 1:30-5:00.

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Life history parameters of the Dusky Shark, *Carcharhinus obscurus*, revisited and their implications to estimates of population increase.

Numbers of dusky sharks, *Carcharhinus obscurus*, in the Western North Atlantic have drastically declined over the past twenty years. Several fishery-dependent and fishery-independent studies have recorded the decline of this slow growing, late maturing, long-lived species. It is imperative for the survival of this species that we develop accurate demographic and biological parameter estimates to ensure proper management. Data sets from the Virginia Institute of Marine Science (VIMS) fishery-independent shark survey, Commercial Shark Fishery Observer Program (CSFOP) fishery-dependent shark survey, and previously published data were analyzed to construct better estimates of gestation period, reproductive periodicity, fecundity, offspring size frequencies, and other biological parameters. These estimates were then used in a stochastic stage-based demographic model to estimate intrinsic rate of population increase and elasticities for population stages.

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Comparison of elasticity patterns of elasmobranchs and mammals with review of vital parameters of lamnids

Vital parameters (age-at-first-reproduction, maximum-reproductive-age, age-specific fertilities, and age-specific mortalities) of lamnids were reviewed. Despite progress in the last 20 years, vital parameters of lamnids and many other elasmobranchs are not sufficiently well-known to produce reasonably accurate population growth rates (λ). Luckily, the elasticity pattern of a species that is needed to evaluate management proposals is fairly robust and does not require an accurate λ . Furthermore, there is no need to calculate λ because the elasticity pattern is determined by age-at-first-reproduction (a) and generation time (A_{bar}) alone, with gestation period (GP) providing a refinement: $E(\text{fertility}) = E_1 = 1/A_{bar}$; $E(\text{juvenile survival}) = E_2 = (a - GP) E_1$; $E(\text{adult survival}) = E_3 = 1 - E_2 = (A_{bar} - a + GP) E_1$. These are lower-level elasticities of the vital parameters as they appear in a life history table and E_2 includes survival to age one. Therefore, they do not sum to one but are easily normalized. The exclusion of survival to age one from E_2 distorts the elasticity pattern, in particular for species with low age-at-first reproduction. A_{bar} is usually not known. However, using an A_{bar} estimate based on the mean A_{bar}/a ratio of 60 elasmobranchs (1.31, coefficient of variation 9.3%, range 1.1-1.8) provided promising results. The elasticity pattern of elasmobranchs as a function of age-at-first reproduction indicated that E_2 is largest for all elasmobranchs if $a > 1$ yr (valid for most if not all elasmobranchs). Accordingly, protection of juveniles will provide the most effective measure to reverse population declines if that has been observed for an elasmobranch species. The mean A_{bar}/a ratio of 50 mammals (2.44, coefficient of variation 33.5%, range 1.2-5.0) is larger and more variable compared to that of elasmobranchs and, accordingly, the elasticity pattern is more complicated.

CARLSON, JOHN K. *NOAA/National Marine Fisheries Service, Southeast Fisheries Science Center, 3500 Delwood Beach Rd., Panama City, FL, 32408, USA*

Can ecosystem models be used to assess the impacts of fishing on shark populations?

Apex predators, like sharks, in marine ecosystems may play a key role in determining food web structure. The exploitation of sharks by fisheries could therefore have large effects on ecosystems by

selectively harvesting apex predators. A multispecies ecosystem model using the Ecopath/Ecosim software was developed for the southeast United States and Gulf of Mexico. Models incorporated time series estimates of biomass, fishing mortality, and bycatch rates were used to evaluate the relative contributions of fishing on shark populations and ecosystem dynamics. Preliminary evidence suggests that direct harvesting of sharks by longline fisheries had insignificant trophic impacts. Recreational harvests on bull sharks caused a slight increase in juvenile shark populations but had little effect on other components of the ecosystem. However, increases in the bycatch of juvenile sharks and other species by shrimp trawls caused profound effects on food webs. Various management scenarios such as closed areas and marine protected areas were also investigated.

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Bioenergetics modeling of the cownose ray, *Rhinoptera bonasus*, in the northern Gulf of Mexico

We used two bioenergetics-based models to examine the relationship between somatic growth and reproduction in the cownose ray, *Rhinoptera bonasus*. Both models simulated the daily dynamics of an individual over its lifetime. One model was a modified version of the classical bioenergetics model, and represents how ingested energy is partitioned among egestion, respiration, excretion, and reproductive products. Prey availability affected ingestion, and all processes were size- and temperature-dependent. The second model, under development, used dynamic optimization to investigate the life history implications of how energy is partitioned between somatic growth and reproduction. Both models assumed mortality rate decreased with cownose ray disc width. Specific laboratory experiments were performed to estimate key parameters of both models. The models were then used to simulate how variation in temperature, prey availability, and reproductive strategies affected the life time growth and pup production of cownose ray in Gulf of Mexico waters. Preliminary results showed that the success of the low-fecundity, low-growth life history strategy of cownose ray is especially susceptible to changes in environmental conditions and mortality rates.

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Relative abundance index for pelagic sharks from the lower Gulf of California: exploratory analysis using a D-distribution approach

The lower Gulf of California (GOC) is a key passing area for shark migration toward the interior of the GOC, the west coast of Baja California Peninsula, the Gulf of Tehuantepec, and Revillagigedo Archipelago. Time series from 1986-1999 derived from longline vessels operation were used to estimate cpue (sharks/100-hooks) for *Alopias pelagicus*, *Carcharhinus falciformis* and *Prionace glauca*, using a D-distribution approach. The D-distribution is useful for estimating the mean and variance when catch per set data exhibit a skewed distribution, including zero and large catches, an inherent behavior of marine animal data. The pelagic thresher shark showed two abrupt declines: from 5.12 in 1986 to 2.12 in 1990, followed by an abrupt decline to 1.65 in 1998 after reaching a peak of 6.51 in 1992-93. The cpue trend for silky shark showed a subtle decrease from 2.1 in 1986 to 1.0 in 1996, after stabilizing at about 1.2 from 1992 to 1995. In 1999, both pelagic thresher shark and silky shark showed an increment in cpue to 4.26 and 2.0, respectively. In contrast, the blue shark showed a slight positive tendency with a maximum of 2.6 in 1998. The convenience and limitations of the method applied to fishery data and factors affecting the estimation are discussed.

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Coming-of-age of shark stock assessment: decision analysis using a Bayesian age-and sex-structured model incorporating multiple fleets and spatial dynamics, and applied to the sandbar shark fishery of the U.S.

The assessment and management of sharks and rays lagged behind that of teleost species for decades. But recent worldwide concern over the conservation and management of elasmobranchs has followed mostly-unchecked increases in their exploitation in the face of stock depletion. Methods for the stock assessment of sharks have thus received renewed attention and have improved substantially over the last ten years. We present here a sophisticated state-of-the-art stock assessment model applied to the US Atlantic Coast sandbar shark (*Carcharhinus plumbeus*) fishery. This is an age- and sex-structured, fleet-disaggregated model that simulates the dynamics of the shark population and the fisheries, taking into account specific characteristics of shark biology. The simulated population is assumed to occupy two areas (the area in the U.S. EEZ and the Mexican part of the Gulf of Mexico) and to have age- and sex-specific movement between them. Bayesian statistical methods are applied to fit the model to the data and deal with the uncertainty in model parameters and assumptions. The model is used to investigate the effects of different assumptions for spatial/temporal distribution of fish on predictions of shark abundance and yield. Taking into account these assumptions, we apply a decision analysis to evaluate the potential consequences of different management measures on future stock size and catches.

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Estimates of sharks represented in the global shark fin trade and assessment of sustainability

The burgeoning and largely unregulated trade in shark fins is believed to represent one of the most serious threats to shark populations worldwide. Given the deficiencies in global shark fin production and trade statistics, quantitative studies of the world's major market for fins in Hong Kong were undertaken to better understand the quantity and species composition of sharks represented. Approximately 29% of daily merchant association auction records were obtained for an 18-month period spanning October 1999 to March 2001. Chinese trade names for fins contained on the sheets were mapped to taxonomic nomenclature using molecular genetic techniques. Bayesian statistical modelling and data-filling methods were implemented in WinBUGS to address the missing records and derive estimates of the total traded weight of fins for each shark species. The model was then expanded to convert fin weights into estimates of the number and landed weight of shark species represented by the trade. These estimates for the Hong Kong auctions were then extrapolated to the entire global trade, using figures from national customs databases. Comparison of landed weight estimates from the trade to the total shark capture production reported to the Food and Agriculture Organization (FAO), allows inferences regarding the accuracy of FAO figures and the degree of utilization of captured sharks in the fin trade. A simple evaluation of the sustainability of existing fin trade demands on shark populations will be presented based on a Schaefer model for blue sharks (*Prionace glauca*).

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Determination of reproductive parameters of chondrichthyan animals for population assessment

Determination of the annual birth rate of a population of chondrichthyan animals requires two mathematical relationships. One expresses the proportion of the female population in maternal condition as a function of size or age of animal, and the other expresses fecundity as a function of maternal size or age. Incorrect application in demographic analysis or in fishery stock assessment of size- or age-at-maturity ogives or of size- or age-at-pregnancy ogives, instead of size- or age-at-maternity ogives, often causes

marked over-estimation of birth rate. Explicit definitions of maturity, pregnancy, and maternity are compared. Logistic regression methods are presented for determination of appropriate parameters and for statistically testing for spatial and temporal effects on these parameters. Various methods for determining male length-at-maturity are evaluated. Spatial and temporal differences in reproductive parameters are illustrated by *Mustelus antarcticus*, *Galeorhinus galeus*, *Pristiophorus cirratus*, and *Callorhinchus milii* in southern Australia from samples collected during three separate periods (1973–76, 1986–87, and 1998–01). The hypothesis for the phenomenon of apparent change in size-at-maternity (and size-at-maturity) caused by gillnet length-selective fishing mortality is favoured to explain observed increases in length-at-maternity (and length-at-maturity) following periods of intensive fishing.

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Estimation of population parameters for the blue shark (*Prionace glauca*) in the North Atlantic from mark-recapture analysis

Blue sharks are an important part of the by-catch in international tuna and swordfish fisheries in the North Atlantic. The multifleet logbooks available with fishery data are not considered to be complete given the large number of incidental captures, variation in release status (alive vs. dead) and unreported captures over time. Thus these data are not suitable for stock assessment and population modeling. Furthermore, stock assessment analysis of a highly migratory species such as the blue shark is difficult at best. The complex sexual and life-stage segregation patterns of the population in the North Atlantic make the modeling process even more difficult. Alternative methods are needed to deal with the problem. We use the tag-recapture database (1962-2001) of the National Marine Fisheries Service (NMFS) Cooperative Shark Tagging Program (CSTP) to derive population parameters for the blue shark in the North Atlantic. Our 6 approach is based upon the use of GIS software for data management, mapping and spatial analysis. Estimates of survival by life-stage and sex are also being developed relative to both spatial and temporal patterns. The potential use of these parameters in future population modeling studies is discussed.

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A metapopulation model for spiny dogfish (*Squalus acanthias*) in the Northeast Pacific

The spiny dogfish is the most abundant shark species in the Northeast Pacific and occurs primarily in coastal waters from Mexico to Alaska. Tagging studies have shown both coastwide and trans-pacific migrations. A transboundary fishery in British Columbia and Washington State has had strong variation in effort over its 130 year history, with a peak in 1944 which has not been matched since. The primary stock assessment of spiny dogfish in Northeast Pacific was based upon a demographic model which relied on ageing techniques, since revised, and did not incorporate indices of abundance. A more recent multispecies spatial model which used Canadian trawl CPUE found evidence of depletions in some parts of British Columbia. Indices of abundance in all areas are highly uncertain, but trawl surveys in the Puget Sound indicate reduced numbers while adjacent, coastal surveys indicate a relatively stable population size. The migrations between these areas with differing population trends suggest the modeling of spiny dogfish as a metapopulation. This paper describes a metapopulation model built to incorporate the many varied and patchy sources of data on spiny dogfish in the Northeast Pacific. We use it to evaluate hypotheses regarding stock structure and rates of mixing between areas, as well as abundance and population trends within each area. This is the first attempt to estimate the changes in abundance of this species over either the history of commercial exploitation or the greater part of its range in the Northeast Pacific.

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Investigating the population dynamics of elasmobranchs: past, present, and future

Population dynamics attempt to describe changes in the cohort-specific abundance of a population in space and time as a result of ecological and genetic processes. Three basic vital rates (birth, growth, and death) and the demographic processes of emigration and immigration, under the effect of various sources of stochasticity, ultimately determine population abundance and fate. Thus, an ideal population dynamics model should capture the interaction of vital rates and demographic processes with all sources of variability. However, the reality for elasmobranch population modeling is quite different. Our knowledge of basic vital rates and demographic processes is still fragmentary for most species, let alone our grasp on the spatial distribution of populations, stock-recruitment dynamics and the effect of most sources of stochasticity on elasmobranch populations. However, considerable progress has been made in the last decade alone. The population modeling approaches applied to elasmobranchs are reviewed and models classified according to their structure (biomass or cohort based), type, cohort type considered, and treatment of time and uncertainty. One main conclusion that emerges is that there may be greater predictive return from investing in increased data collection and quality rather than model sophistication.

AES Life History/Ecology I Saturday June 28, 8:00-12:00.

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Aspects of the life history and population structure of the diamond stingray, *Dasyatis dipterura*

Dasyatis dipterura (Jordan and Gilbert 1880; often inappropriately referred to as *D. brevis*) inhabits shallow, coastal waters from southern California to Peru, including the Galapagos and Hawaiian Islands. Although *D. dipterura* is a common component of artisanal elasmobranch fisheries and trawl fishery bycatch throughout western Mexico, very little is known of the life history of this stingray. Biological information was obtained from 1,119 fishery-derived specimens from the Magdalena Bay Lagoon Complex, Baja California Sur, Mexico. Sampling was conducted during 1998-2000 in four fishing camps. The sex ratio at the primary study site, Puerto Viejo, was 2.32:1 in favor of males in the 1998-99 landings (450 male:194 female; $c_{2,0.05,1} = 101.76$). Specimen disc widths (DW) ranged from 25-89 cm, with females reaching greater sizes than males. Our largest recorded male measured 60 cm DW. Based on examination of reproductive tracts and clasper length-DW relationships in males, size-at-first-maturity was determined to be 45 and 57 cm DW for males and females, respectively. The average DW of females observed in the fishery was 52.1 cm, indicating that the majority of females landed in the fishery were immature. Growth characteristics were estimated by a detailed examination of banding patterns present in thin-sectioned vertebral centra. Age estimates were obtained from 358 specimens (160 male, 198 female). The maximum age, based on vertebral band counts, was 29.165 for males and 28 for females. Age-at-first maturity was determined to be 6-8 for males and 8-12 for females. Gompertz, logistic, and von Bertalanffy growth models were fit to the age-at-DW/weight data for the sexes combined and separately. The annual nature of band deposition was supported through centrum edge and marginal increment analyses. Von Bertalanffy growth parameters, empirical longevity, and mortality calculations will be presented and compared to published values obtained for other elasmobranchs.

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Aspects of the biology of Goblin sharks collected from the Tokyo Submarine Canyon, Japan

The goblin shark, *Mitsukurina owstoni*, is a large, rare species from deep water that is distinguished from all other sharks by the combination of its flat, bladelike, elongated snout, very long-cusped teeth, and long caudal fin that lacks a ventral lobe. Sixty-five males (817-2085 mm TL) and 56 females (928-1961 mm TL) were examined for morphometric growth patterns, distribution, stomach contents and reproductive condition. The specimens were collected via bottom gill nets along a steep slope of the Tokyo Submarine Canyon (100-350 m depth). A bottom gill net fishery in the steep slope areas of the Canyon began relatively recently, and thus provided many specimens of *M. owstoni* for the present study. The allometric size-on-size equation $Y=aX_b$ was used to determine morphometric growth patterns, positive allometry, negative allometry, and isometry. Goblin sharks were abundant between December and April at around 250 m depth. No specimen examined was sexually mature, including the largest male (2085 mm TL) and female (1961 mm TL) specimens examined. Stomachs from 121 specimens were analyzed; of these, 43 stomachs (35.5%) were empty. Prey items included teleost fishes, squids, decapods, isopods and digested food. Teleost fishes consisting of Macrouridae sp. and Stomiidae spp., and decapods consisting of *Pasiphaea sinensis* and *Sergia* sp. were the only identifiable prey in the stomachs of *M. owstoni* examined. The stomach contents in this study suggest

that *M. owstoni* consumed, in order of importance, teleost fishes.

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Some aspects of fisheries biology of the silky shark, *Carcharhinus falciformis*, in Taiwanese waters

A total of 469 specimens (213 females and 256 males) collected from August 2000 to January 2002 at Nanfanao fish market, northeastern Taiwan was used to examine the age ad growth, reproduction, and feeding biology of the silky shark, *Carcharhinus falciformis*, in the waters off Taiwan. The age and growth was determined by annulus counts of caudal vertebra and 11 and 105 14 annuli were counted for females and males, respectively. The monthly changes of marginal increment indicated that translucent and opaque zones on vertebral centra were formed once per year between November and January. The parameters of von Bertalanffy growth equation (VBGE) were estimated as follows: $L_{inf}=358\text{cm TL}$, $K=0.072/\text{yr}$, $t_0=-3.05$ for females; $L_{inf}=326\text{cm TL}$, $K=0.091/\text{yr}$, $t_0=-2.48$ for males. The length at birth was estimated to be 63-75cm TL. Sex ratio of embryos was estimated to be 1:1. Females and males mature at 201-220cm and 208cm TL, which correspond to 8.2-10.2 yrs and 8.7 yrs, respectively. Stomach content is comparatively low and scombers and cephalopods were the dominant food items for this species.

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Age and growth determination of a deep-sea squaloid shark, *Centrophorus cf. uyato*, from the Cayman Trench, W.I.

Age determination is an effort to define one of several life-history parameters required to estimate the population dynamics of *Centrophorus cf. uyato*. Deep-sea commercial fisheries have been established in areas of the world where other *Centrophorus* populations are located. Understanding the population dynamics of this species will provide some of the data required to help prevent over exploitation should a deep-sea commercial fishery establish in this area. Over the two-year period between August 2000 and March 2002, 54 specimens were captured (7 males and 47 females) from depths of 250-913 m. Age was determined from cross-sectioned dorsal fin spines. Growth curves were constructed and size and age at maturity determined for all readable samples.

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Age and growth of the shortfin mako, *Isurus oxyrinchus*, from Baja California Sur, Mexico

The shortfin mako shark, *Isurus oxyrinchus*, is one of the most important species in the commercial and recreational fishery in Mexico. However, little is known about the biology and fishery of this species. The age and growth data is necessary to design an effective fishery management. Age and growth rate of shortfin mako were estimated using the number of growth bands on 93 vertebrae. The sharks were caught on the western coast of Baja California Sur, Mexico, during 2000 and 2003. The technique used for enhancing the contrast of the calcified bands was silver nitrate impregnation. The specimens ranged from 77 to 290 cm Total Length (TL). A significant linear relationship ($r_2 = 0.92$) was found between TL and the vertebrae radius, showing a proportional growth between the structure and body length. The oldest female in the sample was 25 years at 290 cm TL, and the oldest male was 12 years at 208 cm TL. Bands on vertebrae and TL data were used to describe the shortfin mako pattern growth using the von Bertalanffy model. Preliminary estimates of curve parameter with sexes combined were: asymptotic length = 359 cm TL, $K = 0.05$, $t_0 = -4.96$ years. Results suggests that shortfin mako shark has a slow growth that combined with other life-history traits, such as a low fecundity and a delayed reproduction, makes this species susceptible to overfishing.

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Age, growth and maturation of the finetooth shark, *Carcharhinus isodon*, in southeastern U.S. waters: a preliminary report

The life history of finetooth sharks, *Carcharhinus isodon*, in the coastal waters off South Carolina was studied by determining age, growth and size at maturity. Finetooth sharks were collected from the near shore and estuarine waters of South Carolina from April 2002 through April 2003. Cervical vertebrae were extracted from 111 finetooth sharks (49 males and 62 females), ranging in size from 380 to 1262mm FL, and were prepared for age analysis using standard techniques. The annual periodicity of growth band formation was partially verified using marginal increment analysis. Sex specific von Bertalanffy growth models were generated using observed and back calculated data. To determine size and age at which 50% of the population is mature a logistic model was fitted to binomial maturity data using least squares non-linear regression. Females were considered mature if gravid or contained eggs larger than 26 mm in diameter, or when the oviducal gland was 20 mm or greater. Calcification of claspers, ability of claspers to rotate anteriorly, ability of siphon sac to inflate, and the ability of rhipidion to open freely were noted to assess maturity in males. There is a growing body of evidence which indicates that regional differences in important life history characteristics exist within shark species. As a result, the future direction of this study is to compare the life histories of finetooth sharks in the western North Atlantic and the Gulf of Mexico.

