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Tonic Immobility in 12 Elasmobranchs: Use as an Aid in Captive Husbandry

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Tonic immobility (TI), also known as animal hypnosis, has been observed in a wide variety of taxa and reported in all vertebrate classes with the exception of Agnatha. To date, TI has been reported in six species of elasmobranchs. Preliminary results are presented here for five species of galeomorph sharks, one species of squalomorph shark, and six species of batoids. Tonic immobility was induced in the leopard shark, *Triakis semifasciata*; the whitetip reef shark, *Triaenodon obesus*; the blacktip reef shark, *Carcharhinus melanopterus*; the Caribbean reef shark, *Carcharhinus perezi*; the swellshark, *Cephaloscyllium ventriosum*; the California round ray, *Urolophus halleri*; the shovelnose guitarfish, *Rhinobatos productus*; the clearnose skate, *Raja eglanteria*; the cownose ray, *Rhinoptera bonasus*; and the southern stingray, *Dasyatis americana*. The broadnose sevengill shark, *Notorynchus cepedianus* and the yellow stingray, *Urolophus jamaicensis* failed to exhibit the tonic immobility response, but only one individual of each species was tested. The average induction time ranged from 16.7 sec in the shovelnose guitarfish to 45.7 sec in the clearnose skate. Average duration times ranged from 34.3 sec in the clearnose skate to 274.0 sec in the Caribbean reef shark. Depending upon the species involved, TI has been used as an aid in a few husbandry and medical procedures in captive elasmobranches at the National Aquarium in Baltimore. These procedures have included gross examination, measuring lengths, tube feeding, and drawing blood via caudal venipuncture. Using tonic immobility during these procedures is beneficial as once induced, the subject's struggling is minimal and usually requires little restraint.
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Key words: animal hypnosis, shark, ray

INTRODUCTION

Tonic immobility (TI) has been reported to occur in a wide variety of taxa. It has been reported in five classes of invertebrates and in all classes of vertebrates, except for Agnatha [Whitman, 1984]. The TI response is unlearned and is characterized by

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a state of immobility. The immobility may last from < 1 min to several hours [Chertok, 1968; Gallup et al., 1974; Watsky and Gruber, 1990]. In the species of elasmobranchs so far investigated, this has been a horizontal inverted position with the ventral surface facing upward [Kreidl, 1916; Schaefer, 1921a,b; Gruber and Keyes, 1981; Whitman, 1984; Whitman et al., 1986].

Some of the more commonly investigated parameters of TI are: the number of consecutive trials necessary to induce immobility, the time that the subject must be restrained prior to immobility (induction time), the percentage of individuals exhibiting TI in a given time interval, and the length of time that each episode lasts (duration time) [Whitman, 1984]. Tonic immobility has been examined in only a few species of elasmobranchs. Thus far, the TI response has been reported in five species of sharks and one species of ray. The sharks that have been investigated are: the spiny dogfish, *Squalus acanthias* [Lissmann, 1946], the lesser-spotted dogfish, *Scyliorhinus canicula* [Kreidl, 1916; Mangold, 1920], the smooth dogfish, *Mustelus canis* [Whitman et al., 1986], the lemon shark, *Negaprion brevirostris* [Gruber and Keyes, 1981], and the sandbar shark, *Carcharhinus plumbeus* [Whitman, 1984].

During immobility, a relaxation in the muscle tone was noticed in these species. This relaxation has been referred to as the "limp" response [Whitman et al., 1986; Watsky and Gruber, 1990]. A deep rhythmic respiration was also observed as a part of the response. The one species of batoid in which TI was reported is the thornback skate, *Raja clavata,* by Schaefer [1921b], who reported muscular rigidity during immobility. In this response, the pectoral fins curved slightly and the musculature was tense and unrelaxed. For the purposes of this study, this is referred to as the "rigid" response. Tonic immobility has been used as a part of other studies. In the lemon shark, e.g., TI was used to subdue and handle large sharks in the field, in a study of the response itself [Watsky and Gruber, 1990] and in conjunction with bioassays [Gruber and Zlotkin, 1982; Zlotkin and Gruber, 1984]. The goal of the present study was to provide preliminary information on tonic immobility for additional species of elasmobranches and to describe its use as an aid in their captive husbandry as used at the National Aquarium in Baltimore (NAIB).

