JUMPING AND SPINNING BY CARCHARHINID SHARKS: ANOTHER VIEW

FRANK J. SCHWARTZ

University of North Carolina
Institute of Marine Sciences
3431 Arendell Street
Morehead City, NC 28557-3209
Email: fjs@email.unc.edu

Abstract: *Carcharhinus brevipinna* (spinner) and *Carcharhinus limbatus* (blacktip) sharks make spectacular jumps and spinning leaps out of the water. Some believe these are: jumping responses to rid sharksuckers (*Echeneis naucrates*) that attach to their bodies, chaffing, shuttling, or heat hunter- cool rest behaviors. Examination of North Carolina shark data suggests that *C. brevipinna* and *C. limbatus* in temperate waters of North Carolina sense changes in abrupt ocean water temperatures. *Echeneis naucrates* is just along for the ride. Why after forty-six years of longlining only one *Echeneis naucrates* occurred on *C. brevipinna* while many occurred on *C. limbatus* is unknown. Perhaps something in the skin texture, not shape, of *C. brevipinna* deters *Echeneis* from attaching.

INTRODUCTION

Eight species of sharksuckers, in the Western Atlantic (family Echeneidae), possess a dorsal fin modified into a laminated adhesive sucking disk (cephalic disk) that they use to attach to other fishes (Carpenter 2002; Collette 2002; O'Toole 2002; Schwartz 2004). *Echeneis naucrates* Linnaeus, 1758, a worldwide species (except for the eastern Pacific), attains a 900 mm (total length, TL), is common in the western Atlantic and attaches to various hosts, especially sharks (Collette 2002). The blacktip shark, *C. limbatus* (Muller and Henle 1839), a 250 cm TL species, that occurs from Massachusetts to the Gulf of Mexico, Bahamas and south to southern Brazil, often has sharksuckers attached to various parts of its body; conversely the spinner shark *C. brevipinna* (Muller and Henle 1839), a 280 cm TL species that has a similar distribution (Compagno 2002), seems to be devoid of sharksuckers. Both sharks are known worldwide for their dramatic jumps and spinning leaps out of the water before crashing back into the ocean. Many believe the behavior is to avoid sharksuckers *Echeneis* (Compagno 1984; Schwartz 2003; Fulcher and Motta 2006; Voight and Weber 2011). Perhaps as did Donnell (1970), *Echeneis* use the gap located at the front of the head between the premaxillae in front and the nasal and vomer behind as an echolocating bionic function. Castro (2011) questions jumping by *C. brevipinna* and attributes that behavior to only *C. limbatus*.

Although Ritter (2002) and Ritter and Brunnenschweiler (2003) studied the causes of shark jumping behavior in the Bahamas, they did not report water temperatures. Fulcher and Motta (2006) studied the anatomy of the cephalic disc and the force of 3.5 N necessary to dislodge an *Echeneis* from a blacktip shark; water temperatures

ranged 23–27°C. Ritter (2002) and Ritter and Brunnenschweiler (2003) filmed only three of 154 blacktip sharks jumping. Subsequently Brunnenschweiler (2005) noted a swimming speed of 6.3 m/sec was necessary before *C. limbatus* broke the water's surface in leaps. Attached sharksuckers, increased the hydrostatic drag and increased the swimming speed. Hence, sharks with sharksuckers required increased swimming speed prior to jumping (Vogel 1994; Brunnenschweiler 2005, 2006; Speed et al. 2012). Brunnenschweiler (2006) concluded that the shark-sharksucker association was a host- parasite interaction. Others have postulated reasons for the jumping behavior. Cressey and Lachner (1970) claimed that sharks jump to rid themselves of parasitic copepods. Ritter and Godknecht (2000) and Ritter (2002) documented that the shark-sharksucker association was an agnostic behavior prior to jumping. Ritter (2011) noted sharks chaffing along the substrate in an attempt to rid themselves of sharksuckers and that that was the cause for jumping. Frazer and Shlmendine (2002) and Heupel et al. (2003) found that skin hair cells of dogfish, *Scyclorhinus canicula* (Linnaeus, 1758) and blacktip sharks detected barometric pressure changes prior to storms or heavy rains that caused them to swim rapidly away. Could jumping be a function of body shape as the slender shark (*C. brevipinna*) could swim faster and jump more often than the stout bodied *C. limbatus* (Weihs 1981)? Could jumping be a way of evacuating following feeding (Di Santo and Bennett 2011)? Could jumping simply be the result of a shark shuttling between hot and cold water temperatures (thermotaxis) (Froeshke et al. 2010; Speed et al. 2012)? I contend the cause of shark jumping results from response to rapid sharp temperature changes in ocean waters.