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Age and growth in Scalloped hammerhead *Sphyrna lewini* juveniles caught in the Lower Gulf of California

The sharks have a late age growth, low fecundity, long gestation period and slow corporal growth. therefore, it is necessary to know basic biological aspects such as age and growth for a management of this fishery in Mexico. The results of age and growth rate from Scalloped hammerhead *Sphyrna lewini* are shown. The sampling area was the Gulf of California. One hundred seventy organisms (82 males and 88 females) have been collected and 116 vertebrae were obtained. The technique applied was resine and transversal cuts. Growth bands were observed with a video monitor VW 5490. In the length frequency analysis, a size range was found, which varies from 79 cm to 293 cm total length. There is no differences in the relationship vertebrae ratio-total length by sexes ($y=13.024+45.618x$ in males and $y=13.635+42.969x$ in females). The age of 62 organisms was determined (34 females and 28 males) and 54 showed opaque border and 8 hyaline border. The age groups were obtained were from 0 to 2, according to the hyaline borders number. The youngest juveniles with a zero age had 141 cm total length in the largest female and 116 cm in males. The group 1 with a total length of 116 cm in males and 151 in females. In the group 2, the largest male showed 112 cm and 162 cm in females. Each annulus represents 6 months, so the age for the first group was 6 months, the age for the second group was one and the age for the third group was one and a half year. _

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Behavior and ecology of the lemon shark (*Negaprion brevirostris*): a review

Despite the wide public attention given to sharks, surprisingly little is known of their behavior and ecology. One exception is the lemon shark, where over 40 years of laboratory and field research have revealed detailed information on many aspects of its life history and biology. Of the known sensory modalities possessed by sharks, the visual and auditory systems in the lemon shark have been well investigated. The morphology and electrophysiology of the 46 olfactory organ is described, while only scarce data are available for electroreception and the gustatory, magnetic, tactile, thermal and other senses. The intensively studied populations of lemon sharks in Florida Keys and Bimini Islands, Bahamas have provided detailed information on ecology, behavior and bioenergetics, including metabolic requirements, consumption rates, prey species, and conversion efficiencies in juvenile

sharks, which in combination with laboratory findings has allowed for the balancing of bioenergetics equations for both small and large juveniles. Spatial and temporal behavior has been investigated using ultrasonic telemetry in conjunction with measurements of environmental parameters. Life-history traits such as litter size, survival rate, age at maturity, and reproductive rates as well as recent information derived from molecular research on mating systems, population dynamics and population structure, are helping us understand the overall ecology and conservation status of the species. Such information is also important when assessing a population's resistance to environmental change or estimating recovery time after devastation of local populations. However, the ecology and behavior of adults remains an enigma and we believe that this is where future effort should be concentrated.

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Site fidelity and residency periods of white sharks at certain pinniped colonies in South Australia

White sharks (*Carcharodon carcharias*) are listed as vulnerable in Australia and are protected in all State and Commonwealth waters. While generally uncommon, there are areas (sites) where white sharks aggregate or where individuals frequently revisit. These include pinniped colonies that are prime feeding areas for adult and sub-adult animals and are likely important habitat for them. Despite the protective legislation, there is still little firm knowledge of how best to make such protection effective. Methods of reducing by-catch in commercial fisheries, identification of critical habitat, the potential effectiveness of protected areas and the effects of ecotourism viewing of white sharks around pinniped colonies are critical issues for the effective protection and management of white shark populations in Australian waters. There is a need to understand critical habitat areas, in terms of residency periods and site fidelity, in developing threat abatement plans for the species. Automated acoustic listening stations moored on the bottom at the North and South Neptune Islands, and Dangerous Reef were used to examine residency periods and site fidelity at these pinniped colonies. Twenty eight acoustically tagged sharks were monitored over a 500 day period. One of these sites is used regularly by ecotourist operators and we examined the effects of repeated chumming on white shark movements and behaviour.

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Site fidelity, residency times and activity space in grey nurse sharks in eastern Australia

Grey nurse sharks (*Carcharias taurus*) are considered to be critically endangered on the east coast of Australia with diver surveys suggesting their numbers are at all contemporary-time low levels. During certain seasons, grey nurse sharks aggregate at selected rocky reefs on the east coast of Queensland and New South Wales. At this time diver observations suggest the sharks spend much of their time around the caves and gutters of these aggregation sites. To afford greater protection to this species, more information is required on the species daily activity space around the aggregation sites. We used bottom-moored acoustic listening stations to monitor the residency periods of acoustically tagged sharks at sites in New South Wales and southern Queensland. We actively tracked sharks at the same sites to examine their diurnal movement patterns and swimming depth. The sharks tended to be more active at night, moving around the reef areas and in some cases they traveled over 1 km away from their daytime gutters. While swimming depths were generally within a few metres of the bottom, some individuals that moved away from their daytime sites swam for periods in mid-water some 15- 30 m above the bottom. The offshore excursions and mid-water activity may be related to hunting.

HUETER, ROBERT E.; * TYMINSKI, JOHN P.; CASTILLO-GENIZ, JOSÉ LEONARDO; MARQUEZ-FARIAS, J. FERNANDO (*REH, JPT*) *Mote Marine Laboratory, Center for Shark Research, 1600 Ken Thompson Parkway, Sarasota, FL, 34236, USA; (JLCG) Centro Regional de Investigación Pesquera de Ensenada, Carrt. Tijuana-Ensenada km 97.5, rumbo al muelle, El Sauzal de Rodriguez, Ensenada, Baja California, México, Apdo. Postal 1306; (JFMF)*

Instituto Nacional de la Pesca, SAGARPA, CRIP-Guaymas, Calle 20 Sur 605, Col. Cantera, CP 85400, Guaymas, Sonora, México

Investigations of a primary nursery area for the blacktip shark, *Carcharhinus limbatus*, in Quintana Roo, Mexico

The blacktip shark is one of the most important and heavily exploited elasmobranch species in the Mexican artisanal fishery of the Gulf of Mexico. A collaborative team of researchers from Mexico and the U.S. have undertaken a long-term tagging study of young blacktips in Laguna Yalahau, a semi-enclosed lagoon in the northeastern Yucatan peninsula. The project's biologists worked closely with local gillnet fishermen during the peak pupping season to find and capture the sharks for tagging. Since 1995, a total of 390 gillnet sets were made during 6 expeditions to the lagoon resulting in the tagging of 1,160 neonate and young-of-the-year blacktip sharks. Additionally, Peterson mark-recapture methodology was employed during the last two tagging expeditions which estimated that approximately 1,000 sharks were inhabiting the lagoon during our sampling. Of these tagged and released sharks, a total of 205 recaptures have been subsequently reported (17.7%) to us to date. If this high recapture rate is indicative of the fishing pressure on these first-year sharks, it raises interesting questions about the sustainability of fisheries targeting very young animals. These results will be discussed in light of the unique socio-economics and history of this Mexican lagoon.

HEUPEL, MICHELLE R. *Mote Marine Laboratory, Center for Shark Research, 1600 Ken Thompson Parkway, Sarasota, FL, 34236, USA*

Habitat use by three shark species in Charlotte Harbor, Florida

A series of 19 acoustic hydrophones were placed in lower Pine Island Sound, Charlotte Harbor, Florida, to monitor the movement patterns of three shark species. A total of 58 blacktip (*Carcharhinus limbatus*), bonnethead (*Sphyrna tiburo*) and bull (*Carcharhinus leucas*) sharks were collected within the study site and fitted with acoustic transmitters for long-term monitoring efforts. Twenty-six young-of-the-year blacktip sharks were monitored for periods of 1-157 days. Twenty-one bonnethead sharks varying in size and age were monitored for periods of 1-104 days. Eleven bull sharks (125-183 cm TL) were monitored for periods of 3-52 days. Examination of movement patterns of the three species was used to define any overlap or differences in habitat use. Blacktip and bonnethead sharks appeared to use smaller activity spaces and be more resident within the study region than bull sharks. Bull sharks moved into and out of the study region regularly and overlapped their habitat use with those areas used by blacktip and bonnethead sharks. Movement and behavior patterns observed for all three species will be discussed.

*** LOWE, CHRISTOPHER G.; WETHERBEE, BRADLEY M.; HOLLAND, KIM N.; MEYER, CARL G.** *(CGL) Dept. of Biological Sciences, California State University Long Beach, 1250 Bellflower Blvd., Long Beach, CA 90840, USA; (BMW) Dept. of Biological Sciences, Univ. of Rhode Island, 100 Flagg Rd, Kingston, RI 02881, USA; (KNH, CGM) Hawaii Institute of Marine Biology, PO Box 1346, Kaneohe, HI 96744, USA*

Movement patterns of tiger and Galapagos sharks around French Frigate Shoals, Hawaii

During the summer months, breeding activity results in an increased abundance of sea birds, sea turtles and Hawaiian monk seals in the Northwestern Hawaiian Islands. This may represent an increased source of prey for sharks. To correlate shark activity with seasonally increased prey density around French Frigate Shoals (FFS), Hawaii, acoustic listening stations were placed around six small islands throughout the atoll. Thirteen tiger sharks (*Galeocerdo cuvier*) and four Galapagos sharks (*Carcharhinus galapagensis*) were surgically fitted with long-life acoustic monitoring transmitters. Tiger sharks were detected at all islands throughout the atoll and exhibited a strong affinity for East Island (in the center of the atoll) during June and July. Peak detection frequency occurred between 05:30 and 10:00. This activity coincided with the early summer fledging period of blackfooted and Laysan albatross on East Island. Tiger sharks were first detected around the island approximately 1 month prior to fledging and their activity markedly decreased within days after the end of fledging. In winter months, tiger sharks were usually detected near islands in the northern part of the atoll, where peak detection frequency occurred between 21:00 and 03:00. Galapagos sharks were only detected at islands in the north edge of the atoll (particularly Trig Island), during summer and fall when a

majority of the monk seal pups are born. These islands provide seasonal increases in semi-terrestrial prey availability that appears to influence the behavior of these large sharks.

CLARK, TIMOTHY B. *University of Hawaii, Dept. Zoology, 2538 McCarthy Mall, Edmondson 152, Honolulu, HI 96822, USA*

Habitat use of the manta ray (*Manta birostris*) in Hawaii

The manta ray (*Manta birostris*) is coming under increasing pressure from fisheries, yet very little is known about their basic ecology. Manta rays were acoustically tracked along the leeward coast of the island of Hawaii to investigate their fine scale habitat use. Results of this on-going study will be discussed, along with possible relationships to the feeding ecology of the manta.

AES Symposium: Sawfish Saturday June 28, 1:30-4:00.

*** * FARIA, VICENTE V.; RYBURN, JULIE A.; LEANDRO, LUIS F.; NAYLOR, GAVIN J.** *Iowa State University, Dept. Zoology and Genetics, Ames, IA, 50011, USA*

Pristiform molecular phylogeny

The sawfishes, family Pristidae, is comprised of seven species: *Anoxypristis cuspidata*, *Pristis clavata*, *P. pectinata*, *P. perotteti*, *P. pristis*, *P. microdon* and *P. zijsron*. Uncertainty remains about systematic relationships for several of these species (e.g., the *P. perotteti/microdon/pristis* complex). In an effort to elucidate the evolutionary pattern of inter-relatedness for the sawfish group, we sequenced three mitochondrial genes (NADH-2, NADH-4, and Cytochrome B), and one nuclear gene, *rag1* for representatives of six sawfish species. A hypothesis of pristiform evolution is discussed in the context of molecular inference, morphology-based hypotheses, and geographical distribution of the group.

THORBURN, DEAN; PEVERILL, STERLING; * LAST, PETER; STEVENS, JOHN (PL, JS) *CSIRO Marine Research, PO Box 1538, Hobart 7001, Tasmania, Australia (DT) Centre for Fish and Fisheries Research, Murdoch University, Perth, Western Australia 6150, Australia (SP) Queensland Fisheries Service, Cairns, Queensland 4870, Australia*

2002 survey of sawfish populations in rivers and estuaries of northern Australia

The freshwater sawfish *Pristis microdon* is listed as vulnerable on the Commonwealth endangered species act, and there is considerable concern over the population status of the other species of sawfish in Australia. In 2002, a cooperative study between CSIRO Marine Research, Universities, Museums and fisheries agencies of Western Australia, the Northern Territory and Queensland surveyed river systems across the north of the continent. The sampling strategy was affected by the logistics of covering remote and often inaccessible country and was limited to the dry season between May and November. Fishing was carried out mainly using a combination of longlines and gillnets with different mesh sizes and we attempted to sample from upstream habitats such as isolated pools or billabongs down into the estuarine reaches and at times, the coastal margins. Deployment times of fishing gear were kept as short as practical to minimise mortalities. *Pristis microdon*, *P. clavata* and *Anoxypristis cuspidata* were caught during the survey. Other chondrichthyans caught in freshwater were *Carcharhinus leucas* and *Himantura chaophraya*. While no *Glyphis* spp. were caught during the survey, one specimen was captured in the Kimberley region by an associated project team. The greatest number of *P. microdon* captured in freshwater areas were taken in the Kimberley region of Western Australia.

*** CHARVET-ALMEIDA, PATRICIA; ALMEIDA, MAURICIO P.** (PC-A) *Universidade Federal da Paraiba, Dept. Sistemática e Ecologia, Lab. Ictiologia, Joao Pessoa, PB, Brazil; (MPA) Museu Paraense Emílio Goeldi, Coord. Zoologia, Setor Ictiologia, Belem, PA, Brazil*

Fishery, uses and conservation of freshwater stingrays (Chondrichthyes: Potamotrygonidae) in the Marajó Bay (Brazil)

Freshwater stingrays present unique but poorly known biological characteristics and belong to the only group of elasmobranchs completely restricted to freshwater habitats. The Marajó Bay is located in the mouth of the Amazon River and the present study observed aspects related to the fishery and uses of potamotrygonids in this region. Direct field observations, analysis of captures / landings and interviews with local habitants were carried out since 1999. Results indicated that there are 2 types of fisheries and several folklore uses attributed to freshwater stingrays. The captures take place in fishing areas that are predominantly located in islands and involve mainly the use of hook and line, nets and long lines. One of the fisheries is directed to newborn and juvenile specimens that are captured for ornamental purposes and at least 4 species are illegally being explored. These captures are very specific since the rays have to be kept alive / healthy and also depend directly on the market demand. The second type of fishery is practiced by artisanal fishermen and involves the capture of adult specimens as a food source. In this case, occasionally the freshwater stingrays are considered bycatch but in some localities there is a directed fishery. The use of potamotrygonids as edible fish is apparently uncommon in other parts of the Brazilian Amazon basin. Freshwater stingrays are locally also used for unusual / bizarre purposes that range from the preparation of folklore medicine to the use of stings in religious rituals. A quota system should be established in the State of Pará in order to try to

regulate the fishery for the ornamental trade and the artisanal fishery for consumption should be kept at sustainable levels. Fisheries and other uses of potamotrygonid species require the observation of specific conservation recommendations and adequate management.

* **BURGESS, GEORGE H.; CURTIS, TOBEY H.** *Florida Program for Shark Research, Florida Museum of Natural History, University of Florida, Gainesville, FL, 32611, USA*

Temporal reductions in the distribution and abundance of U.S. Atlantic sawfishes (*Pristis* spp.)

The smalltooth sawfish (*Pristis pectinata*) and the largetooth sawfish (*Pristis perotteti*) are tropical marine and estuarine animals that have the northwestern termini of their Atlantic ranges in the waters of the eastern United States. We present a chronology of over 400 verified records of *Pristis* spp. from the U.S. between the years 1782-2002. *P. perotteti* has always been very rare in U.S. waters, verification of its presence being limited to a total of 13 collections from Texas, Florida, and Alabama. *P. pectinata* was historically more widespread and common, with captures ranging from Texas to New York. Warm water temperatures, apparently higher than 15-18°C, are required by this species. As a result, records of *P. pectinata* from areas north of Florida have been largely limited to spring and summer periods when inshore water temperatures reach these temperatures. Southern Florida apparently has a year-round resident population, portions of which may have been involved in northward migrations in the spring and summer, and southerly return movements in the fall. There has been a marked contraction of range of *P. pectinata* along the Middle and South Atlantic bights over the past century, with only one sawfish being captured north of Florida since 1958. The fact that documented sawfish catch records have declined during this period despite tremendous increases in nearshore fishing effort underscores the demise of U.S. *Pristis* spp. populations.

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Conservation of smalltooth sawfish (*Pristis pectinata*) in U.S. waters

Sawfish are among the most endangered fish in the world and yet even the most developed countries have failed to make sawfish conservation a priority. As with other elasmobranchs, the low reproductive potential of sawfish leaves them exceptionally vulnerable to overexploitation and slow to recover from depletion. Scientists with keen awareness of these characteristics stand to influence and improve management of this and other elasmobranch species, yet this potential remains largely untapped. The United States has a stated commitment to precautionary shark management and has led international elasmobranch conservation efforts, including a 1997 proposal to restrict international trade in all sawfish species under the Convention on International Trade in Endangered Species (CITES). Domestic sawfish recovery, however, has not been a U.S. priority due in large part to lack of active, public pressure. The U.S. population of smalltooth sawfish (*Pristis pectinata*) is estimated to have declined by more than 95% and to require more than a century to rebuild. There are no federal sawfish regulations; existing Atlantic and Gulf state measures are inadequate to protect the population. The National Marine Fisheries Service (NMFS) has yet to take final action on a 1999 petition from The Ocean Conservancy to list smalltooth sawfish as Endangered under the U.S. Endangered Species Act, although the final decision is expected soon. This process involved a comprehensive scientific status review for the species and a resulting NMFS proposal for ESA listing that, if finalized, would prompt a recovery plan and may result in designation of sawfish critical habitat and protection of look alike species (*Pristis perotteti*). The history, latest developments and next steps related to U.S. sawfish recovery efforts will be reviewed with a view toward encouraging increased participation from scientists in the management process for this and other imperiled elasmobranch species.

* **SIMPFENDORFER, COLIN A.; WILEY, TONYA R.** *Mote Marine Laboratory, Center for Shark Research, 1600 Ken Thompson Parkway, Sarasota, FL, 34236, USA*

Nursery areas of the smalltooth sawfish in southwest Florida: implications for conservation

Fishing surveys, acoustic telemetry and public sightings data were used to identify and study nursery areas of the endangered smalltooth sawfish, *Pristis pectinata*. Public sighting data indicated that young juveniles (<90cm) occurred in many areas of Florida, with shallow protected estuarine habitats

identified as being the main habitat in which they occurred. Older juveniles (90 to 200 cm) occurred in a similar geographic range, but in a wider variety of habitats, to the young juveniles. Fishing surveys using longlines and beach seines captured at least 15 juveniles, including four very young animals (approximately 80 cm). Six juveniles were fitted with acoustic tags and tracked to gather data on habitat use and residency time. The smallest juveniles showed strong preference for very shallow mud banks and other similar habitats, possibly to avoid predators such as bull sharks (*Carcharhinus leucas*) that occur nearby. Older juveniles occur in less protected habitats, but retain a preference for shallow estuarine areas. Older juveniles displayed long residency times in relatively small areas. The implications of these results for conservation of the smalltooth sawfish population in US waters will be discussed.

CLARK, STEVE; VIOLETTA, GARY; * HENNINGSEN, ALAN; REISCHUCK, VAL; MOHAN, PETE; KEYON, JOE (SC) Sea World, Inc., Corporate Zoological Operations, 7007 Sea World Drive, Orlando, FL, 32821, USA; (GV) Sea World Adventure Park Florida, 7007 Sea World Drive, Orlando, FL, 32821, USA; (AH) Biological Programs, National Aquarium in Baltimore, Pier 3, 501 E. Pratt Street, Baltimore, MD, 21202, USA; (VR) Six Flags Worlds of Adventure, 1060 North Aurora Road, Aurora, OH, 44202, USA; (PM) 5802 Thorndale Drive, Kent, OH, 44240, USA; (JK) Sea World Adventure Park Texas, 10500 Sea World Drive, San Antonio, TX, 78523, USA

Growth in captive smalltooth sawfish, *Pristis pectinata*

All species of sawfish are listed as endangered to critically endangered on a global basis. The smalltooth sawfish, *Pristis pectinata*, is listed as critically endangered in the western Atlantic, and has been extirpated from much of its former range. Many details on the life history of this species are lacking in the literature. Although limited in scope, information from captive specimens may provide information on growth that is otherwise unavailable. We provide results on growth from nine captive specimens, four males and five females. These results indicate that smalltooth sawfish are indeed slow-growing and long-lived. Because of limitations in sample size and size range included, these results are only preliminary in nature. Missing are the critical upper and lower size ranges for this species. Data were fitted to the von Bertalanffy growth model, resulting in the following parameters: $k = 0.067 \text{ yr}^{-1}$, $t_0 = -2.57 \text{ yrs.}$, $L_{\text{inf}} = 385.4 \text{ cm}$, and $k = 0.034 \text{ yr}^{-1}$, $t_0 = -4.09 \text{ yrs.}$, $L_{\text{inf}} = 469.9 \text{ cm}$, for males and females respectively. Although the parameters predict a realistic size at birth of 60 cm TL, limitations of the dataset lead to an underestimate of L_{inf} , as smalltooth sawfish attain a maximum length of 600 cm, and have been reported to reach 760 cm TL. Additional institutional collaboration may add valuable data particularly for the small juveniles. These results provide insight into the shape of the growth curve despite the limitations imposed by captivity, sample size, and size range included. Additional information on morphometrics allowed us to estimate the weight length relation, $W(\text{kg}) = 4.0 \times 10^{-5} \text{ TL}(\text{cm})^{2.565}$, and the TL to FL relationship, $FL = 0.91 \text{ TL} + 9.62$.

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A window of insight into Australian sawfishes through collection and husbandry for public aquaria

The collection of a variety of Australian Sawfishes for Public Aquaria provides valuable data and insights into these animals that would otherwise be difficult to obtain. Due to individual species preferring different habitat types, collection occurs through a broad range of areas. This results in substantial distances being covered to obtain the full variety of species present in Australia. Through holding and husbandry, both in the field and in a specialized facility situation, species specific traits (e.g., temperature ranges), can be observed that may assist in better understanding Australian sawfishes. This understanding combined with the data collected from DNA sampling and long term morphometric studies of these animals whilst in captivity, can assist in the development of relevant long term management of Pristids in Australia.

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The popular image of sawfishes in Western society and its implications for conservation efforts

With sawfish populations under serious threat worldwide, there is a critical need to raise general awareness about these charismatic rays. Establishing widespread public concern about sawfishes will be necessary to achieve the monetary and political support needed for pristid conservation initiatives. However, before successful education programs can be developed, it must be understood how sawfishes are currently portrayed in popular culture. To achieve this objective, over 200 depictions of sawfishes were compiled from various media, including cartoons, literature, television, movies, art, and toys. Content analysis was performed on these depictions to identify dominant themes conveyed about sawfishes through the popular media. A second content analysis was then performed to document how sawfishes are depicted anatomically. Overall, analyses of these representations reveal a profound lack of knowledge about actual sawfishes, with highly erroneous notions of pristid anatomy, distribution, and behavior being advanced. While popular and symbolic portrayals of animals should not be expected to mirror zoological reality, an historical unfamiliarity with pristids, coupled with many pervasive misconceptions, has created a dramatic need for basic education about sawfishes in Western society. By educating the public about sawfish life history and dispelling these popular misconceptions, conservationists can generate the awareness, support, and empathy critical for conservation efforts.