MATERIALS AND METHODS

The subjects used in the investigation were all part of the animal collection at the NAIB with the exception of two individuals of one species that were housed at another institution. The species investigated were the broadnose sevengill shark, *Notorynchus cepedianus*; the swellshark, *Cephaloscyllium ventriosum*; the leopard shark, *Triakis semifasciata*; the blacktip reef shark, *Carcharhinus melanopterus*; the whitetip reef shark, *Triaenodon obesus*; the Caribbean reef shark, *Carcharhinus perezi*; the yellow stingray, *Urolophus jamaicensis*; the California round ray, *Urolophus halleri*; the clearnose skate, *Raja eglanteria*; the shovelnose guitarfish, *Rhinobatos productus*; the Atlantic cownose ray, *Rhinoptera bonasus*; and the southern stingray, *Dasyatis americana*. All subjects were sexed and measured to the nearest two mm. The measurements taken were total length (TL) in sharks as described by Compagno [1984] and disk width (DW) in rays as defined in Compagno et al. [1989] (Table 1). Most of the subjects used in the current investigation were juveniles and many were very young. In fact, all of the southern stingrays were neonates as were two of the swellsharks and two of the clearnose skates. All trials were conducted at

TABLE 1. Subjects used in

Species
Broadnose sevengill shark
Swellshark
Leopard shark
Whitetip reef shark
Blacktip reef shark
Caribbean reef shark
California round ray
Yellow stingray
Shovelnose guitarfish
Cownose ray
Clearnose skate
Southern stingray

[a]Sizes given are total length f

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Each trial was con
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TABLE 1. Subjects used in the investigation

Species	Number	Sex	Size range (mm)[a]
Broadnose sevengill shark	1	female	700
Swellshark	3	male	228–764
	2	female	178–182
Leopard shark	1	male	508
Whitetip reef shark	2	male	636–1050
Blacktip reef shark	2	male	711–767
	1	female	914
Caribbean reef shark	1	male	2026
	1	female	1413
California round ray	1	male	209
Yellow stingray	1	female	194
Shovelnose guitarfish	2	male	343–356
	1	female	330
Cownose ray	5	male	478–680
	2	female	701–991
Clearnose skate	2	male	115–374
	2	female	104–442
Southern stingray	5	male	168–230
	2	female	189–204

[a]Sizes given are total length for sharks and disk width for rays in millimeters.

the NAIB between September 1991 and March 1993 with the exception of those on the Caribbean reef shark, which were conducted at Coral World Bahamas in Nassau, July 1991.

Each trial was conducted by restraining the subject and inverting it dorsoventrally as quickly and gently as possible while keeping it submerged. For small sharks (< 150 cm TL), the investigator placed one hand above the pectoral fins and the other hand grasped the caudal peduncle. For larger sharks, those larger than 151 cm TL, two people restrained and inverted the animal. In this study, the only species inverted in this manner was the Caribbean reef shark. For rays, the investigator placed one hand across the disk on the dorsal surface and the other hand was placed on the ventral surface while inverting the animal. After the subject was inverted, it was held submerged with minimal restraint. The subject usually struggled from the point of capture to the point of induction. The amount of struggling varied but with gentle handling it was minimalized. The most struggling was observed in cownose rays.

Each subject was held inverted until either the onset of the TI response or until 90 sec had elapsed. A marked change in the overall muscle tone was used as the criterion for the onset of TI. This change corresponded to either the "limp" response or the "rigid" response described earlier. If TI was not induced on the first trial, the steps were repeated until TI was observed or until the completion of four trials. Between trials, the subjects were righted and unrestrained for 1 min as a resting period. Once the response was induced, each subject was not restrained until it regained mobility on its own. This time interval was the duration of the trial.