METHODS

C. brevipinna (spinner) and *C. limbatus* (blacktip) sharks were caught with longlining gear between May–November 1972–2012 aboard the R/V Capricorn in Onslow Bay, Atlantic Ocean station (34°38'N, 76°38'W), 3 km south of Morehead City, North Carolina (Schwartz et al. 2010). Sharks caught on the longline were measured for forklengths, (FL), sexed, tagged and returned to the original capture site. *E. naucrastes* that fell off or were attached to a *C. limbatus* were measured for total length (mm, TL). Sixty-seven *Echeneis* were preserved in 10% formalin and transferred to 70% ethyl alcohol for preservation and deposited in the North Carolina State Museum in Raleigh NC, Schwartz (2004). Eighteen *Echeneis* (captured in 1987–1989 and 1991), were kept alive in a concrete outdoor pond 1.2 MI gal, $6.1 \times 9.8 \times 0.75$ m deep supplied with flow through water at the Institute of Marine Sciences to note growth and low water temperature survival observations (Schwartz 2004). Forty-nine were returned to the capture sites.

OBSERVATIONS

Carcharhinus limbatus.—Nine hundred and fifty two *C. limbatus* (559 males, 347 females, 46 unsexed) were captured during longline operations. Fifty-four percent (514) of the *C. limbatus* were captured pre 1990 between 1972 and 1989 (males 313, females 201) and 46 percent (438) were captured post 1990 between 1990–2012, (males 264, females 174). Yearly sizes of *C. limbatus* ranged: males 650–1,200 mm FL; for females 840–2,400 mm FL: males sizes pre-1990 ranged 680–1,115 mm FL, post 1990 715–1,050 mm FL; females pre 1990 890–2,050 mm FL post 1990 810–2,400 mm FL. A total of 134 *E. naucrastes* were found on *C. limbatus*. Sizes of *C. limbatus* with *E. naucrastes* ranged: males 750–1,050 mm FL; females 840–2,400 mm FL, pre 1990; males 680–1,115 mm FL, post 1990 715–1,050 females mm FL. One hundred and sixty four *C. limbatus* were seen jumping during the longline operations. Sizes were similar to *C. limbatus* captured on the longline. Sea water temperatures ranged 18.0–30.7°C.

C. Carcharhinus brevipinna.—Two hundred fifty-two *C. brevipinna* (101 male, 139 females, 12 unsexed) were captured on the east west station between May–September 1974–2012: sizes ranged: males 710–1,400 mm FL; females 400–2,400 mm FL: 144 were captured pre 1990, 108 post 1990. Thirty-seven *C. brevipinna* were seen jumping near the longline: 12 pre-1990, 25 post 1990. Sizes were similar to captured *C. brevipinna* caught on the longline. Sea water temperatures during jumping ranged 20–30°C.

Echeneis naucrastes.—One hundred thirty-four *E. naucrastes* were found attached to 980–1,450 mm FL males; 908–1,975 mm FL female *C. limbatus*. Longline

C. limbatus males were caught from January to October, females June to October. One hundred twenty two *C. brevipinna*, bearing *E. naucrastes*, were captured pre 1990, 12 post 1990. *Echeneis* sizes ranged 67–707 mm TL- x 244 mm. Only one *E. naucrastes* (128 mm TL) was found attached to a 710 mm FL male *C. brevipinna* 7 November 2007, water temperature 27.6°C. Sea water temperatures during capture ranged 27.5–30°C. Eighteen live *Echeneis*, 140–160 mm TL, retained at capture, grew to 219–319 mm TL at death. Lowest death survival temperature was 16.2°C (Schwartz 2004).

A 144 mm TL *Echeneis*, was found attached to: a 2,230 mm FL tiger shark *Galeocerdo cuvier* (Peron and Lesueur, 1822) 7 November 1978; a 145 mm FL *Echeneis* occurred on a 1,186 mm FL Atlantic sharpnose, *Rhizoprionodon terraenovae* (Richardson, 1836) 3 June 1986; a 145 mm TL *Echeneis* was attached to a 870 mm FL female dusky shark *Carcharhinus obscurus* (Lesueur, 1880) 12 July 1988, and a 145 mm TL *Echeneis* was found on a blacknosed shark *Carcharhinus acronotus* (Poey, 1860) 12 July 2012.