Posters Saturday 28 June 16:00-18:00

*Presenter; CCarrier Best Student Poster Award Candidate

1 * FARIA, VICENTE V.; RYBURN, JULIE A.; LEANDRO, LUIS F.; WILEY, TONYA; SIMPFENDORFER, COLIN; NAYLOR, GAVIN J. (VVF, JAR, LFL, GJN) *Iowa State University, Dept. of Zoology and Genetics, Ames, IA, 50011, USA; (TW, CS) Center for Shark Research, Mote Marine Laboratory, 1600 Ken Thompson Parkway, Sarasota, FL, 34236, USA*

Florida sawfish (*Pristis pectinata*) genetic variability: preliminary analyses

Sawfish abundance has been dramatically reduced throughout the past century by fishing and habitat degradation. This lower abundance may reduce the genetic variability of these populations, compromising their capacity to respond to changing selection pressures and thereby increasing their vulnerability to extinction. In the present study we assess the genetic diversity of *P. pectinata* by sequencing the mitochondrial NADH-2 and D-loop regions from individuals sampled at four locations on the Florida coastline. Genetic variability inferences based on our results are discussed in the context of sawfish conservation.

2 *WILEY, TONYA R.; SIMPFENDORFER, COLIN A. UTILIZING PUBLIC SIGHTINGS DATA TO INVESTIGATE THE DISTRIBUTION AND HABITAT USE OF SMALLTOOTH SAWFISH

3C * SCHARFER, ALISSA K.; BURGESS, GEORGE H. *Florida Museum of Natural History, University of Florida, Gainesville, FL, 32611, USA*

Site fidelity and behavior of sharks at a long-term shark feeding dive site

To encourage tourism, commercial dive boat operators often offer shark feeding excursions and provide video footage of the dives to participating SCUBA divers. We conducted a longitudinal study of Caribbean reef shark (*Carcharhinus perezii*) feeding dives occurring at a single location off West End, The Bahamas. We analyzed video tapes of 36 dives recorded over the period of November 1992-September 2001. Data was collected on the following variables: water visibility; human activity; number of sharks and humans per dive; shark parasite load; gender of shark and male maturity; and frequency of feeding attempts, acts of antagonism, and yawning. Site fidelity of individual sharks was investigated by documenting, when possible, markings and scars on each shark. We found that the minimum number of female and male sharks per dive, as well as the parasite load on both sexes, increased temporally. Parasites were most frequently found near gill openings. Bumping of the camera, presumably an act of antagonism, was observed more often in females than in males. The frequency of shark feeding attempts was correlated with the technique of the human feeder. The number of divers and water visibility had no significant effect on the recorded shark behaviors. No seasonal trends concerning recorded behaviors, parasite load, or clasper size were observed. Females and males did not differ significantly in frequency of feeding attempts. Nine individual females and eight males were identified in more than a single dive. Although one individual had a hiatus of 4.5 years between sightings, most of the reappearing individuals were repetitively observed on site over periods of several months. Such site fidelity may be attributable to feeding-induced conditioning of the sharks.

4C * VAUDO, JEREMY J.; LOWE, CHRISTOPHER G.; MOSS, GREGORY J. *California State University, Long Beach, Department of Biological Sciences, Long Beach, CA, 90840, USA*

Round stingray (*Urolophus halleri*) movements and site fidelity at Seal Beach, California: a preliminary report

The round stingray, *Urolophus halleri*, is a common nearshore elasmobranch in southern California waters. At Seal Beach, CA, round stingrays are found in high densities and are responsible for over 300 injuries to humans each year. Little is known about their movement patterns or residence time in the Seal Beach area. Fine-scale movements and site fidelity of round stingrays at Seal Beach are being determined using acoustic telemetry techniques. To date, six rays were manually tracked continuously for up to 90.5 h, and 14 rays have been monitored using acoustic listening stations for up to 151 days.

Manually tracked rays exhibited limited daily movement, with a median rate of movement of 32.0 m h⁻¹, which varied with tidal stage. Rate of movement was lower rate during periods of incoming tide (19.2 m h⁻¹, median) than high slack tide (38.6 m h⁻¹, median) and outgoing tide (44.4 m h⁻¹, median). Acoustically monitored rays typically remained off Seal Beach for weeks after they were tagged. During this time, rays were most often recorded at the mouth of a local coastal river at the west end of Seal Beach. Six rays were observed to move to neighboring beaches between 1 and 2.5 km away during the 151-day period and five of these rays later returned to Seal Beach. So far, rays monitored have showed periods of little movement followed by movement out of the area.

5 MATOTT, MICHAEL; * LOWRY, DAYV; HUBER, DAN *University of South Florida, Dept. of Biology, Tampa, FL, 33620, USA*

Feeding kinematics and the role of jaw protrusion in the sandtiger shark *Carcharias taurus*

To date, most functional and morphological studies of shark feeding have concentrated on identifying correlations with the feeding mechanisms of coastal and benthic species relative to their ecology. Sandtiger sharks *Carcharias taurus* are the only species of the primarily pelagic order Lamniformes that have been successfully held in captivity, which provides an excellent opportunity to examine the feeding kinematics of a representative from this largely unstudied order. *Carcharias taurus* are thought to be opportunistic hunters feeding primarily on fish, squid, and small stingrays. Studying *C. taurus* allows us to compare and contrast its feeding mechanism and ecology with those of other elasmobranchs inhabiting coastal and benthic environments. Feeding events were filmed for five individuals using high-speed digital videography at SeaWorld Entertainment Park, Orlando over a four-month period in order to determine a general kinematic profile of prey capture. The most notable preliminary differences in the kinematic profile of *C. taurus* are the presence of cranial elevation an order of magnitude larger than and relatively greater upper jaw protrusion distances compared to other sharks. Cranial elevation added from 7 to 21 cm to maximum vertical gape distance. Protrusion included both an anterior and ventral component, which qualitatively differs from previous studies of jaw protrusion in sharks. Although significant differences were not found between individuals in the majority of timing variables, differences were found in duration of cranial elevation and total bite duration. As with other studies of lower vertebrate feeding, intraspecific differences apparently represent a significant source of variation. Extensive cranial elevation and upper jaw protrusion are thought to enhance the predatory ability of *C. taurus* by augmenting both vertical and horizontal components of its gape, thereby placing the jaws more in-line with the longitudinal axis of the body and allowing a more perpendicular occlusion of the teeth on prey items.

6 * RIGONATTI, PAULO G.; SOUZA, ANA M. *Universidade de São Paulo, Dept. Zoologia, Rua do Matão-Travessa 14, 05508-900, Cidade Universitária, São Paulo, SP, Brasil*

Preliminary study - defense/attack of stingrays of Rio Javaes, Ilha do Bananal - TO, Brazil

Fluvial stingrays (Myliobatiformes: Potamotrygonidae) are known for causing accidents in humans in the rivers of the Center-west and North regions of Brazil. Previous studies on those accidents attest that the stingrays are the main cause of damages to the man in those areas. This study intends to describe the reactions of *Potamotrygon* stingrays to different stimuli. 29 individuals (8 youngs, 12 males, 9 female) belonging to the *Potamotrygon* genus were collected with a net in Rio Javaes's sandy margins (near Ilha do Bananal), transported inside boxes with water. For the accomplishment of the stimulus, the animals were placed in a pool made with plastic blanket, with 1 m² area and 10 cm deep. The aeration was made through battery air pumps. The disk of the animals was divided in 9 parts, 2 cranial-lateral, 1 cranial, 2 mediallylateral, 1 medial, 2 caudal-lateral and 1 caudal. For animals more than 16 cm wide, stimuli were applied with a stick with 8 cm wide extremity, for animals less than 16 cm wide the stick extremity measured 2.3 cm. 29 experiments were accomplished, in each one of them the 9 sections were stimulated and the respective reactions were registered (escape after the stimulus, attack with the sting, escape visually oriented before the stimulus, no reaction). After each stimulus a recovery period was given and the normalization of the movements of ventilation of the spiracles was observed, only then a new stimulus was accomplished. The results show that in 57% of the cases escape after the stimuli occurred, in 31% attack with the sting, 10% escaped after visualizing the stick

and 2% showed no reaction. So we can say that the attack reactions happen mainly when the animal does not see that something is about to reach it, when the stimulus is given in the caudal and medium parts.

7C * BELTRAN, J.L.; KAJIURA, S.M.; SUMMERS, A.P. (*JB, SMK, APS*) *Ecology & Evolutionary Biology*, 321 Steinhaus Hall, University of California - Irvine, Irvine, CA 92697-2525, US

A Collagen and proteoglycan content in skeletal cartilage

In most vertebrates, cartilage plays just two functional roles – a low friction bearing surface (as in your knees) and contour filler (your nose and ears). However, a successful group of vertebrates, the class Chondrichthyes (sharks, ratfish and rays), has an entirely cartilaginous skeleton implying a far broader range of function for this connective tissue than in other animals. Whereas tetrapod cartilage is quite homogeneous in its response to load and in biochemical composition (within a functional group: bearing surface or contour filler), we have found the cartilage of sharks to be highly variable in material properties. Here we report on the biochemical variation that underlies the large differences that we have found in material properties. Cartilage is a fiber-reinforced composite material, with a network of crosslinked collagen fibers suspended in an aqueous gel of proteoglycans. In four species of shark and one hard-prey crushing stingray we have found four-fold differences in proteoglycan (PG) content and twofold differences in collagen content. The PG content is very tightly correlated with the resilience of the cartilage from these species. Collagen content also appears to have a significant effect on stiffness and strength. The extreme variation in collagen content raises the possibility of non-collagenous fibrous material in the cartilage.

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Fishery, uses and conservation of freshwater stingrays (Chondrichthyes: Potamotrygonidae) in the Marajó Bay (Brazil)

Freshwater stingrays present unique but poorly known biological characteristics and belong to the only group of elasmobranchs completely restricted to freshwater habitats. The Marajó Bay is located in the mouth of the Amazon River and the present study observed aspects related to the fishery and uses of potamotrygonids in this region. Direct field observations, analysis of captures / landings and interviews with local habitants were carried out since 1999. Results indicated that there are 2 types of fisheries and several folklore uses attributed to freshwater stingrays. The captures take place in fishing areas that are predominantly located in islands and involve mainly the use of hook and line, nets and long lines. One of the fisheries is directed to newborn and juvenile specimens that are captured for ornamental purposes and at least 4 species are illegally being explored. These captures are very specific since the rays have to be kept alive / healthy and also depend directly on the market demand. The second type of fishery is practiced by artisanal fishermen and involves the capture of adult specimens as a food source. In this case, occasionally the freshwater stingrays are considered bycatch but in some localities there is a directed fishery. The use of potamotrygonids as edible fish is apparently uncommon in other parts of the Brazilian Amazon basin. Freshwater stingrays are locally also used for unusual / bizarre purposes that range from the preparation of folklore medicine to the use of stings in religious rituals. A quota system should be established in the State of Pará in order to try to regulate the fishery for the ornamental trade and the artisanal fishery for consumption should be kept at sustainable levels. Fisheries and other uses of potamotrygonid species require the observation of specific conservation recommendations and adequate management.

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Age and growth of the porbeagle shark *Lamna nasus* (Bonnaterre, 1788)

The age and growth of the porbeagle shark captured outside the Chilean EEZ in international waters off the central and northern Chilean coast. The study period was between November 2000 and August 2001 and the study area covered from 24°07' S to 37°13' S, onboard artisanal and industrial longline

boats. The age was determined by counting age rings in the vertebrae, using X-rays. The maximal age found was for a 11 years old specimen. From the fitting of several growth in length models the best fit is derived with a modification of the von Bertalanffy model, that considers the Soriano growth in two steps model. The parameters were estimated for sexes combined and the results were: $L_{inf} = 243.13$ cm TL, $K = 0.149$ / year, $t_0 = -1.738$ year, $h = 0.1142$, $th = 6.13$ year. For the age - total weight relationship it was not possible to fit a parametric model, and we obtained non significant fits with the models explored. Therefore, in order to explain the growth in weight generalized additive models (GAM). Our study confirms the low growth rate of the porbeagle shark, in length and weight, during the first 5-6 years as it was found in studies in the north occidental Atlantic Ocean. Financed by Fisheries Research Fund, Chile, (Proyecto FIP 2000-23).

10 SAN MARTÍN, M. JIMENA; BRACCINI, J. MATÍAS; PEREZ, JORGE E.; TAMINI, LEANDRO L.; * CHIARAMONTE, GUSTAVO E. *Estación Hidrobiológica de Puerto Quequén and División Ictiología, Av. Angel Gallardo 470, Museo Argentino de Ciencias Naturales "Bernardino Rivadavia", Buenos Aires, C1405DJR, Argentina*

Life-history strategies of two sympatric skates of the genus *Psammobatis* off Buenos Aires, Argentina

Psammobatis bergi and *P. extenta* are two sympatric skates commonly caught in the commercial bottom trawl fishery of Puerto Quequén (58°50' W; 38°37' S) Buenos Aires, Argentina. A sample of 224 *P. bergi* and 535 *P. extenta* was collected seasonally from the commercial fishery between June 2000 and November 2001 and March 2000 and May 2001 respectively, with the exception of Spring 2000. Both species presented sexual differences in the Total Length (TL) – Total Weight (TW) relationship and also differed in the TL_{50%} of maturity (*P. bergi* females 79.1%, males 75.5%; *P. extenta* females 80.0%, males 84.0%). A seasonal pattern was observed in the Gonadosomatic Index (GI) of *P. bergi* ($H = 37.97$, $p < 0.001$) and in the Liver mass (LM) – TL relationship of *P. extenta*; conversely, the GI of *P. extenta* and the LM – TL relationship of *P. bergi* did not evidence a temporal pattern. Furthermore, the two skate species differed in several morphometric relationships associated with reproduction, namely Oviducal gland width (OW) – TL (*P. bergi* significant [S], *P. extenta* not significant [NS]), Egg case width (EW) – TL (*P. bergi* NS, *P. extenta* S), EW – OW (*P. bergi* S, *P. extenta* NS) and EW/OW – TW (*P. bergi* S, *P. extenta* NS). These species presented low Niche overlap ($S = 0.0132$) and similar Niche Width figures (*P. bergi* $B = 0.11$: Brachyura 91.64%, *P. extenta* $B = 0.0975$: Penoidea + Gammaridea 88.73%). From the evidence presented, it can be inferred that these two sympatric skates present different lifehistory strategies and occupy different niches.

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Diet of the Caribbean sharpnose shark, *Rhizoprionodon porosus*, on the coast of Paraíba - Brazil

The Caribbean sharpnose shark, *Rhizoprionodon porosus*, is the most abundant shark species in the coastal fisheries of Paraíba State, Brazil. It is a coastal shark, with size at birth between 31 and 39cm, and a maximum adult size of 110cm total length (TL). With the objective of analyzing 17 the diet composition and its variation, according to the size classes, 42 samples were obtained from the gillnet artisanal fisheries at the Paraíba coast. Stomach contents were fixed in 10% formalin and preserved in 75% ethanol. The items were counted, weighted, and identified to the lowest possible taxonomic level or category; for the assessment of the importance of prey items, the percentage Index of Relative Importance (%IRI) was used. The sample was composed of 32 males, with TL between 35.1 – 81.5 cm and 10 females with TL between 33.9 – 91.5 cm. Body weight varied from 182.0 to 2232.0g for males and from 133.3 to 3886.0g for females. Of the 42 stomachs examined, seven (16.67%) were empty, nine (21.43%) contained only amorphous substance and the remaining (61.9%) contained semi-digested prey items. The predominant item (%IRI) was teleost fish, representing 97.58%, followed by crustaceans (1.36%) and cephalopods (1.06%). The following prey groups were identified: Clupeidae, Engraulidae, Holocentridae, Ophichtidae and Pleuronectoidei (Teleostei), Penaeidae and Isopoda (Crustacea) and Cephalopoda (Mollusca). Cephalopods were only found in the stomach of adult individuals. The obtained results indicate that *Rhizoprionodon porosus* is

predominantly piscivorous, opportunistic with respect to the teleost species it preys, and supplements its diet with crustaceans and mollusks.

12 **ORLOV, ALEXEI M.** *Russian Federal Research Institute of Fisheries & Oceanography (VNIRO), 17, V.Krasnoselskaya, Moscow, 107140, Russia*

Feeding of Pacific sleeper shark and five deep-benthic skates in the western Bering Sea

Benthic skates and Pacific sleeper shark play an important role in ecosystems of the North Pacific basin. They are a significant element of food webs in benthic communities. Elasmobranchs consume commercially important fish, cephalopods and shrimps. These species themselves have some commercial importance. For example, skates are processed into fish meat jelly and dried skate wing. Pacific sleeper shark does not support a fishery now. The diets of some northern Pacific skates were described only in few papers. Feeding habits and trophic relations of elasmobranchs inhabiting the western Bering Sea were never previously considered. Stomach contents of elasmobranchs brought aboard Japanese trawler Kayomaru No. 28 during summer 1997 were analyzed. The stomach samples were selected without known bias from bottom trawl hauls carried out around the clock in the western Bering Sea between 170° E and 178° W. Stomachs examined and those with food were as follows: 125/102 Pacific sleeper shark *Somniosus pacificus*, 139/123 Aleutian skate *Bathyraja aleutica*, 19/18 Matsubara skate *B. matsubarae*, 68/58 whitebrow skate *B. minispinosa*, 113/86 Alaska skate *B. parmifera*, and 189/179 Okhotsk skate *B. violacea*. The diet of predatory elasmobranchs (Pacific sleeper shark, Alaska skate, Aleutian skate, Matsubara skate, and whitebrow skate) consisted of large crustaceans, cephalopods and fishes. Benthophage elasmobranchs (Okhotsk skate) consumed mainly worms, amphipods and shrimp. Diets of male and female elasmobranchs differed, probably due mostly to the effect of size. The consumption of worms and crustaceans (especially small) in diets of predators declined with increasing their size, whereas proportion of cephalopods and fishes in diet increased. The consumption of worms and small crustaceans by benthophage Okhotsk skates declined with increasing skate size while consumption of crabs and squids increased. Among the species examined, three elasmobranch pairs had a medium level of dietary 37 similarity: Aleutian and Alaska skates, Alaska and whitebrow skates, and whitebrow and Okhotsk skates. Diets of other species differed considerably.

13C **CHIDLOW, JUSTIN A.** *James Cook University, School of Marine Biology and Aquaculture, Townsville, QLD, 4811, Australia/Western Australian Marine Research Laboratory, WA, 6920, Australia*

Age and growth of the Western Wobbegong shark (*Orectolobus* sp. A) based on wild and captive animals

Age and growth of *Orectolobus* sp. A was studied using micro-radiographs of sectioned vertebrae and laboratory growth studies with two fluorochrome marker dyes, calcein and oxytetracycline. Vertebrae from 182 individuals were examined for length at growth band formation. The relationship between total length (cm, TL) and centrum radius (mm, CR) was linear: $TL = 15.92CR + 10.65$ ($R^2 = 0.9$, $n = 68$). Growth bands were difficult to interpret and final counts were obtained from 98 (53%) individuals with a size range of 63 to 146cm total length. The formation time of growth bands in the vertebrae of captive animals varied, with no predictable pattern, indicating that these bands may not form annually. Growth band formation is thought to be influenced by non-periodic changes in centrum or somatic growth rather than with time. Von Bertalanffy growth parameters estimated from vertebral analysis for both sexes combined were $L = 146.5$, $K = 0.12$, $t_0 = -1.45$. Growth parameters estimated from backcalculated length at growth band formation did not agree with those estimated from observed length at growth band formation. Individual growth rates/year of *Orectolobus* sp. A for the period of captivity (423-472 days) varied considerably, ranging from 3.5cm/year to 13.8cm/year in total length (mean = 7.03cm/year \pm 1.15cm SE) and from 0.42kg/year to 3.07kg/year in weight (mean = 1.81kg/year \pm 0.25kg SE). The rates of growth in total length/year for captive animals were similar to growth rates estimated from the von Bertalanffy growth curve.

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Age and growth of the bull shark, *Carcharhinus leucas*, in the northern Gulf of Mexico
Bull sharks, *Carcharhinus leucas*, are a cosmopolitan species occurring in warm-temperate and tropical coastal regions, including the Gulf of Mexico. A total of 180 specimens were collected from both fishery dependent and independent surveys from Louisiana, Alabama, and Florida. Samples ranged from 555 - 2190 mm FL. Vertebrae were removed from below the first dorsal fin and processed for ageing. Samples were cleaned and a 0.3 mm section was cut and stained using crystal violet. Samples were aged by two of the authors, first independently and then after consultation for samples for which an ageing disagreement had occurred. A final age was assigned to each specimen and a von Bertalanffy growth model with Fabens adjustment was fitted to the observed data. The preliminary VBGF, for combined sexes, predicted L_{inf} : 2204 mm FL and K : 0.09, with given a size at birth of 700 mm. Growth models were also fit to the backcalculated age estimates. Preliminary results indicate differences in both parameter estimates to those previously published with our model predicting a lower L_{inf} and a higher K value.

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Preliminary investigation into the biology and movements of the draughtboard shark (*Cephaloscyllium laticeps*)

The draughtboard shark *Cephaloscyllium laticeps* is the most common catshark in the coastal waters off Southern Australia where it is a major higher trophic level predator of temperate reef ecosystems. It is caught as bycatch in lobster traps, demersal trawls, long-line and gillnets. There is currently no targeted commercial fishery for draughtboard sharks, although recently a small number of commercial gill net fishers are trialing the species on the local market. Because draughtboard sharks have a high catchability in traps and gillnets they are potentially vulnerable to population reduction through fishing. Assessing the potential impact of fishing mortality is currently hindered by the lack of knowledge of draughtboard shark biology. The purpose of this study is to investigate specific aspects of life history and biology of draughtboard sharks that will help future management decisions. In addition to collecting reproductive data from dead specimens, hormonal levels have been analysed from blood samples as a means of describing reproductive condition in live animals. Plasma levels of 32 progesterone, testosterone (T) and 17-betaestradiol in females, and T in males were obtained measured by RIA. Stomach content analysis is being used to quantify prey items and biases associated with different fishing gears (gillnets and traps). Preliminary attempts to age the sharks using vertebral ring counts have been problematic. Local movement patterns are being investigated using traditional fin tags and acoustic tags. The fin tags have confirmed that proportions of sharks are recaptured in the same area each year. The acoustic tagged sharks are being caught, tagged and released within an array of acoustic receivers that will enable us to follow their daily movements on and adjacent to the reef system.