TABLE 2. Results of tonic immobility trials in 12 species of elasmobranchs

Species	N	Induction	Average number of trials to TI	Fraction induced
Broadnose sevengill shark	1	No	n/a	0/1
Leopard shark	1	Yes	1.0	1/1
Swellshark	5	Yes	2.0	4/5
Blacktip reef shark	3	Yes	1.3	3/3
Whitetip reef shark	2	Yes	1	2/2
Caribbean reef shark	2	Yes	1	2/2
Shovelnose guitarfish	3	Yes	2	3/3
California round ray	1	Yes	3	1/1
Yellow stingray	1	No	n/a	0/1
Cownose ray	7	Yes	1.6	7/7
Clearnose skate	4	Yes	2.7	3/4
Southern stingray	7	Yes	2.0	7/7

n/a = not available.

RESULTS

The TI response was observed in 10 of the 12 species examined, based upon the previously established criterion. In the two species in which the response did not occur, the broadnose sevengill shark and the yellow stingray, only one specimen of each species was available. In addition, only one subject of the California round ray and the leopard shark were used. Therefore, no analyses were done on these results. Among those species exhibiting the TI response, there was a noticeable relaxation in the overall muscle tone in all species except for the shovelnose guitarfish and the clearnose skate. In these two species, there was a marked rigidity at the time of induction. These two conditions correspond to the "limp" and "rigid" responses previously described. In all species in which TI was induced, a deep rhythmic respiration was observed. This deep rhythmic respiration was noted as a deeper and constant ventilation of the gills, and the respiration rate decreased from the period prior to induction. The TI response occurred on the first trial in all subjects for the whitetip reef shark and the Caribbean reef shark, with varying results for the remaining species.

For sharks, the average number of trials required to induce TI was the lowest for carcharhinids (blacktip reef shark, whitetip reef shark, and the Caribbean reef shark) with the highest value being for a scyliorhinid, the swellshark. Among the batoids, the lowest value was noted in the cownose ray, a rhinopterid. The average number of trials was slightly higher for a rhinobatid (shovelnose guitarfish) and almost three for the clearnose skate, a rajid (Table 2).

For those species in which the TI response was observed, the induction time was the lowest for the shovelnose guitarfish and the cownose ray and was the longest for the clearnose skate and the round ray. The shortest duration time was observed in the clearnose skate and the longest duration time was observed in the Caribbean reef shark. There was also quite a large range observed in those species with multiple subjects in both induction time and duration time (Table 3). It is interesting to note that the clearnose skate had the highest number of trials required to induce TI, the longest induction time, and the shortest duration time. Due to the small number of subjects tested in the current study, the results were not stratified by sex or size.

TABLE 3. Mean inducti
exhibited tonic immobili

Species
Swellshark (5)
Leopard shark (1)
Whitetip reef shark (2)
Blacktip reef shark (3)
Caribbean reef shark (2)
California round ray (1)
Shovelnose guitarfish (3)
Cownose ray (7)
Clearnose skate (4)
Southern stingray (7)

DISCUSSION

Although few cc
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swellshark are among th

It also appears th
Caribbean reef shark are

lasmobranchs

Average number of trials to TI	Fraction induced
n/a	0/1
1.0	1/1
2.0	4/5
1.3	3/3
1	2/2
1	2/2
2	3/3
3	1/1
n/a	0/1
1.6	7/7
2.7	3/4
2.0	7/7

TABLE 3. Mean induction time and mean duration with respective ranges for those species that exhibited tonic immobility

Species	Mean induction time (sec)	Range (sec)	Mean duration (sec)	Range (sec)
Swellshark (5)	36	27–44	85	75–91
Leopard shark (1)	28	28	37	37
Whitetip reef shark (2)	21	18–24	177	165–189
Blacktip reef shark (3)	25	20–31	92	67–121
Caribbean reef shark (2)	30	27–32	274	210–338
California round ray (1)	43	43	52	52
Shovelnose guitarfish (3)	17	14–19	131	126–139
Cownose ray (7)	18	13–22	201	181–229
Clearnose skate (4)	46	32–57	34	29–41
Southern stingray (7)	24	20–29	141	82–210

pecies examined, based upon the
in which the response did not
stingray, only one specimen of
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DISCUSSION