DISCUSSION

Size and shape.—Although *C. brevipinna* and *C. limbatus* attain similar sizes (*C. brevipinna* 2.8 m TL, *C. limbatus* 2.5 m TL (Carpenter 2002; Castro 2011), *C. brevipinna* has a slender body shape with a pointed snout, whereas *C. limbatus* has a stout body and a short blunt “V”-shaped snout (Schwartz 2003). Both species are often seen jumping and spinning. Yet only one *E. naucrastes* was found attached to a single *C. brevipinna* whereas *Echeneis naucrastes* was commonly attached to *C. limbatus*. Brunnschweiler (2005) calculated that a swimming speed of 6.3 m/sec or a 13.5 N drag force (Fulcher and Motta 2006) was necessary before *C. limbatus* could break the water surface; no such data are known for *C. brevipinna*. Perhaps body shape and swimming speed (Weihs 1981) were the reasons *E. naucrastes* frequents *C. limbatus* versus *C. brevipinna*. Alternately something in the skin of *C. brevipinna* deters *E. naucrastes* from attaching. As Wainright et al. (1978) noted in hydrostatic pressure under the skin increased the swimming speed of the shark. Skin stress affects the skin stiffness, thereby permitting *C. brevipinna* out swim an attaching shark sucker.

By year.—One hundred thirty-four *C. limbatus* were collected with attached sharksuckers *E. naucrastes*; one hundred twenty seven (95%) were captured prior to 1990, seven (5%) post 1990. Water temperatures were cooler pre 1990 and warmer in post 1990 (Schwartz et al. 2010).

Denticles.—Bigelow and Schroeder, (84); Castro (2011); Voight and Weber (2011) reported *C. brevipinna* possessed dermal skin denticles with 5–7 ridges, whereas *C. limbatus* possessed five ridges. Thus one would expect

water flow along the shark's denticles would be faster or slower depending on the number of denticle ridges. However, dynamically the flow would be the same (Rosman, pers. comm. 2012). Thus, in relation to jumping, *C. limbatus* possessing 5 denticle ridges does not have an advantage over *C. brevipinna* that has 5–7 denticle ridges.

Disturbances.—Although Myrberg et al. (1972) and Myrberg (1978) noted that sharks sensed disturbances up to 250 m away. *C. brevipinna* and *C. limbatus*, in North Carolina, seemed oblivious to motor sounds made by the R/V Capricorn patrolling the longline nearby. Heupel et al. (2003) documented blacktip sharks skin hair cells detected storms and pressure changes prior to their fleeing an area. All such disturbances might cause jumping and spinning.

Temperature.—Most elasmobranchs lack the ability to maintain their body temperature independent of the ambient water temperature (Di Santo and Bennett 2011). A few maintain higher body temperatures: dogfish *Mustelus canis* (Mitchill, 1788) Casterlin and Reynolds 1979, porbeagle *Lamna nasus* (Bonnaterre, 1788), White shark *Carcharodon carcharius* (Linnaeus, 1758; Satchell 1999), and blacktip reef shark *Carcharhinus melanopterus* (Compagno 1984; Sims et al. 2006). Several authors noted sharks behave differently to storms (Heupel et al. 2003). Even though Hight and Lowe (2007) noticed stress caused shuttling between water temperatures (thermotaxis) Sims et al. (2006) found stress induced feeding and digestion. Likewise back and forth movements between water areas were a heat hunter-cool rest response that aided in digestion. Wetherbee et al. (1987) found stress caused evacuation during jumping. Schwartz (2003) documented the yearly seasonal shifts in *C. brevipinna* and *C. limbatus* occurrences as water temperatures decreased or cooled and that *C. limbatus* females jumped more often than males. *E. naucratus* tolerated water temperatures as low as 12.6°C before death (Schwartz 2004). *C. limbatus* and *C. brevipinna* detected abrupt water temperature changes that triggered stress responses (Crawshaw 1979) and jumping.

CONCLUSIONS

More *C. brevipinna* than *C. limbatus* were captured in pre 1990 years than post 1990 years when ocean waters changed from cool to warm. *E. naucratus* was just along for the ride. Abrupt changing water temperatures were the causes for sharks jumping and leaping as *C. brevipinna* and *C. limbatus* deftly detected these changes. Thus, sharks are more than puppets of the environment (“Spielballe der Umgebung,” Krehl and Soetbeer 1899) and reflect morphological and physiological behavior adaptations that detect specific thermal conditions (Di Santo and Bennett 2011) that cause *C. brevipinna* and *C. limbatus* to jump and leap out of the water.