16 COLONELLO, JORGE H.; * LUCIFORA, LUIS O. Instituto Nacional de Investigación y Desarrollo Pesquero, Casilla de Correo 82, Correo Central, Mar del Plata 7600, Argentina

Ontogenetic dietary shift in the Rio skate, *Rioraja agassizi*

The Rio skate is an endemic species from the Southwest Atlantic. It is abundant off Argentina and Uruguay, which may make it an important benthic predator. However, the feeding habits of *Rioraja agassizi* are unknown in the region. We analyzed the feeding habits of the Rio skate from two areas: the La Plata River estuary (LP, 34-37° S) and off Blanca Bay (BB, 39-41° S). We examined 140 specimens, of which 114 had prey into the stomach. The specimens were sorted into four groups: juveniles from LP (15), juveniles from BB (42), adults from LP (18), and adults from BB (39). Cumulative prey curves as a function of sample size were constructed in order to estimate the minimum sample size for describing accurately the diet of each group. All curves showed that the sample size was large enough as to describe the diet of each group. Prey importance was quantified through the percent index of relative importance (IRI). Also, the prey-specific importance index (Pi) was calculated. The IRI gives information about the population feeding habits, while Pi brings

individual-based information on foraging strategy. In general, decapod crustaceans were the most common prey (IRI = 55.5%). The diet of juveniles from both areas was composed mainly of amphipods (IRILP = 65.1%, IRIBB = 42.5%). Adults of both areas were mostly specialized in the consumption of decapod crustaceans (IRILP = 88.6%, IRIBB = 64.8%). Polychaetes and cephalochordates were consumed more often in BB than in LP. Pi showed that most juvenile individuals (43.1%) were specialized in the consumption of amphipods (Pi = 66.5). In contrast most adults (58.9%) consumed mainly decapod crustaceans (Pi = 76.3). This ontogenetic shift in diet could be due to several causes such as changes in mouth structure and dentition, changes in energetic requirements and/or prey availability.

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Predation on eggcases of skates (Rajidae) in the Southwestern Atlantic: quantification and life history implications

Mean predation rates (\pm SD) on eggcases of four skate species, *Bathyraja macloviana*, *B. albomaculata*, *Amblyraja doellojuradoi*, and *Psammobatis* spp., from the Southwestern Atlantic were estimated to be 0.151 (\pm 0.230), 0.423 (\pm 0.344), 0.254 (\pm 0.390), 0.150 (\pm 0.288), respectively. These 90 estimates are within the ranges reported elsewhere (14-40%). Eggcases of *B. albomaculata* were preyed on in higher proportion than expected from their abundance, and suffer a heavier predation rate where the snail *Trophon acanthodes* was present. Predation rates were not correlated with the thickness of the eggcase wall, which indicates that other factors (ecological or chemical) could explain this pattern. Five types of boreholes were found in the eggcases, one was attributable to muricid gastropods, one to naticid gastropods, a third type to an unknown gastropod (probably *Fusitriton magellanicus*), and the remaining were of unknown origin. Published cladistic analyses showed that skates are secondarily oviparous and maximized adaptations for a living in deep water. We suggest that oviparity in skates appeared as an adaptation to maximize fecundity (45-150 eggs per year, as compared to 2-18 pups annually or biannually in viviparous guitarfishes, the plesiomorphic sister clade of skates). If a predation rate of 24% (the mean of predation rate of all skate species studied to date) is applied to the range of fecundities reported for skates, the result is that 18-114 viable pups are produced annually per female skate. Even with a high mortality rate of 64% (the only direct estimate of natural mortality for any elasmobranch), each female skate produces 17-54 eggs annually. These values are higher than most elasmobranch fecundities. This maximization of fecundity is possible mainly because the fecundity of oviparous species is not limited by body size, as in viviparity. The protracted egg-laying season (4-12 months) of most skates (like in many other deep-sea fishes) maximizes the number of eggs laid.

18 * **LUCIFORA, LUIS O.; MENNI, ROBERTO C.; ESCALANTE, ALICIA H.** (LOL) *Instituto Nacional de Investigación y Desarrollo Pesquero, Casilla de Correo 82, Correo Central, Mar del Plata 7600, Argentina;* (RCM) *Museo de La Plata, Departamento Científico Zoología Vertebrados, Paseo del Bosque s/n, La Plata 1900, Argentina;* (AHE) *Universidad Nacional de Mar del Plata, Departamento de Biología, Funes 3250 segundo piso, Mar del Plata 7600, Argentina*

Reproduction of the shark *Galeorhinus galeus* from Argentina: support for a single Southwestern Atlantic population

It has been hypothesized that Southwest Atlantic school sharks *Galeorhinus galeus* migrate seasonally between southern Brazil and northern Argentina for mating and pupping. Lack of data on life history of school sharks from Argentinean waters precluded the test of this hypothesis. In this study, the reproductive biology, seasonal occurrence, and embryo growth of school sharks from off Argentina are described. A total of 411 school sharks (123 males and 288 females) were examined. Female size at 50% maturity was 124.72 mm total length (TL). Fertility was, on average, 1.77 pups smaller than fecundity. Differences between fecundity and fertility were not dependent on mother size. The largest embryos were found in late October and November in coincidence with ovulation. This indicates that gestation lasts about 12 months. Embryo growth was described by the Gompertz model (with $L_{inf} = 29.77$, $k = 0.021$, and $a = -1.171$). Four groups of females were recognized: juveniles up to 129 cm

TL, with translucent-to-white ovarian follicles (<19 mm wide); mature non-ovulating females with yellow ovarian follicles (17.5-27.5 mm wide), low gonadosomatic index (GSI), and empty uteri; mature ovulating females with larger yellow ovarian follicles (42-57.5 mm wide), high GSI, and uteri empty or with recently ovulated eggs; and pregnant females carrying term embryos, with minute ovarian follicles. These observations give support to the 3-year-long reproductive cycle proposed earlier. Males dominated the catches in October and April (63-71% of examined specimens). Females were more abundant than males from November to March (67-100%). The pattern of occurrence and reproductive condition of school sharks in northern Argentina are complementary to that from southern Brazil. This supports the hypothesis that there is a single large population of school sharks in the Southwestern Atlantic that performs reproductive migrations between southern Brazil and northern Argentina.

19 * **LITHERLAND, LENORE E.; COLLIN, SHAUN P.** (LEL, SPC) School of Biomedical Sciences, Department of Anatomy and Developmental Biology, University of Queensland, St Lucia 4072, Australia

Visual ecology in elasmobranchs: photoreceptor and ganglion cell distributions predict interspecific variation in lifestyle and feeding strategy

The importance of vision remains unknown in many species of elasmobranchs. Here, we examine the morphology and distribution of both photoreceptor and ganglion cell populations in the retina of a range of species, in order to assess their spatial resolving power and strategies for localising both prey and predator. The retinæ of five species (the ornate wobbegong, *Orectolobus ornatus*, the white tip reef shark, *Triaenodon obesus*, the great white shark, *Charcharodon carcharias*, the epaulette shark, *Hemiscyllium ocellatum*, and the eastern shovelnose ray, *Aptychotrema rostrata*) representing a range of lifestyles (benthic, pelagic, diurnal, nocturnal) were investigated and morphological and topographic characterization of both cell populations revealed marked variation. Anatomical measures of visual acuity ranged from 2.5 to 4.5 cycles per degree in regional specialisations (*areae* and horizontal streaks) mediating acute vision. The retinal location of these acute zones varied, emphasizing the relative importance of vision in different parts of each species' visual field. The distribution of both ganglion and photoreceptor cell populations were analysed in the same eye in each species and specialised areas of increased density were found to lie in register. However, differential analyses of rod and cone densities revealed localized differences in distribution suggesting different parts of the visual field may be more important during diurnal (cone-dominated) and nocturnal (rod-dominated) vision. Two and three localized retinal regions mediate acute vision in the frontal and lateral parts of the visual field in *O. ornatus* and *T. obesus*, respectively, while an elongated region of increased cell density extends horizontally across the retinal meridian mediating acute vision across a much larger and panoramic part of the visual field in *H. ocellatum* and *A. rostrata*. The retina in *C. carcharias* is unique and possesses a single and localized area for mediating increased visual acuity.

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Preliminary findings on the distribution, abundance, and reproductive biology of deepsea scyliorhinids off central California

These findings are part of a broad-based ecological investigation into the life history of three deep-sea catsharks (Scyliorhinidae), *Apristurus brunneus*, *A. kampae* and *Parmaturus xaniurus*, in the eastern North Pacific. Preliminary results on the distribution, abundance, and reproductive biology of these species off central California will be presented. Specimens were collected from trawl and longline survey cruises by the National Marine Fisheries Service (NMFS) from June 2002 through May 2003 from Año Nuevo to Point Sur, California. Distribution, occurrence, and abundance of specimens were analyzed to identify trends associated with season, depth, maturity, sex, and species. On average, longline hauls were mainly comprised of *P. xaniurus*, with an occasional catch of gravid female *A. brunneus*. *Parmaturus xaniurus* were usually found 72 less than 485 m deep. Conversely, trawl cruises were primarily comprised of *Apristurus* spp. *Apristurus brunneus* were typically found between 300-942 m, while *A. kampae* occurred deeper than 1,005 m. The total lengths at first reproductive maturity were determined for all species using nidamental gland width, egg diameter,

and outer clasper length measurements, as well as gonadosomatic indices (GSI) for males and females. Size at first reproductive maturity as determined by GSI is being compared to the maturation of other sexual organs to determine if development is synchronous. Initial analyses are attempting to determine if reproductive seasonality is evident by associated changes in the GSI and hepatosomatic index (HSI).

21C * DICKEN, MATT L.; SMALE, MALCOLM J; BOOTH, TONY (MLD, MJS) Port Elizabeth Museum, PO Box 13147, Humewood, Port Elizabeth 6013, South Africa; (TB) Rhodes University, Department of Ichthyology and Fisheries Science, Grahamstown, 6410, South Africa
An initial estimate of the population size of the juvenile Spotted ragged tooth shark (*Carcharias taurus*) in Eastern Cape nursery areas off South Africa

A maximum likelihood model is developed using mark-recapture data to estimate the population size of immature, juvenile Spotted ragged tooth sharks in the Eastern Cape of South Africa. The model is composed of 4 major components: (1) A population dynamics model, which describes the number of tagged animals surviving to the next time interval. (2) An Observation model, which describes how the tags are recovered and reported. (3) A likelihood function that specifies the likelihood of observing a specific number of recoveries as a function of the number expected according to a specific set of parameters of the population dynamics and observation models. (4) A bootstrapping program to estimate variances for the parameters F (Fishing mortality), Z (Total mortality) and N (Population size). There was insufficient contrast in the data to estimate all model parameters consequently an instantaneous tag shedding rate, non-reporting rate and M (natural mortality) had to be fixed while allowing free estimation of F (Fishing mortality), Z (Total mortality) and N (population size). In this study fishing mortality was estimated to be 0.127 year⁻¹, with a 95% confidence level ranging from 0.089 and 0.158. Total mortality Z was estimated to be 0.327 year⁻¹, with a 95% confidence level ranging from 0.289 and 0.358. The mean annual population estimate for juveniles from 1994/95 to 2001/2 was 5540 with a 95% confidence level ranging from 4583 and 6306.

22 * JAIME, MARIO; GALVÁN, FELIPE Centro Interdisciplinario de Ciencias Marinas, Instituto Politécnico Nacional, Apartado Postal 592, La Paz, Baja California Sur, 23000, México
Pelagic shark catch in Baja California Sur, Mexico, and its relationship with environmental factors

Within the top predators of marine food chains, sharks are in a key position for its place of hunters and scavenging animals. Environmental factors associated to their abundance location would be use for shark management. Catch of 6 pelagic shark species in the western coast of Baja California Sur, Mexico, and its relationship with environmental factors were analyzed. Logs data were from two fishing boats that operated from September 1996 to June 2001. The fishing method was a multifilament gillnet of 2000 m length. A total capture of 289 tons was registered. 71 % corresponded to the blue shark, *Prionace glauca*; 12 % to silky shark, *Carcharhinus falciformis*; 10% to mako shark, *Isurus oxyrinchus*; 3 % to pelagic thresher *Alopias pelagicus*; 2 % to smooth hammerhead shark, *Sphyrna zygaena*; 1 % to oceanic whitetip shark *Carcharhinus longimanus* and the rest (> 1 %) to non identified organisms. The capture by unit effort (CPUE) was defined as kilograms/fishing effective hours. The higher abundance was registered in front of Bahia Magdalena. Images of sea surface temperature (SST) were obtained from the NOAA-AVHRR and photosynthetic pigment images from SeaWiFS project, NASA/Goddard Space Flight Center. The shark distribution and the CPUE were related to these oceanographic satellite images. Pigment concentrations have significant effect in the abundance of *Prionace glauca* and *Carcharhinus falciformis* perhaps for its prey aggregation. Water temperature had its most significant effect for two species: *Carcharhinus falciformis* showed higher abundance and preference for 27-30 °C, whereas *Alopias pelagicus* showed preference for 23 - 25 °C.

23 * MANCINI, PATRÍCIA L; AMORIM, ALBERTO, F. Universidade Estadual Paulista, UNESP, Instituto de Biociências, Departamento de Zoologia, Av. 24-A, 1515, Rio Claro, SP, 13506-900, Brazil

Fishery biology of bigeye thresher shark, *Alopias superciliosus*, caught by Santos longliners off Brazil

The bigeye thresher shark analyzed in this paper were caught by longliners settled in Natal city, Rio Grande do Norte State and Santos city, Sao Paulo State. The individuals from Santos were caught from North and South/Southeast of Brazil. Observing Natal longliners data (1986-2000), in number of fish, it increased from 1986 (41 fish) to 1988 (103 fish) following a decreasing in 1994 (7 fish) and 1999 (15 fish). The Santos data (1971-2001) suggest that it was probably rejected in the beginning of the period. Yield tendency increased from 1971 (1 ton) to 1989 (85 ton) and decreased until 2001 (20 ton). The average CPUE and weight have shown light increasing trend for the all period with 18 kg/10,000 hooks and 120 kg respectively. Based on Santos Fishing Terminal (2002/2003 period) 35 individuals from North (N) were examined, and 82 from South/Southeast (S/SE). The sex ratio was 0,4/1 in N and 1/1 in S/SE. The length and weight range from 137cm (42kg) to 157cm (86kg) with average of 147cm (66kg) for male in N and the length and weight range from 97cm (21kg) to 164cm (98kg) with average of 133cm (67kg) for male in S/SE. The length and weight range from 112cm (40kg) to 136cm (133kg) with average of 157cm (86kg) for female in N and the length and weight range from 88cm (23kg) to 191cm (259kg) with average of 131cm (77kg) for female in S/SE. The length-weight relationship (N to S/SE) was: $W = 28.46 L^{3.01}$ and $R^2 = 0.89$ for females ($n = 67$); $W = 28.76 L^{2.92}$ and $R^2 = 0.94$ for males ($n = 50$); $W = 28.53 L^{2.91}$ and $R^2 = 0.89$ for grouped sexes ($n = 117$).

24 * **MASSA, ANA M.; HOZBOR, NATALIA M.** *Instituto Nacional de Investigacion y Desarrollo Pesquero (INIDEP), Paseo Victoria Ocampo N° 1, Escollera Norte, 7600, Mar del Plata, Argentina*

Exploitation of cartilaginous fishes from Argentina: current situation and needs for an effective management

In the past, cartilaginous fishes from the Argentinian shelf (34° to 55° S) were discarded, but currently they are actively exploited (due especially to the opening of new markets). We examined effort (fishing hours), catch (tons), and catch per unit of effort (CPUE, tons/fishing hours) from Argentinian official fishing statistics. From 1992 to 1998 the smallest fleet (up to 20 m length) landed chondrichthyans. Since 1994 a fleet of large boats (> 28 m length) increased its fishing pressure on chondrichthyans. Until 1994 chondrichthyan landings did not exceed 20000 tons per year. Since 1994, chondrichthyan landings exceeded 25000 tons annually in Argentinian ports. The landings peaked in 1998 with 35500 tons. This increase was due mainly to higher landings of skates (Rajidae) from 1994 onwards. From 1992 onwards a decrease in the landings of sharks (many species lumped together) was observed, while the landings of smoothhounds (mainly *Mustelus schmitti*) and angel sharks (*Squatina* spp.) were kept at 10000 and 4000 tons, respectively. The trend in CPUE was decreasing for all fleets. The maximum decrease was for the fleet > 28 m, with CPUEs of school sharks (*Galeorhinus galeus*), angel sharks, smoothhounds, and sharks falling more than 50%, and CPUE of skates falling by 36%, 93 which clearly indicates a negative effect of fishing on abundance. An improvement in the catch statistics for all fisheries is needed for achieving accurate population assessment and effective management. Given that elasmobranchs are poorly known in Argentina, it is also important to carry out studies on ecology, life history and biology. In Argentina there are not management strategies for chondrichthyans, only maximum sustainable quotas are established for smoothhounds, angel sharks, skates and sharks. Taking into account the vulnerability of chondrichthyans, and the growing demand of chondrichthyan products from Argentina, a management strategy should be implemented as soon as possible.

25C * **TODD, TERRANCE N.; WALDBESER, LILLIAN S.; WARD, ROCKY** (*TNT, LSW*) *Texas A&M-Corpus Christi, Physical and Life Sciences CS 242, 6300 Ocean Drive, Corpus Christi, TX 78412, USA* (*RW*) *Texas Parks and Wildlife, Perry R. Bass MRFS, HC 02, Box 385, Palacios, TX 77465, USA*

Detection of genetic variation in *Rhizoprionodon terraenovae* and *R. porosus* using singlestranded conformational polymorphisms (SSCP)

The Atlantic Sharpnose Shark, *Rhizoprionodon terraenovae*, and the Caribbean Sharpnose Shark, *R. porosus* are small coastal-temperate and tropical sharks of the continental shelves that overlap in

distribution along the Gulf of Mexico, Florida and around the Yucatan Peninsula to the Caribbean Sea. In order to properly distinguish between the two species, current methods require counting caudal and precaudal vertebrae. These species used to be highly abundant within their prospective ranges, but current fishery pressures have caused declines in landing at some locations. Assessment of population size and structure is necessary to determine future management plans for this species. Use of SSCPs is a viable method to differentiate between the two species and to measure population structure. SSCP analysis was able to detect unique haplotypes indicative to a particular species. Use of sequencing confirmed the variation between the species with an estimated nucleotide divergence as high as 1.08%. AMOVA analysis comparing Atlantic sharpnose sharks collected in the Bay of Campeche with samples obtained from four other sites throughout the Gulf of Mexico and along the Northwestern Atlantic Ocean found that the eleven haplotypes observed were evenly distributed throughout the range ($F_{ST} = 0.022$, $p=0.191$). However significant differences were observed in pairwise analysis between the Bay of Campeche and other sites. These differences disappeared when samples were examined based on temporal data suggesting that genetic bottlenecks are occurring in the *R. terraenovae* along the Mexican Coast.

26 * **LOPEZ, J. ANDRES; RYBURN, JULIE A.; FEDRIGO, O.; NAYLOR, GAVIN J.P.** *Iowa State University, Dept. Zoology and Genetics, Ames, IA, 50011, USA*

Two independent partial duplications of cytochrome b in the mitochondrial genome of triakid sharks

In the course of a study aimed at determining the phylogenetic relationships of the sharks of the family Triakidae, we discovered a partial duplication of the cytochrome b gene in the mitochondrial genome of members of two different triakid genera: *Mustelus* and *Hemitriakis*. In both cases, the duplicated sequences are located downstream of the cytochrome b gene and upstream of the control region. The large amount of change evident in the region immediately downstream of the functional cytochrome b gene indicate that the Threonine and Proline transfer RNAs normally occupying this position are no longer encoded at this site. Phylogenetic analyses of the duplicated sequences and the functional cytochrome b gene strongly support two different origins for the duplicated sequences. The two duplication events show remarkable similarities in location and gene region affected. The duplicated regions begin 51 and 59 bases downstream of the cytochrome b gene and include sequences that would encode the last 166 and 184 amino acid residues of cytochrome b. The duplicated region of *Hemitriakis* has acquired a considerably greater number of mutations than that of *Mustelus* when each is compared to its putative parent sequence. This disparity may be due to differences in the rate of substitution or in the time of origin. Documented cases of changes in the organization and content of mitochondrial genomes of vertebrates remain relatively uncommon; however, the few reports on mitochondrial sequence duplication reveal interesting commonalities. The characteristics of the duplication events we have discovered in triakid sharks correspond well with many of those common features and thus strengthen the case for a common mechanism of origin.

27C * **KEENEY, DEVON B.; HEIST, EDWARD J.** *Southern Illinois University, Fisheries and Illinois Aquaculture Center, Department of Zoology, Carbondale, IL, 62901, USA*

Microsatellite loci isolated from the blacktip shark with cross-species amplification in Carcharhinidae and Sphyrnidae

The conservation and sustainable exploitation of the world's shark populations has been a concern among marine fisheries biologists for decades. However, highly variable molecular markers suitable for investigating population structure and other aspects of molecular ecology are available for few shark species. In this study, we characterize 1 monomorphic and 15 polymorphic microsatellite loci isolated from the blacktip shark, *Carcharhinus limbatus*, and present results of cross-species amplification in 11 *Carcharhinus* species, 4 additional genera from the family Carcharhinidae, and 2 species from the genus *Sphyrna*. An unenriched library of 2,304 cloned fragments produced only 36 (1.6%) colonies positive for dinucleotide repeat motifs, indicating microsatellite loci are relatively scarce in blacktip sharks as in other carcharhinid species. We subsequently produced an enriched library with a much higher (48%) fraction of positive clones. Heterozygosities of polymorphic loci ranged from 0.04 to 0.96 with 2 to 22 alleles per locus in 28 blacktip sharks tested. Amplification products were observed at 9 to 13 loci in 10 *Carcharhinus* species with 5 to 11 loci polymorphic per

species. All of the other species examined were polymorphic at 1 to 8 loci. The range of variation and widespread cross-species amplification of these microsatellite loci demonstrate their potential utility for investigating the population structure and molecular ecology of numerous shark species.