Although few conclusions can be drawn due to the small number of subjects, these preliminary results indicate that the leopard shark, the swellshark, the blacktip reef shark, the Caribbean reef shark, the whitetip reef shark, the shovelnose guitarfish, the cownose ray, the southern stingray, and the clearnose skate exhibit the TI response. Further testing may reveal differences between sexes or differences based on size. The maximum number of trials conducted in the present study is less than the 10 used by Whitman [1984] and Whitman et al. [1986] due to time constraints. In addition, handling was minimized because the animals were part of a captive collection. Whitman [1984], in her investigation of TI in juvenile snadbar sharks, reported that the average number of trials required for successful induction and the average duration were greater for females. These differences, however, were not statistically significant, yet, the probabilities for the occurrence of an episode of TI were statistically significant and females were found to be more likely to exhibit the response. It has also been suggested that the frequency of induction may increase with an increase in size and age for the sandar shark [Whitman, 1984] and the smooth dogfish [Whitman et al., 1986].

The values of mean induction time and mean duration time reported in the current investigation are within the range of the values reported for other species. In previously studied species in which quantitative results were available, the mean induction times were 38.4 sec for the sandbar shark [Whitman, 1984], 32.5 sec for the smooth dogfish [Whitman et al., 1986], and ~ 15 sec for the lemon shark [Watsky and Gruber, 1990]. The mean duration times were 88.0 sec, 61.9 sec, and 1,600 sec, for the sandbar shark, smooth dogfish, and lemon shark, respectively. These values were for both sexes and the values for the lemon shark were at the beginning of a habituation experiment. Gallup et al. [1971] and Whitman [1984] have stated that the number of trials for successful induction indicates how susceptible the animal is to induction of TI. Based upon the average number of trials required to induce immobility, it appears that the clearnose skate, the southern stingray, and the swellshark are among the least susceptible to the induction of TI.

It also appears that the whitetip reef shark, the blacktip reef shark, and the Caribbean reef shark are among the most susceptible to induction. These preliminary

results further substantiate an earlier report that tonic immobility is more stable and durations much longer in the lemon shark than in other species of sharks [Watsky and Gruber, 1990]. Care should be used when repeatably using TI, as habituation may occur, resulting in decreasing durations. Watsky and Gruber [1990] determined that habituation does occur in the lemon shark, but is more pronounced in spaced trials (one trial per day) than massed trials (12 trials per day).

Tonic Immobility as an Aid in the Captive Husbandry of Elasmobranchs

Tonic immobility has been used at the NAIB as an aid when handling elasmobranches for a variety of procedures. The overall goal in using TI in these procedures was to minimize struggling by the animal. Animals with induced TI did not thrash about, increasing the possibility of injury due to trauma. Further, the person handling the animal required little force to restrain it. TI was most commonly used to immobilize the animal for overall gross examinations. These routinely included examination of the snout, eyes, nares, and ventral surface. In addition, the subjects were examined for the presence of external parasites, mainly trematodes. Monogeneans are common parasites in elasmobranchs, and a summary table of these parasites and their hosts is presented by Cheung [1992].

The TI response was induced in a lemon shark to administer nutrition and fluids (mainly electrolytes) orally by way of tube feeding. This procedure was carried out to prevent dehydration, as the shark had not eaten for an extended period of time. The physiological effects of fasting confinement upon the spiny dogfish have been described by Martini [1978]. In addition, TI was induced in this lemon shark at the beginning of a freshwater dip. This 5-min freshwater dip was repeated several times over the course of 2 months in an attempt to eradicate adults of the monogenean trematode, *Dermophthirius nigrellii*, a common parasite of the lemon shark [Gruber and Keyes, 1981; Cheung et al., 1982].