Acknowledgments: The Institute of Marine Sciences supported the longline study. Joe Purifoy, Glenn Safrit, Ray Churchill and Claude Lewis were able assistants during the 1972–2012 longline study. Joe Smith (NMFS, Beaufort) reviewed the manuscript. P. Marraro NOS Beaufort and J. Miller Duke Marine Lab, Beaufort obtained important references. G. Hogue (NC SM, Raleigh) supplied catalogue numbers for the catalogued *E. naucratus* within the IMS collections in Raleigh. G. Safrit typed the text.

LITERATURE CITED

- BIGELOW, H. B., AND W. C. SCHROEDER. 1948. Fishes of the Western North Atlantic, Vol. Pt. 1. Lancelets, Cyclostomes and Sharks. Sears Mar. Res. Yale Univ. New Haven Conn. 576 p.
- BONNELL, B. 1970. Disc of *Echeneis* has an echo locating organ. Science Culture 36:671–676.
- BRUNNSCHWEILER, J. M. 2005. Escape velocities in jumping blacktip sharks. J. Roy. Soc. Interface 2:389–391.
- BRUNNSCHWEILER, J. M. 2006. Shark sucker-shark interaction in two Carcharhinid sharks. Mar. Ecol. 27:84–94.
- CARPENTER, K. E. 2002. The Living Resources of the Western Central Atlantic, Vol. 1. Introduction Mollusc, Crustaceans, Hagfishes, Sharks, Batoid fishes and Chimeras. Identification guide for fishery purposes and American Society of Ichthyol. Herpetol. Spec. Publ. 5 FAO, Rome, Bull. 5. 599 p.
- CRAWSHAW, L. I. 1979. Responses to rapid temperature changes in vertebrate ectotherms. American Zool. 19:225–237.
- CASTERLIN, M. E., AND W. W. REYNOLDS. 1979. Shark thermal regulation. Comp. Biochem. Physiol. 64A:451–473.
- CASTRO, J. I. 2011. The Sharks of North America. Oxford Univ. Press, NY. 613 p.
- COLLETE, B. B. 2002. Echenidae, Remoras (sharksuckers, disc fishes). Pp. 1414–1419 in K. E. Carpenter (ed.), The Living Marine Resources of the Western Coastal Atlantic, Vol. 2. Bony fishes. Pt. 2. (Opistognathidae to Molidae), sea turtles and marine mammals. FAO species identification fish guide for fishery purposes and Amer. Soc. Ichthyol. Herpetol. Spec. publ. no. 5 FAO, Rome. Pp. 1374–2127.
- COMPAGNO, L. J. V. 1984. FAO fish species catalog. Vol. 4. An annotated and illustrated catalog of shark species known to date. FAO fish synop. 125(4)(2):2 p.
- COMPAGNO, L. J. V. 2002. FAO species catalog. Vol. 4. Sharks of the World. An annotated and illustrated catalogue of shark species known to date. Vol. Pt. 2. Carcharhinidae. Requiem sharks, ground sharks, blue sharks, sharpnose sharks. Pp. 466–496 in K. E. Carpenter (ed.), A living marine resources of the Western Central Atlantic. Vol. 1. Introduction, Molluscs, Crustaceans, Hagfishes Sharks, Batoid fishes, Chimaeras FAO Species Identification Guide for Fishery Purposes and Amer. Soc. Ichthyol. and Herpetol. Spec. Publ. no. 5.
- CRESSEY, R. F., AND E. A. LACHNER. 1970. The parasitic diet and life history of disc fishes (Echeneidae). Copeia 1970:310–316.
- DI SANTO, V., AND W. M. BENNETT. 2011. Is post-feeding thermotaxis advantageous in elasmobranch fishes? J. Fish. Biol. 78:195–207.
- FRAZER, R. J., AND R. I. SHELMENDINE. 2002. Dogfish hair cells sense hydrostatic pulses. Nature 415:495–496.
- FROESKE, J., G. W. STUNZ, AND M. L. WILDHABER. 2010. Environmental influences on the occurrences of coastal sharks in estuarine waters. Mar. Ecol. Prog. Ser. 407:279–292.