28 * **CASTRO, ANDREY; DELIUS, BRYAN; LOWRY, DAYV; BURGESS, GEORGE; MOTTA, PHILIP** (AC, DL, PM) *University of South Florida, Dept. of Biology, Tampa, FL, 33620, USA; (BD, GB) Florida Museum of Natural History, Division of Fishes, University of Florida, Gainesville, FL, 32611, USA*

Inter-tooth distance as a predictor of body length in sharks

The dental morphology and patterning in sharks has long been used to predict both species and body size, with somewhat limited success. The lack of fit between dental patterns and body size is partially due to monognathic and dignathic heterodonty, as well as varying tooth size along the jaw margins. The ability to accurately predict body size from bite patterns is important for better understanding shark attack on humans and even submarine equipment, both civilian and military. To this end, we measured inter-tooth distance and tooth size for the two anterior and first four lateral teeth on both the upper and lower jaws, as well as jaw circumference, in a variety of carcharhinid and lamnid sharks, and regressed these against total length. Tooth gap distance is an accurate predictor of body size (upper jaw $R_2 = 0.83$) (lower jaw $R_2 = 0.82$) for twelve carcharhinid species as a group. More triangular upper jaw tooth spacing is isometric ($m = 1.05$) whereas the narrow and more pointed lower teeth ($m = 0.89$) display negative allometry. Taken individually different carcharhinid species display somewhat variable spacing patterns. Tooth bearing circumference is also isometric and predictive ($R_2 = 0.94$) of total length. White and mako sharks display greater tooth gap spacing for a given length than carcharhinids with high regression coefficients and low variability. These simple measures taken from bitten submarine equipment and organisms allow quick assessments of shark size. This research continues with collection of additional data on potentially hazardous or commercially destructive species and identification of species specific damage patterns.

29 **DEAN, MASON N.; * NANCE, HOLLY A.; HUBER, DAN R.** (MND, DRH) *University of South Florida, 4202 East Fowler Ave., SCA 110, Tampa, FL, 33620, USA; (HAN) The University of Texas at Austin, Jackson School of Geosciences, Mail Code C1140, Austin, TX, 78712, USA*

Functional morphology of jaw trabeculation in *Narcine brasiliensis*: an application of high-resolution X-ray computed tomography

The design of efficient, yet durable structures that retain their integrity under dynamic loading regimes has long challenged engineers and functional morphologists alike. The trade-off between weight and strength can be optimized by hollowing a structure and replacing its inner core with support struts. In animals, this design is observed in sea urchin test, avian beak and wing bone, and the cancellous bone of tetrapod limbs. Additionally, within the elasmobranch fishes, mineralized trabeculae have been reported singularly in durophagous myliobatid stingrays (Elasmobranchii: Batoidea), and are believed to be absent in basal members of the batoid clade. However, this study presents a secondary case of batoid trabeculation in the lesser electric ray, *Narcine brasiliensis*, a small, benthic member of the electrogenic Torpediniformes. While orientation of myliobatid trabeculae is perpendicular to the crushing plane of the jaws, high-resolution X-ray images reveal that the trabeculae of *N. brasiliensis* are arranged in the frontal plane, normal to the long-axis of the jaws. This morphological difference might be explained functionally. Stingrays use their reinforced jaws to crush bivalves, yet *N. brasiliensis* feeds by ballistically protruding its jaws into the sediment to retrieve polychaete prey. At peak protrusion, the jaw arch is medially compressed such that the trabeculae are positioned to resist the forces resulting from this excavation mechanism. These struts are localized to specific areas most likely to experience the highest load: the medial quadratomandibular jaw joint and the thinnest section of the jaw immediately caudal to the tooth plates. In this way, these supports are positioned to resist both compression at the jaw joint, and local buckling of the jaws as they contact the sediment. Thus, trabeculation in batoids appears to perform strikingly different ecological functions, and was either independently derived in two taxa or was secondarily lost by intermediate members of this clade.

30C * **FORNI, JESICA B.; KAJIURA, STEPHEN M.; SUMMERS, ADAM P.** *Ecology & Evolutionary Biology, University of California, Irvine, CA 92697, USA*

Stereo olfaction in hammerhead sharks – smells like a red herring

The evolution of the hammerhead shark cephalofoil has been the subject of much speculation. The 'enhanced olfaction' hypothesis persists as one of the most popular explanations for the evolution of this peculiar structure despite the lack of empirical evidence. It has been suggested that the widely separated nares provide sphyrnid sharks with better directional localization of odors and that the accompanying lateral expansion of the nasal capsules provides them with a larger volume in which to accommodate a larger nasal organ. We tested these hypotheses by comparing the morphology of the peripheral olfactory system for representatives of all eight sphyrnid shark species and two closely related carcharhinids. Although the maximum narial separation distance is greater for sphyrnids than carcharhinids, a prenarial groove along the anterior edge of the cephalofoil of most sphyrnid species channels water into the nares, effectively reducing the separation distance. Therefore, whereas sphyrnids sample a greater volume of water, they are not able to resolve odor direction any better than carcharhinids. To address the question of olfactory acuity, the surface area of the individual lamellae, which comprise the olfactory rosette, was compared among species. Although sphyrnids possess a significantly greater number of lamellae than carcharhinids, the total lamellar surface area did not differ among the species. Therefore, the inability of the sphyrnids to spatially resolve odors any better than the carcharhinids, coupled with the similar lamellar area among the species, combine to suggest that the 'enhanced olfaction' hypothesis is not strongly supported as a mechanism for the evolution of the hammerhead shark cephalofoil.

31C * **ARI, CSILLA; KÁLMÁN, MIHÁLY** *Semmelweis University, Dept. Anatomy, Histology and Embryology, Budapest, Hungary*

Supposed sexual dimorphism on the cerebellum of the ray *Mobula japonica* (order *Myliobatiformes*)

In the most advanced forms of Chondrichthyes the brain/body weight ratio (relative brain weight) matches those found in birds and mammals, and surpass those of other vertebrates. According to the recent studies the largest relative brain weights belong to the species of the *Myliobatiformes* order, e.g. the *Mobula japonica*. The determinants of this conspicuous brain size are the telencephalon and cerebellum. Size and outer structure of the cerebellum extremely diverges among Chondrichthyes (Northcutt, 1978), in several groups (*Isurus*, *Dasyatis*, *Mobula*) the gyrification matches the mammalian and avian cerebella. Intraspecific variations of cerebellar morphology can be considerable, but the investigation in a *Dasyatis* sp. could not find it to be correlated to size or sex. The neuronal structure of cerebellum is similar in all Chondrichthyes (actually, in all Vertebrates), as we also found in *Raja erinacea*, *Dasyatis americana* and *pastinaca*, and *Mobula japonica*. Immunostaining against GFAP revealed astrocytes in the molecular layer, similar to birds and mammals, whereas it detected no Bergmann-glia. The size of the cerebellum did not differ significantly between males and females, but in the latter ones a leftward prominence caught the eye, suggesting a sexual dimorphism. Although the female cerebella were recognizable by their asymmetry, even a series of measurements performed on 5-5 male and female cerebella, could not find a parameter to prove the difference significantly. The investigation continues in the analysis of the surface pattern, to reveal its regularities and coin a terminology for its description. In this analysis the gyrification index is to be determined, like in the cortex of mammals (see e.g., Zilles et al., 1988, 1989), and a higher number of specimens are to be investigated.

32 **COSTA, OSCAR T. F.; * ARAÚJO, MARIA L. G.; DUNCAN, WALLICE L. P.; FERNANDES, MARISA N.** (*OTFC, MLGA, WLPD*) *Federal University of Amazonas State, Dept. Morphology, Cytology Lab, 3000 Rodrigo O. J. Ramos Road, Manaus, AM, 69700-000, Brazil; (MNF) Federal University of São Carlos, Dept. Physiological Sciences, São Carlos, SP, 13565-905, Brazil*

Stereological analysis on the gills of freshwater stingray *Potamotrygon motoro*

The stingray *Potamotrygon motoro* (Chondrichthyes, Potamotrygonidae) occurs in the Amazon and Plata Basin. Although this species is intensively exported as ornamental fish, no information exists about the morphometry of the respiratory system, which can be used as base for future programs of specie conservation or comparative studies of gas exchanges systems in lower vertebrates. The stereological morphometry of vertical sections profiles in fish gill enables the functional capacity for

O₂ transport to be established. Following this method, the harmonic mean thickness (tht) of the lamellar diffusion barrier and the total lamellar surface area at gills are related to produce the morphometric diffusing capacity of O₂ and CO₂ and the anatomical diffusing factor. To avoid technical artifacts, the fish gills were fixed *in situ* in flowing 2.5% glutaraldehyde in 0.1M phosphate buffer followed by immersion in the same fixative. Trimmed arches were orientated for embedding in glycol methacrylate, exhaustively sectioned and 15 analyzed in a light microscope coupled with a drawing tube. The gills of *P. motoro* are composed of five arches, the first of which bears only a hemibranch. The gases must pass through two epithelial cells, the basement membrane, and the flange of the pillar cell, as they move between the blood and the water at lamella. The tht of the lamellar barrier was estimated in 4.75 mm (2/3 tht = 3.17 mm). This value (reflecting the efficacy of gaseous exchange) is comparable with that of trout but exceeds three times that of tuna, remaining within the range waiting for water-breathing fish. Ours results indicate a good agreement between smallest diffusion distance and most active fish, particularly in view of the fact that *P. motoro* is one of the more active freshwater stingrays. This study discusses the implications of the gill morphometry for gas-exchange function in Amazonian elasmobranchs fish.

33 **WHITEHEAD, DARRYL L.** *University of Queensland, Centre for Marine Studies, Brisbane, QLD 4072, Australia*

Comparisons of ampullae of Lorenzini obtained from *Carcharhinus leucas* native to various habitats

Ampullae of Lorenzini were examined from *Carcharhinus leucas* captured in the freshwater reaches of the Brisbane River and from sharks obtained from the marine waters of Moreton Bay. On sharks from both habitats, ampullary pores (0.14 to 2.5 mm, diameter) are distributed across the head area of the shark and have a mean number of 2052, 59% of these pores appear on the 91 ventral surface of the head. There are two general forms of the canal epithelial cells, flattened squamous and ridged cells that contain a high density of vacuoles and appear to release material into the lumen of the canal. The alveolar sacs contain numerous receptor and supportive cells bound by tight junctions and desmosomes. The pear-shaped receptor cells possess a single kinocilium that extends into the ampullary lumen. Along the basal surface of the receptor cells are junctions with unmyelinated neural terminals. A central centrum stage consisting of a luminal layer of cuboidal epithelial cells overlying squamous epithelial cells lies in the center of the basal ampullary region. This overlies the primary incoming afferent nerve, which radiates from this central area to divide and connect with all receptor cells. Apically nucleated supportive cells produce a rigid ampullary wall and possess a low number of microvilli.

34 * **FURTADO-NETO, MANUEL A.; CARR, STEVE** (MFN) *Universidade Federal do Ceara, Departamento de Engenharia de Pesca, Rua Joao Cordeiro 638, Fortaleza, CE, 60110-300, Brazil; (SC) Department of Biology, Memorial University of Newfoundland, NF, A1B3X9, Canada*

Molecular phylogeny of angel sharks (Squatinae, Elasmobranchii) from Brazil

Angel sharks (Squatinae; Elasmobranchii) comprise a single genus that includes fifteen extant species. Three species of the genus *Squatina* are endemic to the continental shelf of southeastern South America, between latitudes 24°S and 42°S: *Squatina argentina*, *S. guggenheim*, *S. occulta*. In 1991, *Squatina occulta* was described and *S. guggenheim* was redescribed. Before that, only one species was thought to occur in the southern coast of South America whereas *S. occulta* and *S. guggenheim* were misidentified as *S. argentina* in some studies. PCR (polymerase chain reaction) was used to amplify 401-base pair sequences of the mitochondrial DNA cytochrome b gene from each species. Sequences of this gene from the three species of *Squatina* were obtained. Phylogenetic analyses were performed with the PAUP computer program of Swofford. Maximum parsimony tree was obtained with the heuristic search algorithm. The phylogenetic analyses indicate that the three species from southern Brazil constitute a monophyletic group, with the newly described species *S. occulta* more closely related to *S. guggenheim* than to *S. argentina*. This result suggests that evolution of the genus *Squatina* in southeastern South America waters occurred from deeper to shallower waters. Probably, *S. argentina* was the first species to occupy the continental shelf in depths of 200m or more. Fossil records suggest that this genus has existed since the Upper Jurassic. *S. occulta* and *S. guggenheim* may have evolved more recently and speciation probably occurred as an adaptation to life

in shallower waters on different types of sea bottom. If this suggestion is true, *S. guggenheim* that lives from 0 to 80m, is the most recent species among the three *Squatina* from southern Brazil.

35 * **IBRAHIM, AHMED; SUMMERS, ADAM** *University of California, Irvine Ecology & Evolutionary Biology, Irvine, CA 92697-2525, 195 Cornell, Irvine, CA 92612, USA*

Bioenergetics of the little skate (*Raja erinacea*)

The Rajidae is a speciose clade (245 species) of dorsoventrally flattened cartilaginous fishes that are all oviparous. They lay a flat, rectangular egg capsules with a pair of posterior and anterior horns emanating from the corners that generally contains a single embryo. The little skate (*Raja erinacea*) is a common species of the Eastern North Atlantic with a development time of 12 to 18 months. We measured the metabolic rate of the little skate using two approaches: respirometry, and calorimetry. Oxygen consumption was measured in increments of 15 or 30 minutes for ten individuals at various developmental stages. The mean recorded metabolic rate was 0.0543 mg O₂/hr.g. Oxygen consumption over the nine month development period was calculated to be 0.352 g O₂/g. Homogenized skate tissue (n = 20) was processed with micro-bomb calorimetry. The mean caloric content among the individuals was 4.25 kcal/g and 4.22 kcal/g in yolk samples. Regression analysis of yolk conversion efficiency in the embryo was found to be over 100%, suggesting that there is an alternate route for energy input other than the yolk.

36C * **BACKEY, JOAN M.; DICKSON, KATHRYN A.** *California State University, Fullerton Department of Biological Science 800 N State College Blvd. Fullerton, CA., USA 92831*

A comparison of lactate processing in endothermic and ectothermic sharks

When compared with ectothermic shark species, lamnid sharks have higher activities of lactate dehydrogenase (LDH) in the fast, glycolytic myotomal muscle (white muscle, WM) used to power high-speed bursts. Lamnid sharks produce large amounts of lactate from WM glycogen, which may subsequently be oxidized or used to resynthesize glycogen. In fishes, it is believed that gluconeogenesis occurs within the WM, yet the gluconeogenic potential of lamnid shark tissues has not been reported. To assess this, we measured the activity of four enzymes required for gluconeogenesis (pyruvate carboxylase, malic enzyme, phosphoenolpyruvate carboxykinase, and fructose-1,6-bisphosphatase) in the WM, liver, red muscle (slow, oxidative muscle), and heart ventricle of the short-fin mako shark (*Isurus oxyrinchus*). Pyruvate carboxylase was not detected in any tissue samples. Malic enzyme activity was highest in the heart and red muscle of the mako shark. Fructose-1,6-bisphosphate activity was greatest in the liver and white muscle tissues. Phosphoenolpyruvate carboxykinase activity was greatest in the liver tissue and was not detected in WM. Because pyruvate carboxylase was not detected, it appears that none of the four tissues studied can carry out gluconeogenesis using the pathway known to occur in other vertebrates. However, if the reaction catalyzed by pyruvate kinase (PK) can be reversed, as has been suggested for teleosts, then gluconeogenesis may be possible. Because the PK activity is high in mako shark WM, we are currently investigating if the WM PK can catalyze the conversion of pyruvate to phosphoenolpyruvate for gluconeogenesis.

37 * **DUONG, CINDY A.; POWERS, AMANDA; DICKSON, KATHRYN A.** *California State University, Fullerton, Department of Biological Science, 800 N. State College, Fullerton, CA 92834, USA*

The contribution of mitochondrial proton leak to heat production in lamnid sharks

Endothermic fishes can elevate the temperature of certain tissues above water temperature through adaptations in the circulatory system (counter-current heat exchangers) that conserve metabolically generated heat. Although adaptations for heat retention in endothermic fishes have been well studied, sources of heat production in endothermic tissues are not well understood. Proton leak is an intrinsic, non-enzymatic property of the inner mitochondrial membrane that may serve as a heat source in endothermic fishes. This study involves comparing mitochondrial proton leak rates of two endothermic tissues in the short-fin mako 50 shark (*Isurus oxyrinchus*): red muscle and liver. The rate of proton leak across the mitochondrial membrane is a non-linear function of membrane potential and is measured by titration of respiration rate with inhibitors of the electron transport chain. The respiration rate and membrane potential in isolated mitochondria was measured simultaneously using

a Clark-type polarographic oxygen electrode and a lipophilic probe (TPMP+), respectively. Based on preliminary measurements, mitochondrial proton leak rates are similar in the red muscle and liver of the mako shark. Ongoing experiments include measuring mitochondrial proton leak rates of red muscle and liver in ectothermic sharks for a comparative study, as well as determining mitochondrial densities of these endothermic tissues.

38C * **FANGUE, NANN A.; RUMMER, JODIE L.; BENNETT, WAYNE A.** (NAF)
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Comparative batoid thermal tolerance

Most of what is known about temperature's effects on distribution and activity of elasmobranchs comes from anecdotal field descriptions. The purpose of our study was to empirically model the relationship of acclimation temperature on upper and lower thermal tolerance of three batoid species from different thermal habitats and use these data to construct ecological thermal tolerance polygons defining each species' thermal niche as an aerial measure ($^{\circ}\text{C}_2$). The Atlantic stingray, *Dasyatis sabina*, was the most eurythermic species with a polygon area of 978 $^{\circ}\text{C}_2$. Conversely, the blue spotted ribbontail stingray, *Taeniura lymma*, and big skate, *Raja binoculata*, from equatorial Indonesia, and the cold California coast, respectively, were stenothermic species with polygon areas of 350 and 216 $^{\circ}\text{C}_2$. The Atlantic stingray encounters a wide range of seasonal temperatures from nearly freezing to over 35 $^{\circ}\text{C}$, and demonstrated marked gains in cold or heat tolerance as acclimation temperatures change. Conversely, the big skate, limited to deep, cold, stable waters off the Pacific west coast, exhibited almost no change in thermal tolerance as acclimation temperatures changed. Stenothermic blue spotted ribbontail stingrays showed a hyperthermal polygon pattern with moderate changes in polygon area relative to changing environmental temperature. The three species tested in our experiments clearly demonstrate that elasmobranchs have evolved sophisticated thermal strategies to exploit a wide range of thermal habitats.

39 * **LACY, ERIC R.; COLGLAZIER, JOAN; VAZQUEZ-MARTINEZ, RAFAEL**
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Acid-base and osmo-regulation in the Atlantic stingray: possible role for coelomic fluid

Elasmobranch fish maintain solute and acid/base balance by regulating transepithelial transport across the epithelia of the gill, kidney and rectal gland. Another possible regulatory site is the epithelium surrounding the coelomic cavity that secretes fluid into that space. Coelomic fluid in many lower vertebrates including elasmobranch fish can exit the body via paired abdominal pores, two slit-like openings adjacent to the cloaca. Analyses were made of solutes (Na^+ , K^+ , Cl^- , protein, urea) and pH in coelomic fluid (CF), plasma (PL), and in surrounding seawater of male and female euryhaline, Atlantic stingrays, *Dasyatis sabina*, adapted to full-strength and dilute Charleston, SC Harbor seawater. The PL and CF osmolality values were nearly at unity with the full-strength ($\gg 900$ mOsm) seawater. Concentrations of cations and anions in CF and PL were approximately 25-50% less than in the surrounding fullstrength seawater. Urea concentrations in CF and PL were nearly at unity. CF pH was acidic (5.1-5.4) compared to PL (7.1-7.3) and seawater (7.6-7.7). Transfer of rays to diluted seawater (451 mOsm) for 24 hrs reduced CF and PL osmolality (17% and 20%, respectively), and concentrations of Na^+ , Cl^- , and K^+ in PL and CF. Urea, a major osmolyte in marine elasmobranchs, decreased only 5% and 8% in PL and CF, respectively. The CF pH remained markedly acidic (pH 5.7) in dilute seawater conditions. These results suggest that the coelomic epithelium may act as a selective transport site of solutes and hydrogen/bicarbonate ions to maintain the acid base and solute homeostasis in stingrays in concert with coelomic fluid excretion through the abdominal pores.

40C * **MANDELMAN, JOHN W.; FARRINGTON, MARIANNE A.** (JWM) *Northeastern*
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The physiological effects of commercial fishing on the spiny dogfish (*Squalus acanthias*)

Despite the wealth of current literature related to the physiological responses of teleosts (primarily salmonids) to exhaustive activity and the typical stressors associated with commercial-fishing, little

study in this realm has addressed the responses and resulting fitness of elasmobranchs, namely those harvested directly. The spiny dogfish (*Squalus acanthias*) is currently an extremely controversial NW Atlantic ground-fishery, whose actual population calculations are heavily debated among regulators and fisherman. It is highly established that female spiny dogfish possess incredibly long gestation periods and very small litters. Robust females are the larger of the two sexes and most coveted by fishermen when the fishery is directed. Of particular interest is the (discarded) bycatch mortality of the spiny dogfish and the associated stress indicators due to commercial-fishing. These findings will enable the derivation of more accurate population figures while arming regulators with data to help implement appropriate measures in the best interest of maintaining the maximum sustainable yield of the species. Concurrently quantifying the stress indicators allows one to speculate and pinpoint the physiological causes (in addition to physical causes) of post-release discard mortality. Blood samples were taken via caudal peduncle puncture from 230 spiny dogfish across three separate treatments and five separate MW to NW Atlantic sampling expeditions during the course of 2002. In accordance with the conventional haematological stress parameters, deproteinized whole-blood lactate, whole-blood hematocrit, plasma protein, and serum levels of glucose, Cl⁻, K⁺, Na⁺, and osmolality were measured from blood taken immediately following normal ottertrawl, longline and relative short-term captivity. Hematocrit levels of the dogfish captured by 83 otter-trawl were significantly higher than those taken by the less exhaustive longline and the pseudo-controlled captive environments, suggesting that dogfish release a greater amount of red blood cells upon exhaustive aerobic activity associated with otter-trawl fishing.