- FULCHER, E. A., AND P. J. MOTTA. 2006. Suction disk performance of Echineid fishes. *Can. J. Zool.* 24:42–50.
- HEUPEL, M. E., C. A. SIMPENDORFER, AND R. E. HEUTER. 2003. Running before the storm: blacktip sharks respond to falling barometric pressure associated with tropical storm Gabrielle. *J. Fish. Biol.* 63:1357–1363.
- HIGHT, P. V., AND G. G. LOWE. 2007. Elevated body temperature on an adult female leopard shark, *Triakis semifasciata*, while aggregating in shallow near shore embayments: evidence for behavioral thermal regulation. *J. Exp. Mar. Physiol. Ecol.* 352:114–128.
- KREHL, L., AND F. SOETBEER. 1899. Untersuchungen uber die Warmeokonomie der poikilothermen Wirbelthiere. *Archiv fur die gesammte Physiologie des Menschen und der Thiere* 77, 611.
- MYRBERG, A. A., JR. 1978. Underwater sound, it's effect on the behavior of fishes. Pp. 395–417 in E. Hudson and E. F. Mathewson (eds.), *Sensory Biology of Sharks, Skates and Rays*. Arlington, Virginia Off. Naval Res., VA.
- MYRBERG, A. A., S. J. HA, S. WALENSKI, AND J. C. BANBURY. 1972. Effectiveness of acoustic signals in attracting epipelagic sharks to an underwater sound source. *Bull. Mar. Sci.* 22:926–949.
- O'TOOLE, B. 2002. Phylogeny of the species of the superfamily Echenoidea (Perciformes; Carangoidei; Echenidae, Rachycentridae, and Coryphaenidae), with an interpretation of echeneid hitchhiking behavior. *Can. J. Zool.* 80:596–623.
- RITTER, E. K. 2002. Analysis of sharksucker, *Echeneis naucrates* induced behavior patterns in the blacktip shark *Carcharhinus limbatus*. *Env. Biol. Fishes* 65:111–115.
- RITTER, E. K. 2011. Use of sand ripples to enhance chafing in Caribbean reef sharks (*Carcharhinus perezi*) and Blacktip sharks (*Carcharhinus limbatus*) *Bull. Mar. Sci.* 87:413–419.
- RITTER, E. K., AND J. M. BRUNNSCHWEILER. 2003. Do sharksuckers, *Echeneis naucrates*, induce jump behavior in blacktip sharks, *Carcharhinus limbatus*? *Mar. Fresh. Behav. Physiol.* 36(2):111–113.
- RITTER, E. K., AND A. J. Godknecht. 2000. Agonistic displays in the blacktip shark (*Carcharhinus limbatus*) *Copeia* 2000:282–284.
- SATCHELL, G. H. 1999. Circulatory system. Distinctive attributes of the Circulation of Elasmobranch Fish. Chp. 9: 218–237 in *Sharks, Skates and Rays, Biology of Elasmobranch Fishes*. W. C. Hamlett (ed.). Johns Hopkins Press, Baltimore, MD.
- SCHWARTZ, F. J. 2003. *Sharks, Skates and Rays of the Carolinas*. Univ. Nor. Car. Press, Chapel Hill, NC. 161 p.
- SCHWARTZ, F. J. 2004. Five species of sharksuckers (Echenidae) in North Carolina. *J. Nor. Car. Acad. Sci.* 120(2):44–49.
- SCHWARTZ, F. J., J. PURIFOY, AND G. SAFRIT. 2010. Variations in shark longline catches 1972–2008: Real or climatically inferred? *J. NO. Car. Acad. Sci.* 126:18–20.
- SIMS, D. W., V. J. WEARMOUTH, E. J. SOUTHWALL, J. M. HILL, P. MOORE, K. RAWLINSON, N. HUTCHINSON, G. C. BUDD, D. RIGHTON, J. D. METCALFE, J. P. NASH, AND D. MORRITT. 2006. Hunt warm, rest cool: bioenergetic strategy underlying diel vertical migration of a benthic shark. *J. Animal Ecol.* 75:176–190.
- SPEED, C. W., M. G. MEEKAN, I. C. FIELD, C. R. MCMAHON, AND C. J. A. BRADSHAW. 2012. Heat-seeking sharks: support for behavioural thermoregulation in reef sharks. *Mar. Ecol. Prog. Ser.* 463:231–244.
- VOGEL, S. 1994. *Life in Among Fluids. Physiological biology of flow*. Boston Univ. Press, Princeton, MA. 467 p.
- VOIGHT, M. M., AND D. WEBER. 2011. *Field Guide of Sharks of the Genus Carcharhinus*. Verlag D. Fredick Pfeil, Munchen. 151 p.
- WAINRIGHT, S. A., F. MOSSBERG, AND J. H. HEBRANK. 1978. Shark skin function in locomotion. *Science* 207:747–749.
- WEIHS, D. 1981. Voluntary swimming speeds of two species of large Carcharhinid sharks. *Copeia* 1:219–222.
- WETHERBEE, B. M., S. H. GRUBER, AND A. L. RAMSEY. 1987. X-radiographic Observations off food passage through digestive tracts of lemon sharks. *Trans. Amer. Fish. Soc.* 116: 763–767.