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Reproductive biology of Pacific angel shark *Squatina californica* at the South Western Gulf of California

Squatina californica is a body flattened shark with sandy benthonic habits. Its pectoral expanded and very developed fins seem to be wings, what gives to this shark its name. In Mexico is captured in directed fisheries or as secondary fishery at shrimp one, and is one of the most 87 important sharks for regional commerce. A description of reproductive biology of the Pacific angel shark (*S. californica* Ayres, 1859) is presented. 376 organisms were obtained in four fishing camps from September 2000 to May 2002. Pacific angel shark showed a sexual ratio of 1.41 F: 1 M in adults, while at embryos the proportion was 1 F: 1 M. Sizes for this region vary from 30 to 99 cm with dominant sizes between 60 y 90 cm. First sexual maturity size for both genders was at 80 cm TL. There were captured 26 gravid females, with a range from 1 to 11 embryos by female, at different stages of development, for a total count of 104 embryos. Fecundity was measured by number of embryos by female, and has its larger frequency between 5 and 6. Females with greater fecundity measured from 85 to 90 cm TL. Also histological processes are applied to testis of males in order to describe them and to know the spermatid development stages.

42 * ALMEIDA, MAURICIO P.; CHARVET-ALMEIDA, PATRICIA; VIANA, ANDERSON S. *Museu Paraense Emílio Goeldi, Coordenação de Zoologia, Setor de Ictiologia, Avenida Perimetral 1901, Terra Firme 66077-530, Belém, Pará, Brazil*

Polychromatic and morphometric aspects of the freshwater stingray *Potamotrygon scobina* (Chondrichthyes: Potamotrygonidae) (Pará, Brazil)

The potamotrygonid stingrays are the only elasmobranchs completely adapted for living in freshwater environments and are restricted to some Neotropical river basins. Dorsal color patterns have been widely used as important criteria in the identification of freshwater stingrays. The intra-specific dorsal color variability (polychromatism) that occurs in the Potamotrygonidae Family almost always results in misidentifications or the use of different designations for a same species. A total of 385 specimens was capture in the Marajó Bay region during the years of 2000, 2001 and 2002. All of them were previously identified as *Potamotrygon scobina*. These specimens were separated into two size groups that included 80 neonates / juveniles and 305 sub adults / adults. A dorsal color pattern characterization study was carried out considering the shape, distribution and presence / absence of previously defined figures. Three dorsal color patterns were observed for neonate / juveniles individuals and four patterns were verified for sub adults / adults specimens. The sub adults and adults

specimens had 31 external morphometric measurements taken that were submitted to multivariate statistical analysis. Principal Component and Discriminant Function Analysis were used to verify the existence of differentiated groups. The results obtained indicated that all four color patterns overlap and that no particular group was formed. Results also indicated that the *P. scobina* specimens sampled formed a single group independent of the variations among the dorsal color patterns. Conclusively, two new color patterns were described for neonate / juvenile specimens and three new patterns were included for sub adult / adults. Extreme care is recommended when using uniquely dorsal color patterns to identify potamotrygonid freshwater stingrays.

43 * **DIAZ DE ASTARLOA, JUAN M.; MABRAGAÑA, E.** (JMDA) *Departamento de Ciencias Marinas, Facultad de Ciencias Exactas y Naturales, Universidad Nacional de Mar del Plata, Funes 3350, B7602AYL, Mar del Plata, Argentina. Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET); (EM) Museo del Mar, Mar del Plata, Argentina*

***Bathyraja cousseau* sp.n., a new softnose skate from the southwestern Atlantic (Rajiformes, Rajidae)**

A new species of the rajid genus *Bathyraja* Ishiyama is described from the southwestern Atlantic. The description was based on 20 specimens collected from off northern Patagonia and southern Malvinas Islands. Methods for making measurements and counts followed standard procedures. One mature male and one mature female were dissected in order to examine the skeletal structures (neurocranium, scapulocoracoids and claspers). The specimens exhibit a rhomboid-shaped disc, its length 0.5 times in total length. Preorbital length 2.41 - 2.93 times interorbital distance. A large and more distinct round pale area ocellus-like, margined with dark brown on posterior part of each pectoral base of the upper side of disc. Lower surface of the disc largely creamy- white, with posterior margins of pectoral fins, and edges of posterior lobes of pelvic fins narrowly edged dusky brown. Underside of tail almost entirely dark-brown. Upper surface of disc completely covered with numerous small spinules, also placed on interorbital area, tail, dorsal fins and posterior pelvic lobes. No ocular thorns. A row of 7 to 9 strong thorns in a median dorsal line (two of them set on the nuchal and 1 to 2 thorns on the suprascapular regions). No gap between nuchal-suprascapular and the anterior median thorns. Tail with 16 to 18 strong midrow thorns extending from axil of pelvic fins to the first dorsal fin. Males with elongated, slender rod-shaped claspers. Dorsal fins densely spinulose, close to the end of tail and with no space between them. Ventral surface of disc, pelvics, claspers and tail without of dermal denticles. Besides the external morphological features, skeletal characteristics are also analysed, and are compared with those of other congeneric species. *Bathyraja cousseau* n. sp. was named in honor of Prof. Dr. María Berta Cousseau who has been contributing greatly to the marine fishes of Argentina.

AES Physiology, Conservation & Fisheries Sunday June 29, 8:00-12:00.

MIRACLE, ANN L.; * WALSH, CATHY J.; ANDERSON, MICHELE K.; LITMAN, RONDA T., LITMAN, GARY W.; ROTHENBERG, ELLEN V.; LUER, CARL A. (ALM, RTL; GWL) University of South Florida, Department of Pediatrics, Children's Research Institute, 140 Seventh Avenue South, St. Petersburg, FL 33701, USA; (CJW, CAL) Mote Marine Laboratory, Center for Shark Research, 1600 Ken Thompson Parkway, Sarasota, FL 34236, USA; (MKA, EVR) California Institute of Technology, Division of Biology 156-29, 1201 East California Boulevard, Pasadena, CA 91125, USA

Ontogenetic expression of lymphocyte-specific genes implicate unique lymphoid tissues in generating elasmobranch immune repertoire

The expression of immunoglobulin (Ig), T-cell receptor (TCR), recombination-activating gene-1 (Rag-1), and terminal deoxynucleotidyl transferase (TdT) genes was used to identify the roles of lymphomyeloid tissues during the 12-weeks of embryonic development and after hatching in the clearnose skate, *Raja eglanteria*. At 8 weeks of embryonic development, Ig and TCR genes are sharply up-regulated. Throughout embryogenesis, TCR and TdT expression is limited to thymus, suggesting this site as a primary source of T-cells as it is in mammals. TCR expression is not detected in peripheral sites (spleen and intestine) until after hatching and in adults, implicating these tissues as potential secondary lymphoid sites. High levels of expression of both Rag-1 and TdT in the thymus are consistent with rearrangement and junctional diversification, respectively, of TCR genes. B-cell expression is more complex. Beginning at 8 weeks of embryogenesis, highest relative abundance of IgM and IgX expression is seen in the spleen while at the same stage, IgX is expressed in greater abundance relative to IgM in Leydig organ, liver, and even thymus. The coincidental embryonic expression of Ig and Rag-1 genes in spleen, liver, Leydig organ and gonad suggests that B-cell development occurs at multiple sites in contrast to the apparent restriction of T-cell development to the thymus. The substantial Ig gene expression in embryonic thymus raises the possibility that thymus could be an additional early site of B-cell development. In adult skates, greatest expression of IgM and IgX is in the Leydig organ.

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Evolutionary origins of lymphocytes: mapping emergence of T-cell and B-cell transcriptional networks in early vertebrates

The evolutionary origins of lymphocytes can be traced by phylogenetic comparisons of key genetic features. Homologs of rearranging T-cell receptor and immunoglobulin (B-cell) receptor genes have not been identified in any extant life form more phylogenetically primitive than cartilaginous fish, even though homologs of transcription factor genes essential for the development of T-cells and B-cells are present throughout all vertebrate and most invertebrate groups. Examination of gene sequences, gene duplication, orthology, and conservation of DNA binding domains for transcription factor genes can help define the emergence of lymphocytes early in vertebrate evolution. Using a representative elasmobranch, the clearnose skate, *Raja eglanteria*, homologs of transcription factor gene families, including GATA-3, EBF-1, and various PU.1 and Ikaros family members have been identified and have been shown by sequence similarity and domain structure to be orthologous to higher vertebrate counterparts, including mammals. Structurally, these factors show high homology to their mammalian counterparts in every known functional domain. Co-expression of transcription factors and antigen receptors within specific tissues indicates conserved use of T-cell versus B-cell factors. One striking difference from mammals is an unexpected divergence in the use of certain B-cell factors into separate tissues. The results indicate that portions of the gene regulatory networks that operate in mammalian T-cell and B-cell development were present in the common ancestor of

mammals and cartilaginous fish, at the time that rearranging antigen receptors emerged.

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Maternal investment of thyroid hormones in the embryonic bonnethead shark, *Sphyrna tiburo*

The normal development of vertebrates depends on the presence of thyroid hormone (TH). TH influences the basal metabolic rate, differentiation of the central nervous system, skeletal and somatic growth, and sexual maturation. The presence of TH has been detected in the egg yolk of teleost fish and has been shown to positively influence growth and survivorship of offspring. This study verifies the presence and concentration of TH in the egg yolk of the placental viviparous Bonnethead shark, *Sphyrna tiburo*. Sharks were collected from three sites along the Florida gulf coast. TH in shark yolk and maternal serum are quantified by use of radioimmunoassay (RIA). In addition, the thyroid gland of the embryonic shark is examined histologically for the endogenous production of TH.

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Is angiotensin II a ubiquitous regulator of elasmobranch interrenal gland steroidogenesis?

The presence of the renin-angiotensin system (RAS) has recently been indisputably established in elasmobranchs, but its role in elasmobranch physiology is still unclear. In other vertebrates, angiotensin II (AII) stimulates the synthesis of mineralocorticoids (MC), which subsequently act as antinatriuretic factors. The elasmobranch interrenal gland produces a unique steroid (1 α -3 β -hydroxycorticosterone; 1 α -B) with MC activity, but conflicting evidence exists regarding the AII-dependent regulation of its synthesis. To better define the role of AII in the elasmobranch interrenal gland, we used degenerate primers in coupled reverse transcription/polymerase chain reactions (RT-PCR) to isolate sequence of the AII receptor (AT₁) mRNA from the euryhaline elasmobranch *Dasyatis sabina*. These reactions produced a product of the expected size. Subsequent sequence analysis revealed this product to be 70% identical to the eel AT₁ receptor mRNA. Specific primers used in RT-PCR indicated the expression of AT₁ mRNA in a variety of *D. sabina* tissues, including the interrenal gland. Quantitative PCR indicated no significant difference in the steady-state expression of AT₁ mRNA between interrenal glands of fresh water-adapted and seawater-adapted *D. sabina*. The sensitivity of the elasmobranch interrenal gland to AII is probably governed by other factors, such as circulating AII concentrations and/or post-translational modification of AT₁. The expression of AT₁ in the interrenal gland of *D. sabina* is an indication that RAS impinges upon the function of the interrenal gland. As 1 α -B synthesis is the primary function of the elasmobranch interrenal gland, steroidogenesis is the most likely target of RAS regulation.

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Gastric pH changes associated with feeding: using pH to study the foraging ecology of sharks

Little is known about the feeding chronology of elasmobranchs due to their high mobility, potentially large size, and difficulties in captive maintenance. Changes in gastric pH of leopard sharks (*Triakis semifasciata*) were quantified as an indicator of feeding periodicity, frequency and daily ration. Adult leopard sharks were fed automated pH/temperature data loggers and subsequently fed meals of squid for periods ranging from 5-14 d. Ration size was varied 44 between 0.1-2.1 % of the sharks body weight. To determine the effect of the pH probe on acid secretion, gastric samples were taken from juvenile leopard sharks at different time intervals after feeding and pH was measure externally. In situ, continuous measurements of pH shows that empty stomachs have a low pH of 1.54 \pm 0.46 (SD) and that feeding causes a rapid increase in pH followed by a more gradual return to baseline levels. There was a strong positive relationship between change in pH and meal size ($r_2=0.72$, $p=0.001$). Lab serial

sample measurements show that pH 1 h after a meal was 3.31 ± 0.35 , whereas 96 h after a meal pH had dropped to 1.75 ± 0.24 . There were no significant differences in pH between continuous in situ, and lab serial sample measurements. Gastric acid secretion may be continuous in leopard sharks and may offer a mechanism to increase digestive efficiency of sharks. Changes in gastric pH can be used to estimate feeding periodicity, frequency and daily ration size in leopard sharks in the wild.

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Organochlorine contaminants in sharks of the U.S. east coast

Even at sub-lethal concentrations of exposure, organochlorine contaminants such as pesticides and industrial chemicals pose significant health hazards to marine organisms. These compounds have been associated with a variety of health disorders in several taxa, especially those inhabiting increasingly degraded nearshore and estuarine habitats. Due to use of such regions as pupping and/or nursery grounds, certain shark species are often exposed to organochlorine contaminants at concentrations that may have detrimental effects on embryonic development, maturation, growth, and/or reproductive activity. However, despite the risks that such effects pose to these fishes, few studies have investigated the levels of these compounds in elasmobranch populations. To address such concerns, the present study describes organochlorine levels in three shark species (the bonnethead shark *Sphyrna tiburo*, blacktip shark *Carcharhinus limbatus*, and the sandbar shark *Carcharhinus plumbeus*) inhabiting estuaries and nearshore regions of the east coast of the United States. Topics including routes of exposure and potential effects of contaminant accumulation are discussed.

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Case studies of elasmobranch husbandry at Oceanário de Lisboa II

During 2002 Oceanário de Lisboa introduced two large *Mobula mobular*, one large *Manta birostris* and two small *Prionace glauca* in its Opean Ocean 5.000 m³ exhibit. Notes on the husbandry challenges created by the introduction of such unusual species are given, with regards to feeding and general behavior.

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Distribution, abundance and reproductive biology of the blue shark *Prionace glauca* in the Southeastern Pacific Ocean

Prionace glauca is a cosmopolitan oceanic species fairly well known in most oceans, however there is a lack of information about its distribution, abundance and reproductive biology in the Southeastern Pacific off Chile. In order to determine the distribution, abundance and reproductive cycle of the blue shark in the Southeastern Pacific off Chile, a sampling program was conducted onboard artisanal and industrial longline boats that operate in international waters off the Chilean EEZ. The study period was between November 2000 and August 2001 and the study area covered from 24° 07' S to 37° 13' S, off the Chilean coast. The sex proportion showed a dominance of males in the captures, which is coincident with the spatial sexual segregation hypothesis proven in several world oceans. A macroscopic sexual maturity scale was developed using the onboard experience, finding sexually mature female specimens with offspring and spent in over 145 cm TL sizes. Considering the external morphological male sexual characteristics, the best maturity indicator was the clasper texture, being the largest percentage of mature specimens found at sizes of 195 cm TL or over. The birth period in the study area was determined to be between July and November, being 52 cm TL the birth size. The mean fecundity was determined to be 33 offspring, with a range between 3 y 62 offspring per female. Our findings are compared with those of other studies in other oceanic areas. Financed by Fisheries Research Fund, Chile, (Proyecto FIP 2000-23).

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Observations of shark by-catch from the artisanal driftnet fishery in the central coast of Venezuela

The artisanal fishery at Playa Verde, located in the central coast of Venezuela, has the most landings of billfish in the country. Shark by-catch represents, after frigate fish, the third group in importance in these landings. This study describes the species composition, biometry, sexual maturity and CPUE of shark landings from two periods: September 1998 – July 1999 and February – May 2002. Twelve species of sharks, belonging to seven families and four orders, were identified. The most common species landed were, in order of decreasing abundance: *Carcharhinus falciformis*, *Isurus oxyrinchus*, *Sphyrna lewini*, *Prionace glauca* and *Alopias superciliosus*. Through a comparative analysis of size structures and sexual maturity stages, adult individuals of *A. superciliosus*, *Carcharhinus obscurus*, *I. oxyrinchus*, *Isurus paucus*, *P. glauca*, *Pseudocarcharias kamoharui* and *S. lewini*, were observed. However, only pregnant females of *A. superciliosus*, *C. obscurus* and *S. lewini* were recorded. The sex ratio of *I. oxyrinchus* (3M:1F) and *S. lewini* (1M:6,7F) deviate significantly from the expected ratio (1M:1F). The largest shark abundance was observed during the first seven months of the year, coinciding with the upwelling period. Yearly CPUE values showed a decreasing trend in 1992-1999, with a slow recovery thereafter. The shark composition reported at Playa Verde, was more similar to those observed by oceanic commercial longliners of tuna and swordfish than from artisanal fisheries from the eastern coast of Venezuela.

* **ARAUZ, RANDALL M.; BALLESTERO, JORGE L.** *Programa Restauración de Tortugas Marinas / Costa Rica. 1203-1100, Tibás, San José, Costa Rica* A review of shark fisheries in Central America; species composition, historical catch and fishing effort data, and management issues Shark fisheries in Central America have taken place in coastal waters for decades. By the late 70s, these fisheries were showing signs of overfishing. Longline fisheries were introduced in Costa Rica in 1982, and by 1988 the fleet included over 500 vessels. Costa Rica allows the landing of shark products from international longline fleets (over 100 vessels) with no control. Piracy is a common problem, as well as landing of fins alone, against Costa Rica regulations that demand fins attached. Shark fins from this industry are exported to Taiwan. Carcasses are exported to El Salvador and Guatemala, for processing of steaks and export to Mexico. Local fishermen of these countries can no longer supply the market. Catch rates of sharks during longline operations in the EEZs of Costa Rica and Nicaragua during the last 10 years are examined, including catch data from an ongoing project. Management recommendations to mitigate impact are closures, limit landing operations of international fleets and initiate reporting by international and national fleets alike, evaluate use of off set circle hooks, blue bate die and dehookers, and provide funding for education of fishermen programs.

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Collapse of shark fishery in the Gulf of California, Mexico

During 1995 to 2002 we visited two fishing camps in the Gulf of California, Mexico: San Francisquito and El Barril, B.C., there, elasmobranch fishery is artisanal; fishermen use 22ft vessels, drift-gillnets (10-12in sms) for big sharks, and bottom-gillnets (6in sms) for small sharks, skates and rays. We observed elasmobranch catch composition. Shark's CPUE was calculated based on landing registries of June and July 1991, 1994 and 2002. We also did a census in a carcasses' waste ground to compare with catch composition. Main organisms caught with driftgillnets were individuals of families: Charcharhinidae, Sphyrnidae and Alopiidae. *Rhinobatos productus* and *Mustelus californicus* were the main species caught with bottom-gillnets. Although the Gulf of California is an important shark congregation area to mate and as nursery, due to overfishing, results show a decreasing tendency of CPUE, reaching a collapse in July 2002, when companies had to stop fishing in the middle of the season.

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Shark management in the United States Atlantic Ocean: status, challenges, and options

The Highly Migratory Species (HMS) Management Division of the National Marine Fisheries Service (NOAA Fisheries) has initiated development of Amendment 1 to the Fishery Management Plan (FMP) for Atlantic tunas, swordfish, and sharks based on the results of the 2002 stock assessments of large coastal sharks (LCS) and small coastal sharks (SCS). The amendment will establish rebuilding plans for overfished shark stocks and actions to prevent overfishing of other shark stocks. The amendment will also address concerns regarding bycatch of protected and prohibited species and exempted fishing permit processes. Challenges facing domestic Atlantic shark management include the need to improve knowledge of essential fish habitat, the lack of a current stock assessment for pelagic sharks, the lack of detailed biological data for some species, the demand for increased observed coverage, as well as widespread problems with species-specific identification and the subsequent problems confounding 42 species-specific management. The options in the rule will be based on the 2002 LCS and SCS stock assessments as well as comments received during public meetings held in February and March of 2003. Management options include, but are not limited to, quotas, trip limits, methods to account for mortality, time and area closures, recreational retention limits, gear limitations, and landing requirements.

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Shark essential fish habitat

The Magnuson-Stevens Fishery Conservation and Management Act defines essential fish habitat (EFH) as those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity. The National Marine Fisheries Service (NMFS) regulatory interpretation of this Act requires that EFH be described and identified within the U.S. Exclusive Economic Zone for all life stages of each species in a fishery management unit. Shark species managed under the NMFS Final Fishery Management Plan for Atlantic Tunas, Swordfish, and Sharks are found in a variety of habitats and have diverse life history characteristics. Many of these shark species are highly migratory and cover a variety of areas and habitats during their seasonal migrations. Habitat preferences for some species also differ during changes from one life history stage to the next. These differences combined with the paucity of life history information available for many species create unique problems in the determination of shark EFH. These problems will be discussed and updated information regarding NMFS shark EFH designations will be presented.

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Freshwater stingray conservation program at Amazonas State, Brazil

The neotropical stingray family Potamotrygonidae is the only Elasmobranch group in which all members live in freshwater environments. Freshwater stingrays have the same life-cycle limitations of marine forms, in addition to their environmental limitations. It is these environmental limitations that have brought the fish into closer contact with humans, and has produced in a stronger antagonism between fish and people. Much of this antagonism stems from the injury caused by the sting, which results in a serious infection. To avoid accidents, riverine people often mutilate or kill freshwater stingrays. In the last decade, however, the exotic colors of these species have made them popular

attractions in public aquariums and among fish hobbyists. Their importance as ornamental fish has grown to the point that 23.500 freshwater stingrays are now exported annually from Manaus. At least five species are represented in this trade: *Potamotrygon motoro*, *Potamotrygon orbignyi*, *Potamotrygon schroederi*, *Paratrygon aiereba* and a yet undescribed species of *Potamotrygon*. To regulate the ornamental fishery in freshwater stingrays, an export quota was developed for the species that represent 25 most exports (Law no. 22/98; IBAMA 1998). The ornamental fish industry has assumed the responsibility for the conservation program of freshwater stingrays. This program is considering not only the action of ornamental fishermen on the populations, but also the changes in their environment and the impact of the negative fishery used to reduce populations around centers of human activity.

AES Life History/Ecology II Sunday June 29, 1:30-4:45.

100 * **MCLAUGHLIN, DONNA M.; MORRISSEY, JOHN F.** *Department of Biology, 114 Hofstra University, Hempstead, NY, 11549-1140, USA*

Reproductive biology of *Centrophorus cf. uyato* from the Cayman Trench, Jamaica

Centrophorus is a genus of family Squalidae in order Squaliformes. Members of *Centrophorus* typically are gray to brown, with large green eyes, spines anterior to both dorsal fins, and pectoral fins that often have a free rear tip that extends well under the first dorsal origin. They are most abundant below 200 meters depth. The organism in this study may be a species of *Centrophorus* that has not been described previously. Unfortunately, the taxonomy of this genus is currently in a great deal of uncertainty. The characteristics of this species most closely resemble those of *Centrophorus uyato*, hence our use of *Centrophorus cf. uyato*. Specimens were obtained via horizontal longline at depths of 250-913 meters. The reproductive biology of 8 male and 51 female *cf. uyato* have been examined. This species is sexually dimorphic, with females attaining a larger size than males. The smallest mature male was 81.2 cm total length whereas the smallest mature female was 91.5 cm total length. Females are aplacentally viviparous with a maximum of two pups per litter. The pups acquire nutrition via their large external yolk sacs. There was no evidence of additional maternal contributions to the nourishment of the embryos. Oocytes continued to develop throughout gestation. Most females carrying developing embryos had two large (>3.3 cm), equally developed ovarian oocytes, which leads us to believe that they ovulate soon after parturition. This species seems to exhibit complete sexual segregation during the non-breeding season, with mature males being completely absent from the study site during the summer months.

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A tale of two ovaries: reproduction in the salmon shark (*Lamna ditropis*)

The salmon shark (*Lamna ditropis*) is an apex predator in the North Pacific Ocean. The population dynamics of this species is important for biological and management reasons. In order to understand salmon shark population dynamics in the North Pacific, basic biological traits must be characterized. An understanding of the natural history of the salmon shark, including the reproductive cycle is central to the estimation of demographic parameters for conservation and management. Most of the existing literature about this species is based on the animal's appearance as by-catch in salmon gill nets in the western North Pacific until the early 1980's. However, the salmon shark is highly migratory and these studies cover only a slice of the reproductive cycle. The current study is one of the few focused on reproductive biology. Results are based upon samples from Prince Williams Sound and other locations across the North Pacific Ocean. Research objectives are: estimate size of maturity, seasonality of reproductive events and to study other physiological characteristics of salmon shark reproduction. This is accomplished by examinations of the reproductive tracts, analysis of serum reproductive hormone concentrations and examination histological tissue sections. Results thus far suggest mating by pubescent females and size at maturity, apparent differences in oviductal gland structure pre and post puberty, and anatomical correlations with reproductive hormone concentrations.

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Reproductive biology of silky shark *Carcharhinus falciformis* off the west coast of Baja California Sur

The silky shark inhabits warm-tropical and subtropical waters throughout the world. In the eastern Pacific it ranges from Baja California Sur to Peru. Even though it is heavily exploited in the Gulf of Mexico and in the Pacific coast, its reproductive processes have received little attention. The species appears in the waters off the Pacific coast of Baja California Sur from June to October. Generally, adults are more common in the captures. The overall sex ratio was 1:0.6 females per male (n = 295). Clasper development and the presence of sperm aggregates suggest that males mature at about 182 cm TL, while ovarian egg diameters and the presence of uterine eggs or developing embryos show that female maturation occurs at about 180 cm TL. The reproductive anatomy and the sperm storage of

both male and female are described. Gestation appears to last about twelve months. We noted the absence of a defined seasonality for reproduction in the west coast off Baja California Sur populations.

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Reproduction of blue shark, *Prionace glauca*, in the western coast of Baja California Sur, Mexico

The blue shark *Prionace glauca* is the most abundant shark species in the Baja California waters. It is found all year in the western coast of Baja California Sur. Samples were obtained in the fishing camps of Punta Belcher and Punta Lobos in Baja California Sur, from August 2000 to February 2003. Measurements of reproductive organs, claspers length, length and width of the oviducal gland, and diameter of the biggest oocyte for the determination of the sexual maturity in males and females were used. 974 blue sharks, 627 males and 347 females have been sampled. The biggest abundance was in winter and spring, associated to lowest water temperatures. Males ranged from 81 cm to 270 cm TL; whereas females were from 90 cm to 252 cm. Sex ratio in adults was 2M:1H, which suggests a sex segregation when they reach maturity; whereas in embryos the sex ratio was 1M:1H. Size of first maturity for males is 180 cm TL, and 92 185 cm for females. Most of the juvenile males were found during winter and spring; whereas adults were found in summer. We recorded 35 pregnant females with 33 to 40 embryos in average with different development phases. Size range for pregnant females was 185 cm to 252 cm TL. We did histological analysis, including spermatogenesis in males, and sperm storage in the oviducal glands of females.

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Breeding biology of the lemon shark, *Negaprion brevirostris*: inference through genotypic reconstruction of unsampled adults

We present a new technique involving computer-assisted, manual genotypic reconstruction of unsampled individuals to infer parentage and patterns of breeding in the lemon shark, *Negaprion brevirostris*. By employing nine highly variable microsatellite loci, we used genetic tags of unsampled parents to demonstrate that lemon shark mating is polyandrous, iteroparous 63 and that the same females return biennially to a particular nursery to produce litters of 8 to 18 half-siblings. In contrast, males rarely if ever return to the same nursery. Between 1995 and 2000 we sampled 910 lemon sharks. We determined year-of-birth for 735 young sharks and assigned these young to sibling groups using the program Kinship. We then used the sibling groups to reconstruct genotypes for their unknown parents. We were thus able to assign 710 juvenile sharks to one of 45 female genotypes (96.3%) while 485 (66.0%) were assigned to one of 84 male genotypes. Results demonstrated that adult females reliably and accurately returned to Bimini, Bahamas on a biennial cycle for parturition, and the majority of litters were the result of polyandry (multiple mating with two or more males) by females. However, adult males rarely sired more than one litter at Bimini. Thus, males almost certainly mate over a broader range than females and our finding of low genetic diversity throughout the western Atlantic is likely explained by male-mediated gene flow. Genetic tagging of unsampled adults, based on multilocus genotypes of newborn sharks, proved to be an effective method of unraveling details of the breeding biology of this protected large, coastal, species.

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Reproductive biology and habitat utilization of skates along the eastern Bering Sea continental slope

The reproductive biology and habitat utilization of skates collected along the eastern Bering Sea continental slope was studied (EBSCS). Data were collected during a National Marine Fisheries Service (NMFS) exploratory research cruise along the EBSCS during June-July 2002. A total of 1,330 specimens comprised of nine species were examined for reproductive information. The survey area extended the length of the EBSCS from northwest of Unalaska Island (55° 95'N, 168° 51 92'W) to the southern Navrin Canyon (60° 16'N, 179° 68'W) in waters ranging from 209 to 1,556 m deep. The survey area was divided into two strata types, one by area and another by depth. The EBSCS can be characterized by three distinct habitats; a broad, gentle, sloping area referred to as shelf habitat, areas bisected by submarine canyons referred to as canyon habitat, and areas of steep profile referred to as slope habitat. Skates are an important component of the demersal fish community along the EBSCS and are commonly caught in groundfish fisheries. Despite the abundance and diversity of skates in this region very little is known about their basic life history and ecology. The results presented are part of an ongoing, broad-based, study of the demersal chondrichthyan fauna in the eastern North Pacific and Bering Sea.

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Trophic spectrum of Pacific angel shark *Squatina californica* in the southern Gulf of California, Mexico

During September 2000 to May 2002, shark stomach contents were sampled monthly in the southern Gulf of California, Mexico. The objective to our study is to know the spectrum trophic of Pacific angel shark, *Squatina californica*, and their variations by lengths and sex. We apply the Index of Relative Importance as a measure of trophic preferences. A total of 376 stomachs were examined, which 163 (43%) contained food and 213 (57%) were empty. The spectrum trophic was of 22 prey species, 14 fishes, 2 cephalopods and 5 crustaceans, corresponding to 12 family, 11 genus, and 14 species. According to the Index of Relative Importance, the most importance prey were the fishes (67%) and unidentified organic matter (11%), followed by benthic fishes, mainly Daisy Midshipman *Porichthys margaritatus* (6.2%), *Diplectrum spp* (4.1%) and the inotted lizardfishes *Synodus evermanni* (3.6%). The analysis of importance of each sex, indicated that females feed more on fishes and unidentified organic matter, representing 62.4% and 10.5% respectively. The fish *P. margaritatus* (10.9%), *Diplectrum spp* (6.8%), *S. evermanni* (1.8%) and rainbow cusk eel *Ophidion iris* (1.6%); while males, the rest of fishes contributed 71.4% of the food supply, the unidentified organic matter represented 88.3%, the peanut rock shrimp *Sicyonia penicillata* (8.5%), *Diplectrum spp* (5%) and lizardfish *S. evermanni* (3.3%). No significant differences were found in the gravimetric composition of prey species between sexes ($P > 0.05$).

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Stomach contents of pelagic sharks in the Eastern Pacific Ocean

The bycatch of large predators, including sharks is common in the tuna purse-seiner fishing in the Eastern Pacific Ocean. We analyze 508 stomach contents from 6 shark species and three shark groups, which were sampled at sea by observers of the Inter-American Tropical Tuna Commission (IATTC) aboard of vessels from Colombia, Mexico, Panama, and Venezuela. The purse-seine sets yielding the samples were distributed across the geographical range of the EPO tuna fishery during December 1992 through September 1994. Our results including that Blue shark (*Prionace glauca*) predate mainly on cephalopods (decapods), *Argonauta spp.* and *Onychoteuthis banksii*. The Bull shark (*Carcharhinus leucas*) feed on *Auxis spp.* and cephalopods. Silky shark (*C. falciformis*) predate on *Engraulis mordax*, *Cubiceps pauciradiatus* and *Decapterus spp.* The mako shark (*Isurus oxyrinchus*) consumes *Abraliopsis spp.*, *Acanthocybium solandrii*, *Auxis spp.* and *Euthynnus lineatus*. The white nose (*Nasolamia velox*) feed on *Katsuwonus pelamis* and *Thunnus albacares*; whereas the oceanic white tip (*C. longimanus*) predate on *C. pauciradiatus* and *Stenoteuthis oualaniensis*. The group of hammerhead sharks feed on cephalopods (*S. oualaniensis*, *Dosidicus gigas*, and *Abraliopsis falco*). The

group of thresher sharks consumes on epipelagic fishes as *E. mordax*, *C. pauciradiatus* and mesopelagic fishes as *Benthoosema panamense*. The carcharhinid group feed mainly on *E. mordax*. Discussion on width breadth and overlapping between shark species will be shown.

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Trophic ecology of the silky shark *Carcharhinus falciformis* in Baja California Sur

Stomach contents of 264 silky sharks were analyzed. The sharks were caught in Punta Lobos (PL) and Punta Belcher (PB), located in the west coast of Baja California Sur, during summer and fall 2000-2002. Sixty six percent of all sharks contained food in their stomachs. In PL the jumbo squid *Dosidicus gigas* was the main prey species (30.5% of Index of relative importance), whereas the red crab *Pleuroncodes planipes* (44.5% IRI) was in PB. Using the width breadth (Levins Index) and diversity index (Shannon-Wiener), the silky shark is a specialist feeder in both areas, because predate mainly in three species (red crab, jumbo squid and jack mackerel). We found a trophic overlap (Morisita-Horn index) between sexes and between juveniles and adult males.

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The diet of the sandbar shark, *Carcharhinus plumbeus*, in Chesapeake Bay and adjacent waters

Chesapeake Bay, USA and the barrier islands of Virginia's Eastern Shore are important nursery grounds for the northwest Atlantic population of the sandbar shark *Carcharhinus plumbeus* (Carcharhinidae). The abundance of species in the Bay during the summer months (May through October) provides a diversity of prey items for both neonates and returning juveniles. The sandbar shark's role as a predator in the summer food web of Virginia coastal waters indirectly affects commercially important species, and monitoring its diet is an important component of ecosystem-based management. Previous studies of sandbar shark diet have encompassed very small study areas (Chincoteague Bay, VA, USA) and very large areas (from Georges Bank to Cape Hatteras). This study has characterized the diet of *C. plumbeus* in the Chesapeake Bay, Virginia, as well as the adjacent waters Virginia's Eastern Shore, highlighting differences in diet within various portions of the nursery area, as well as ontogenetic changes in diet. Stomach samples were obtained in 2001 and 2002 from 234 sharks caught in gillnets or by longline gear. These data were analyzed using standard diet indices of frequency of occurrence, number, and weight for each prey type. Historical data from the Virginia Institute of Marine Science (VIMS) Shark Ecology program were also analyzed. Ontogenetic changes in diet were evident, with crustacean prey decreasing in importance and frequency with increasing shark size, and elasmobranch prey importance and frequency increasing with increasing shark size. While previous research in Chincoteague Bay, VA showed the blue crab, *Callinectes sapidus*, as the dominant crustacean in sandbar shark diet, the mantis shrimp, *Squilla empusa*, dominated the crustacean portion of the diet in this study.

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Trophic ecology of scalloped hammerhead juvenile (*Sphyrna lewini*) in the Gulf of California

The scalloped hammerhead shark *Sphyrna lewini* is one of the most important species caught in Mexican waters. We describe the feeding habits and evaluate the trophic level of *Sphyrna lewini* in the southern Gulf of California. The scalloped hammerhead shark is caught by fisherman in the SW of the Gulf of California. The methods used were: the Index of Relative Importance (IRI), Prey species diversity (Index of Shannon-Wiener), diet breadth (Levin's standardized Index), dietary overlap by sexes and size (Morisita-Horn Index), and stable carbon ($^{13}\text{C}/^{12}\text{C} = \text{d}_{13}\text{C}$) and nitrogen ($^{15}\text{N}/^{14}\text{N} = \text{d}_{15}\text{N}$) isotopic analysis. A total of 139 stomachs of scalloped hammerhead sharks were analyzed. According to the IRI, the juveniles of scalloped hammerhead feed mainly on demersal and epipelagic fish (*Scomber japonicus*, *Synodus evermanni*, *Sardinops caeruleus*, *Auxis thazard*) and mesopelagic

cephalopods (*Dosidicus gigas*, *Abraliopsis affinis*, *Onychoteuthis banksii*). The diversity of prey species and diet breadth are relatively low 5 ($H\phi = 2.74$ and $BI = 0.16$). These results indicate that scalloped hammerhead shark is a specialist predator considering their preference on few prey species. A significant overlap between sexes was found ($CI = 0.76$). The recorded lengths were lower than 150 cm, therefore they are considered juvenile aggregations and have a dietary overlap among age-groups between 87 and 110 cm and between 119 and 142 cm. The stable carbon and nitrogen isotopic analyses shown that juveniles have a higher trophic position than adults of this species. No difference in the trophic position was observed between sexes. Bahia de La Paz is believed to be the *Sphyrna lewini* nursery zone.

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Feeding habits of the dominant ray species in the Almejas Bay (B.C.S., Mexico) artisanal fishery

Rays are one of the most abundant and ubiquitous groups of fishes in tropical and subtropical marine nearshore environments, where they often occupy high trophic levels. Global fishing pressure has increased on rays, typically without regulations or catch records. In Almejas Bay, Baja California Sur, an artisanal ray fishery operates primarily from April through August. Sampling of rays from this fishery for diet composition was conducted at Puerto Viejo, in June 1998-2000 (20 days, 34 vessel trips) and August 1998-1999 (35 days, 92 vessel trips), with 62 supplemental samples collected in 2001 and 2002. Of 4,035 elasmobranchs landed among at least 22 species, four species (*Rhinobatos productus*, *Dasyatis dipterura*, *Narcine entemedor*, and *Gymnura marmorata*) comprised 91.7% of the catch. Sex ratios, length frequencies, CPUEs (number/vessel) and a description of the fishery will be presented. This fishery peaked in June (total CPUE = 42.74), targeting mainly gravid female *R. productus* (CPUE = 21.48) and *N. entemedor* (CPUE = 10.74). In August, the fishery operated at a diminished capacity (total CPUE = 22.30), subsisting primarily on resident populations of *D. dipterura* (CPUE = 9.46) and *G. marmorata* (CPUE = 4.74). Stomachs and foreguts excised, preserved, and examined from 2,184 total specimens provided data on ontogenetic, intergender, and interannual differences in diet and facilitated comparisons of dietary overlap. *Rhinobatos productus* preyed primarily on crustaceans (shrimp and crabs) and, to a lesser extent, polychaetes with fishes also taken by large specimens. All sizes of *G. marmorata* consumed exclusively teleost fishes with a single occurrence of a squid. The diet of *D. dipterura* consisted mainly of epibenthic and infaunal invertebrates, including pea crabs, small bivalves, and polychaetes. *Narcine entemedor* fed primarily on polychaetes, sea slugs, and eels. The diets of these species did not exhibit a high degree of overlap, potential facilitating their coexistence.

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Feeding kinematics of the leopard shark *Triakis semifasciata* Girard 1854: an ontogenetic perspective

Though limited, research regarding ontogenetic changes in the feeding kinematics and behavior of elasmobranchs suggests that substantial changes may occur during neonatal stages. These changes are hypothesized to correlate with predator abilities, prey attributes, and/or changes in fluid dynamics. To establish whether ontogenetic changes in feeding kinematics occur in the leopard shark *Triakis semifasciata* and begin to investigate the basis for these changes, a Redlake high-speed digital video camera filming at 250 fields/s was employed on a weekly basis for one year to record prey capture events in four individuals feeding on five prey types. Several external morphological characters associated with the feeding apparatus of the sharks were also measured on a weekly basis throughout this year. When feeding on dead prey, average bite duration showed a gradual but significant increase (110 - 125 ms) over time, as did the majority of other timing variables. By contrast, timing variables within an individual generally decreased over time when feeding on live prey. Excursion variables tended to decrease in magnitude within an individual over time, with the exception of hyoid depression. The result of this discrepancy is that sharks employed a functionally smaller oral aperture and depressed their hyoid relatively more as they aged. These changes in kinematics were accompanied by negative allometric increases in mouth width and positive allometric changes in mouth length, causing the mouth to become narrowed anteriorly and elongated, presumably facilitating suction feeding. Though suction feeding was used with dead prey over the duration of this study, leopard sharks adopted a ram-dominated feeding modality with respect to live prey as time progressed, indicating a behavioral rather than morphological alteration. The results of this preliminary study indicate that changes in feeding kinematics occur in young leopard sharks and that these changes have both behavioral and morphological bases.

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Like a rock: structural properties of the shark vertebral column

There is a common perception that the skeleton of cartilaginous fishes must be inferior to that of bony fishes in stiffness and strength. However, this idea has never been tested, and the functional extrema achieved by some sharks casts doubt on this generality. We examined structural properties and composition of the vertebral column of seven cartilaginous fishes. We chose animals that varied widely in morphology, ecological niche, and inferred swimming speed. Strength, stiffness, % water, % mineral, and % collagen were compared among species. Not surprisingly, strength is correlated with the percentage of mineralized tissue. Shark vertebral centra are similar in stiffness to mammalian trabecular bone (>100 MPa). Average shark centra were 43% water by weight, and dry vertebrae were 47% mineral and 53% dry organic material. The torpedo ray was the only batoid fish in our data set. The ray had lower mineral content and higher water content than the other species and was an order of magnitude less stiff. This trend may be related to the locomotor mode of batoid fishes, as the vertebral column should experience less stress in a pectoral fin undulator than in an axial undulator.

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The sexually dimorphic cephalofoil of bonnethead sharks

We have documented an overlooked sexual dimorphism in the head shape of a common, wellstudied species of shark, the bonnethead *Sphyrna tiburo*. Sexually mature male bonnethead sharks have a distinct bulge along the medial, anterior edge of the cephalofoil. This change in morphology is attributed to the elongation of the three rostral cartilages in the snout of the males at the onset of sexual maturity. A Procrustes analysis revealed that the head shape of adult males differs significantly from adult females and immature males whereas the head shape of embryonic and juvenile sharks does not differ between the sexes. The elongation of the rostral cartilages corresponds temporally with

the elongation of the clasper cartilages in males. We suppose that the same mechanism responsible for stimulating growth of the clasper cartilages secondarily affects the rostral cartilages. If true, the phenomenon of rostral cartilage sexual dimorphism in elasmobranchs may be more widespread than previously imagined. Such a widespread dimorphism would be difficult to detect by eye because of the already pointed snout morphology of most shark species. Our results also have taxonomic implications for the genus *Sphyrna*. Head shape of *Sphyrna tiburo tiburo*, the bonnethead from the Atlantic was compared to *Sphyrna tiburo vespertina*, the Pacific bonnethead shark. A significant difference was again found between the subspecies, with the Pacific specimens of both sexes having a head 32 morphology that more closely resembled mature males from the Atlantic. The Procrustes analysis points out a significant morphological difference that was not apparent to the investigators who synonymized *S. vespertina* into *Sphyrna tiburo*, and perhaps it should be restored to specific status.

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Observations on the skeleton of the heterocercal tail of sharks (Chondrichthyes: Elasmobranchii)

We present new illustrations and descriptions of the skeleton of the heterocercal tail of twelve species of sharks represented by multiple adult specimens. Nine species from the family Carcharhinidae were examined (bull shark, *Carcharhinus leucas*; blacktip shark, *C. limbatus*; dusky shark, *C. obscurus*; sandbar shark, *C. plumbeus*; tiger shark, *Galeocerdo cuvieri*; Atlantic sharpnose shark, *Rhizoprionodon terraenovae*; bonnethead, *Sphyrna tiburo*; great hammerhead, *S. mokarran*; and scalloped hammerhead, *S. lewini*). We also studied one species of Alopiidae (common thresher shark, *Alopias vulpinus*), as well as one species of Ginglymostomatidae (nurse shark, *Ginglymostoma cirratum*) and one species of Triakidae (smooth dogfish, *Mustelus canis*). Our most interesting observations concern anatomical relationships of the hemal arches and hypural elements that support the ventral fin-web of the hypochordal lobe of the caudal fin and the modified neural arches and spines that support the epichordal portion of the caudal fin. The patterns of these skeletal elements differ in many details from the patterns described previously for the heterocercal caudal fin of actinopterygians such as paddlefishes, and these differences offer insight into general aspects of the anatomy of heterocercal caudal fins. This paper is in honor of Hans-Peter Schultze and his many contributions to the anatomy and systematics of vertebrates. Supported by DEB-0075460 and the Jane H. Bemis Fund for Research in Natural History.

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Variation in morphology and function of batoid wing skeletal elements

The skeleton of the wings of skates and rays consists of a series of radially oriented cartilaginous fin rays fanning out from the pectoral girdle. Each fin ray is segmented into small, longitudinally oriented ceratotrichia, traditionally represented as simple cylindrical building blocks. High-resolution radiography reveals the pattern of calcification in ceratotrichia and their organization within the fin ray to be considerably more complex and variable than previously thought. The length, width and branching pattern of these elements varies between families and within genera. In addition we documented the presence of reinforcing projections running between fin rays. The wings are reinforced in different areas in different families, and among animals with different lifestyles (pelagic, semi-pelagic, and benthic). We interpret this variation as a proxy for differential function and performance. There may be useful characters in this morphology of the ceratotrichia for phylogenetic analysis as there is a great deal more variability than has been appreciated. We suppose that further biomechanical investigation of the batoid wing skeleton, including latitudinal stiffness, variation in types of ceratotrichia, and correlations between stiff areas of the wing and swimming mode, will give insight into ancestral swimming modes of batoids.

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Under pressure to swim fast: shark myotomal pressure increases with increasing swimming speed

High speed swimming requires a stiff body to maximize thrust delivered along the main axis of the fish. Swiftly swimming bony fishes have few vertebrae (e.g. 22 in marlins), and have substantial bony zygapophyses that span the intervertebral joints. This results in a very stiff vertebral column, which provides the requisite whole-body stiffness. Some sharks are remarkably fast swimmers, yet they have a large number of discoidal vertebrae (180 precaudal in the mako shark) that seem ill-suited to resisting flexion. In order to obtain a better understanding of the ways in which fish with cartilaginous skeletons perform at levels similar to fishes with bony skeletons, we tested the hypothesis that sharks can dynamically change internal body pressure during locomotion. We implanted pressure transducers in the epaxial musculature of spiny dogfish sharks and swam them in a flow tank at speeds from 0.25 to 1.75 body lengths per second. The myomeric pressure varied sinusoidally over the course of the tail beat cycle, from subambient to superambient, attaining peaks at the extremes of body curvature. Contralateral pressures were 180 degrees out of phase. Intramuscular pressure increased significantly with speed, suggesting a possible mechanism for increasing body stiffness for high-speed swimming. We expect that faster-swimming sharks such as makos and great whites will be pressurized to a greater extent.

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The Odontobase project: first results

The Odontobase project has been created two years ago to permit an identification of chondrichthyan fishes by the mean of their isolated demo-epidermic structures (dermal denticles, thorns, tubercles, bucklers). This identification is based on the study of all species of sharks, skates and chimaeras at different stages of growth and is focused on the morphology of the basal plate, peduncle, crown, on the relations between peduncle and crown and on the presence of superficial relief. Twenty morphological characters have been identified and used in a first attempt in European species. The first results indicate that the characteristics of the isolated dermal structures can be used sometimes to the specific level in some genera (*Somniosus*, *Alopias*) and only at the generic level for other ones (*Scyliorhinus*, Rajidae). These first observations confirm that some genetically and ecologically closely related groups share the same type of dermal covering and permit to question on the validity of some species.

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Comparative morphology of dermal denticles of *Rhizoprionodon* (Elasmobranchii, Carcharhinidae) and related genera

The morphology of dermal denticles in six species of *Rhizoprionodon* (*R. lalandii*, *R. porosus*, *R. terraenovae*, *R. oligolinx*, *R. acutus* and *R. taylori*), *Loxodon macrorhinus* and *Scoliodon laticaudus* were comparatively investigated by optical and Scanning Electron Microscopy. Ontogenetic variation was estimated on the basis of growth series of *R. lalandii*. Dermal denticles of mouth floor, nictitating eyelid, anal fin, clasper and lateral trunk were examined in search of phylogenetically informative characters. Comparisons of skin samples of the same individual revealed that there is no significant differences in the morphology of dermal denticles in various portions of the trunk (i. e., lateral, dorsal and ventral portions). Species comparisons resulted in differences in number of cusps, keels, ornamentation and relative proportion of each scale (height x width). Trunk dermal denticles of species that reach larger body size when adults, generally have more numerous keels and cusps. In *Rhizoprionodon*, dermal denticles become more complex in form and distribution with increasing growth. In juveniles, dermal denticles are more sparsely distributed, with fewer keels and cusps than adults. Pre-adults have a combination of juvenile and adult denticles, alternating simpler regions with more complex ones.

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Caudal spine replacement rates of the round stingray (*Urolophus halleri*): implications for public safety

The round stingray (*Urolophus halleri*) is a common ray along nearshore sandy beaches and bays in southern California. This ray is particularly abundant along Seal Beach, California during summer and fall months where 200-400 stingray-related injuries are reported annually. In an attempt to reduce injury to beach goers, a stingray spine-clipping study was conducted. To evaluate the efficacy of spine-clipping, natural spine replacement rates and population size of stingrays at Seal Beach was determined. Of the 2183 stingrays caught, tagged, and released at Seal Beach, only 13 (0.06 %) have been recaptured over a 3-year period, indicating a large, mobile population. Spine lengths of all rays caught were measured to determine spine shedding rates for the population. Field and laboratory studies indicate spines are not replaced as a direct result of removal or clipping. Spine replacement was observed between August through October, when a majority of rays were found with two spines, one primary (1°) and one secondary (2°). The 2° spine is first detectable under the 1° spine in July, and by August the 2° spine is 50-75% the length of the 1° spine. Laboratory studies confirm annual spine replacement and shedding of the 1° spine. The large population size of Seal Beach stingrays and timing of spine replacement indicate that even a large-scale spine-clipping program would be ineffective in reducing risk to beach goers.

*** NAYLOR, GAVIN J.P.; RYBURN, JULIE A.; FEDRIGO, OLIVIER; LOPEZ, J. ANDRES** *Dept. of Zoology and Genetics, Iowa State University, Ames, IA 50011, USA*

Phylogenetic interrelationships among the major groups of sharks deduced from molecular sequence data

An estimate of the phylogenetic relationships among different groups of extant sharks will be presented and discussed. The inference is based on sequence derived from 3 mitochondrial genes and one nuclear gene (approx. 5 kb) sequenced for representatives of all recognized extant shark families and the majority of extant genera (approximately 150 taxa).

*** LEANDRO, LUIS F.; RYBURN, JULIE A.; FARIA, VICENTE V.; NAYLOR, GAVIN J.** *Iowa State University, Department of Zoology and Genetics, Ames, IA 50011, USA*

Phylogenetic inference of the order Squaliformes based on nuclear and mitochondrial sequence data

The superorder Squalomorphii includes the Hexanchiformes, Pristiophoriformes and the Squaliformes. The Squaliformes are grouped into 6 families, 22 genera and roughly 87 species; however, there are several taxonomic uncertainties regarding this group. Representatives for 13 out of the 22 known Squaliform genera were sequenced for the mitochondrial genes NADH-2, NADH-4, Cytochrome B, and the nuclear gene rag1. These sequences were used in phylogenetic analysis. Hypotheses for inter-generic relationships supported by our data will be discussed and compared with previous morphological and molecular hypotheses.

AES Phylogeny & Biogeography Mondya June 30, 1:30-3:15.

* **CASTRO, JOSE I.; NAYLOR, GAVIN J. P.; MARQUEZ-FARIAS, J. FERNANDO** (JIC) Mote Marine Laboratory, 1600 Ken Thompson Pkwy, Sarasota, FL 34236, USA; (GJPN) Dept. of Zoology, Iowa State Univ., Ames, Iowa 50011, USA; (JFM-F) Instituto Nacional de Pesca CRIPGuaymas Sonora, Mexico

A new species of nurse shark from the Pacific Ocean

A new species of nurse shark from the Pacific Ocean is described. It differs from the Atlantic nurse shark, *Ginglymostoma cirratum*, in body proportions, anatomical characteristics, tooth morphology, and dental formula. The name of the new species will be announced at the meeting.

* **KEENEY, DEVON B.; HEUPEL, MICHELLE; HUETER, ROBERT E.; HEIST, EDWARD J.** (DBK, EJH) Southern Illinois University, Fisheries and Illinois Aquaculture Center, Department of Zoology, Carbondale, IL, 62901, USA; (MH, REH) Center for Shark Research, Mote Marine Laboratory, Sarasota, FL, 34236, USA

Phylogeography of the blacktip shark, *Carcharhinus limbatus*, based upon mitochondrial control region sequences

While many coastal shark species have discontinuous distributions along tropical and subtropical continental margins, very little is understood about the origins, historical dispersal, and current levels of conductivity of their widespread populations. We analyzed geographic patterns of variation in the mitochondrial control region from blacktip sharks, *Carcharhinus limbatus*, to investigate genetic relationships among disjunct, extant populations of this species. Phylogenetic analysis of blacktip sharks collected from the coasts of South Africa, western Australia, eastern Australia, Baja California, the Caribbean Sea, the Gulf of Mexico, and the western North Atlantic Ocean produced two distinct groups of haplotypes separated by 8 substitutions: an Atlantic Ocean/Gulf of Mexico/Caribbean Sea group and an Indian Ocean/Pacific Ocean group including Baja California. A much lower amount of variation was observed within these two groups and haplotypes differed by few substitutions versus comparisons between groups. Issues such as centers of radiation, historical dispersal patterns, and current gene flow will be addressed.

* **DE CARVALHO, MARCELO R.; GRANDE, LANCE; MAISEY, JOHN G.** (MRC) Departamento de Biologia, Universidade de São Paulo, Av. dos Bandeirantes, 3900, Ribeirão Preto, SP 14040-901, Brazil; (LG) Department of Geology, Field Museum of Natural History, Roosevelt Road at Lake Shore Drive, Chicago, IL, 60605-2496, USA; (JGM) Division of Paleontology, American Museum of Natural History, Central Park West at 79th St., New York, NY, 10024-5192, USA

Phylogenetic relationships of stingrays: insights from the Eocene Green River genera

The results of a phylogenetic analysis of stingray genera, based on morphological characters, will be presented. The analyses were undertaken as part of a larger study describing a new fossil freshwater stingray genus from the Green River Formation of Wyoming (Early Eocene). The impact of the new taxon (and that of *Heliobatis*, the other stingray genus from Green River) on the phylogenetic relationships of Recent stingrays will be discussed. The results of our phylogenetic study of stingrays, the most comprehensive to date based on morphological characters, contradicts those of previous authors in relation to various components. Biogeographic implications concerning the evolution of the Neotropical freshwater stingrays (Potamotrygonidae) will be advanced, suggesting that potamotrygonids are considerably older than previous (Late Miocene) estimates.

* **STEVENSON, DUANE E.; ORR, JAMES W.; HOFF, GERALD R.; MCEACHRAN, JOHN D.** (DES, JWO, GRH) National Marine Fisheries Service, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Bldg. 4, Seattle, WA 98115-0070, USA; (JDM) Department of Wildlife and Fisheries Sciences, Texas A&M University, College Station, Texas 77843, USA

Additions to the skate fauna (Family Rajidae) of Alaska

Skates of the genera *Raja* and *Bathyraja* constitute a significant proportion of the groundfish assemblages of the Gulf of Alaska, Aleutian Islands, and Bering Sea. Although these fishes are important components of both shallow and deepwater marine ecosystems in these regions, their populations have been inaccurately represented by fisheries monitoring programs due to difficulties in obtaining accurate species identification. As a result of collaborative efforts among taxonomists and fisheries biologists, recent NMFS bottom trawl surveys reflect great improvements in the reliability of skate identifications. A data set compiled from the catch records of NMFS bottom trawl surveys from 1999-2002, including the Gulf of Alaska, Aleutian Islands, and Eastern Bering Sea, gives a comprehensive overview of the skate fauna of Alaska. This data set includes a total of 13 recognized species of skates (3 species of *Raja* and 10 species of *Bathyraja*). In addition to these 13 recognized forms, as many as three undescribed forms of 41 *Bathyraja* have been discovered, and several other taxonomic questions have arisen. An overview of the skate fauna of Alaska will be presented, along with an introduction to one new form and an outline of future research directions.

* **MUSICK, JOHN A.; HARBIN, MELANIE M.** *Virginia Institute of Marine Science, College of William and Mary, Fisheries Science Department, P.O. Box 1346, Gloucester Point, VA 23062*

Historical zoogeography of the Selachii

Analyses were conducted on the zoogeography of the extant orders of sharks, incorporating the most recent phylogenetic and paleontological information. In order to test dispersal and vicariance hypotheses, vagility (dispersal ability) of taxa was estimated by examining the geographic ranges of species and species diversity within each order. Other factors examined were body size, behavioral habit (benthic, benthopelagic, pelagic) and habitat (neritic, bathyal, oceanic). There was a strong negative correlation of size with species diversity. Most sharks are <100cm in total length. Benthopelagic species were slightly more speciose than benthic species and pelagics were depauperate. Surprisingly, although neritic habitat was speciose, species that occupied both neritic (>200m) and bathyal (>200m) or strictly bathyal habitats together contributed the highest shark diversity, whereas oceanic habitats had a small number of species. This contradicts the popular notion that sharks are most diverse in shallow tropical seas. To the contrary, shark diversity is highest in cool or cold deeper water habitats where the order Squaliformes and the Carcharhiniform family Scyliorhinidae are particularly speciose. There was a strong inverse relationship between body size and range. Likewise benthic species had the smallest and pelagic species had the largest ranges. Within the major orders Orectolobiformes, Carcharhiniformes and Squaliformes all showed a strong relationship between body size and range, except for the largest size class (>300cm TL) within the Squaliformes, which is dominated by *Somniosus* a bi-polar species. The Orectolobiformes, all of which are benthic (except the very large oceanic *Rhincodon typus*) had smaller ranges at size than either Carcharhiniformes or Squaliformes. Ancient vicariance, the late Jurassic breakup of Pangaea, may be largely responsible for the present distribution of the Heterodontiformes, Orectolobiformes, and Squatiniformes, all benthic, neritic groups with very low vagility. Other groups have high vagility and have dispersed across large expanses of open ocean. Geographic areas of particular interest are Australia with very high shark diversity and endemism and the eastern North Pacific where the diverse bathyal Squaliformes are virtually absent.

* **INGRAM, WALTER; JONES, LISA** *NOAA, National Marine Fisheries Service, Southeast Fisheries Science Center, Pascagoula, MS, 39567, USA*

Distribution of deep-water elasmobranchs and correlations with hydrographic variables in the U.S. Gulf of Mexico

The impact of both target and non-target fisheries mortality on elasmobranch stocks is of increasing concern world-wide. Most elasmobranch fisheries have proven unsustainable as evidenced by the collapse of directed shark fisheries. Increasing exploitation of deep-water elasmobranchs combined with a general lack of knowledge of their ecology, establishes the need for investigations into life history, ecology, and fishery response. Bottom trawl surveys that are useful for assessing U.S. Gulf of Mexico (Gulf) elasmobranchs were conducted from 1988 to 1996 by the National Oceanic and Atmospheric Administration (NOAA)/National Marine Fisheries Service (NMFS). All finfish and elasmobranchs were weighed, enumerated, measured for length and, in many cases, sexed. Bottom trawling at 911 stations was conducted for 30 minutes with either a 27.5 m high-opening bottom trawl

(HOB) or a 37.5 m Shuman trawl in depths from 12 m to 406 m. Environmental data (i.e., station depth; surface, midwater and bottom temperature; surface, midwater and bottom salinity; and midwater and bottom dissolved oxygen) were also collected. Elasmobranch distributions were both visually and statistically analyzed. Multivariate analysis of variance (Wilks' $\lambda=0.113$, $P < 0.0001$) and canonical linear discriminant function analysis [eight out of nine canonical variables found to be significant ($P < 0.01$ for each)] indicated environmental differences between elasmobranch species, with station depth, dissolved oxygen and salinity the primary factors affecting distribution. Visual analysis of distribution maps indicated Gulf-wide occurrences for many species. The five most frequently occurring species [genus species, frequency of occurrence (i.e., number of occurrences/number of trawls)] were Atlantic sharpnose shark (*Rhizoprionodon terraenovae*, 0.216), Atlantic angel shark (*Squatina dumerili*, 0.108), smooth dogfish (*Mustelus canis*, 0.086), Cuban dogfish (*Squalus cubensis*, 0.043), and spreadfin skate (*Raja olseni*, 0.029). Using such a multi-species/multivariate environmental approach augments a major goal of NOAA's strategic plan to protect, restore, and manage use of coastal and ocean resources through ecosystem management.

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Distribution, abundance, and reproductive status of skates landed in groundfish surveys off central California, USA

Although skates have long been a common component of bycatch and discard among eastern north Pacific trawl fisheries, very little is known of their biology, distribution, or abundance throughout this region. In California, landings of skates have markedly increased since the early 1990's. Fishing pressure has notably impacted the abundance, population structure, and distribution of skates in the North Atlantic, emphasizing the need for baseline biological information of this poorly known group. Since September, 2002 members of the Pacific Shark Research Center have been working in cooperation with the National Marine Fisheries Service (NMFS), Santa Cruz Laboratory to investigate the life history, ecology, and systematics of central California skates. Data are being collected from monthly NMFS trawl surveys across five depth strata ranging from 18-823 m. We report on preliminary analyses of surveys conducted between September, 2002 and March, 2003. An approximate total of 1,500 specimens comprised of six species have been examined. The most abundant species, *Raja rhina*, comprised more than 50% of the overall catch followed by *Bathyraja kincaidii*, *R. binoculata*, *R. inornata*, and *R. stellulata*, respectively. Depth distribution and relative abundance of skates will be presented and compared by season, sex, reproductive status, and occurrence with the other chondrichthyans collected in these surveys.

ASIH Session or Additional Posters?

* **BRACCINI, J. MATIAS; WALKER, TERENCE I.; GILLANDERS, BRONWYN M.**

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Information for ecological risk assessment of piked spurdog (*Squalus megalops*) off southeastern Australia

The life-history traits of the Australian population(s) of the piked spurdog (*Squalus megalops*) are being determined and available data on catch history, distribution and gillnet selectivity are being collated and analyzed. As part of a quantitative ecological risk assessment of the chondrichthyan fauna, essential information on the reproductive biology, the age and growth, and the dietary composition of this shark species is being recorded from samples obtained from southeastern Australia. The data will be used to determine the ogives of the onset of maturity and of breeding and maternity as a function of length and age of shark, estimate the gestation period and reproductive cycle, determine the fecundity of females, and estimate their biological productivity. The growth rate and maximum age of each sex and the feeding habits and ecological role will also be determined. This study aims to gain knowledge of the basic biology and to provide the data and parameter inputs to models for ecological risk assessment, IUCN red list assessment, and management and conservation of this species.

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Biogeography of fishes of the Gulf of Mexico

A total of 1,454 fish species in 681 genera, and 221 families are documented from the Gulf of Mexico. These totals represent about 64.3% of the species, 79.4% of the genera, and 92.5% of the families recorded from the Central Western Atlantic. A majority of the fishes in the Gulf of Mexico are wide ranging continental fishes, wide ranging insular fishes, and deep-sea benthic and pelagic fishes. Secretive insular fishes are less well represented. Despite the relatively high diversity, only about 5% of the fish species are endemic to the Gulf of Mexico. The majority of the endemic species are limited to either the eastern, northwestern, or southern sub regions of the Gulf. Only 9 endemic species are ubiquitous throughout the Gulf. Based on percent endemism, the Gulf cannot be considered a cohesive biogeographical region or province. However, based on its high diversity and unique warm temperate and tropical components, the Gulf is a distinct biogeographical area.

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Sharks in peril: a review and analysis of IUCN listed shark species

For a number of reasons, (low fecundity and intrinsic rate of increase, late maturity and long life), many shark species are particularly vulnerable to extinction. As of February 2003, the International Union for Conservation of Nature and Natural Resources (IUCN) has red listed 63 species of sharks worldwide. These species are variously listed as near threatened (31), vulnerable (13), data deficient (9), endangered (5), conservation dependent (4), and critically endangered (1). In this analysis, I review, when available, the life history parameters, distributions, and level of exploitation of the shark species that appear on the IUCN list. Emphasis was placed on those species occurring in the Atlantic. The near threatened (NT) category includes the greatest diversity of species, including many of the largest members of the Carcharhinidae. Other families included in the NT category are the Scyliorhinidae, Lamnidae, and Sphyrnidae. Given the almost complete lack of biological information available for most shark species, it is curious that only 10 species are listed as data deficient (DD). The DD category includes notables such as *Sphyrna mokarran* and *Megachasma pelagios*. The families with the greatest numbers of species listed are the Carcharhinidae (20), Triakidae (11), Scyliorhinidae (5), Lamnidae (4), Squatinidae (4), Sphyrnidae (3), Hexanchidae (2), and Odontaspidae (2). Eleven families have a single species listed. It is interesting that the vulnerable category includes the largest sharks such as *Rhincodon typus*, *Cetorhinus maximum*, and *Carcharodon carcharias*. Attention given to these high risk shark species, may suggest additional candidates for listing and can more clearly define necessary conservation measures.