The TI response was also utilized in other species when providing fluids, such as the swellshark, the sandbar shark, the smooth dogfish, and the leopard shark. In all cases, the animal had not eaten for an extended period and appeared thin. In addition to tube feeding, the TI response was also induced when drawing blood via caudal venipuncture in the sandbar shark, the smooth dogfish, the cownose ray, the whitetip reef shark, and the previously mentioned lemon shark. Tonic immobility has also been utilized to keep an animal immobile while measuring it. This procedure worked best on batoids such as the shovelnose guitarfish, the southern stingray, and the cownose ray because the disk width measurement is the same from either the dorsal or ventral surface. Although this procedure was used to measure sandbar sharks and smooth dogfish, care was taken to maintain a plane of measurement across the dorsal surface of the shark. The TI response was used in field tests of simulated transport of the Caribbean reef shark for gross examination and to immobilize the shark while making adjustments to the experimental container (unpublished results). It should be noted, however, that a strong stimulus can terminate TI, such as oral administration of a surfactant. This was the basis of using various substances in bioassays of shark repellents on the lemon shark as described by Gruber and Zlotkin [1982], Zlotkin and Gruber [1984], and Watsky and Gruber [1990]. Therefore, one should be ready to restrain the animal during procedures such as drawing blood or giving a freshwater dip. It is hoped that with continued use on the previously mentioned species, as well as new one well.

CONCLUSIONS

1. The tonic immobility res
shark, the whitetip reef shark, the
clearnose skate, the round ray, th
southern stingray.

2. Based upon the average
it appears that the clearnose ska
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and the blacktip reef shark appe

3. These results further sub
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4. Tonic immobility may
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REFERENCES

Chertok, L. Animal hypnosis. Pp.
ABNORMAL BEHAVIOR IN
M.W. Fox, ed. Philadelphia, W.
1968.

Cheung, P.J.; Nigrelli, R.F.; Ru
Cilia, A. Treatment of skin lesio
lemon sharks, *Negaprion brevir*
caused by monogeneans (*Dermo*
JOURNAL OF FISH DISEASES
1982.

Cheung, P.J. Parasitic diseases of e
Pp. 782–807 in FISH MEDI
Stoskopf, ed. Philadelphia, W
1992.

Compagno, L.V.J. SHARKS OF
FAO SPECIES CATALOG. No
Part 1. FAO, Rome, 1984.

Compagno, L.V.J.; Ebert, D.A
GUIDE TO THE SHARKS A

tioned species, as well as new ones, TI will prove beneficial in other procedures as well.

CONCLUSIONS

1. The tonic immobility response was induced in the swellshark, the leopard shark, the whitetip reef shark, the blacktip reef shark, the Caribbean reef shark, the clearnose skate, the round ray, the shovelnose guitarfish, the cownose ray, and the southern stingray.

2. Based upon the average number of trials required to induce tonic immobility, it appears that the clearnose skate and the southern stingray are among the least susceptible to the induction of TI. The whitetip reef shark, the Caribbean reef shark, and the blacktip reef shark appear to be the most susceptible to the induction of TI.

3. These results further substantiate an earlier report that TI is more stable and duration times much longer in the lemon shark than in other species of sharks [Watsky and Gruber, 1990].

4. Tonic immobility may be used as a tool to immobilize an elasmobranch for a variety of procedures that require handling the animal. The choice of species is, however, an important consideration.

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REFERENCES

Chertok, L. Animal hypnosis. Pp. 129–158 in ABNORMAL BEHAVIOR IN ANIMALS. M.W. Fox, ed. Philadelphia, W.B. Saunders, 1968.

Cheung, P.J.; Nigrelli, R.F.; Ruggieri, G.D.; Cilia, A. Treatment of skin lesions in captive lemon sharks, *Negaprion brevirostris* (Poey), caused by monogeneans (*Dermophthirius* sp.). JOURNAL OF FISH DISEASES. 5:167–170, 1982.

Cheung, P.J. Parasitic diseases of elasmobranchs. Pp. 782–807 in FISH MEDICINE. M.K. Stoskopf, ed. Philadelphia, W.B. Saunders, 1992.

Compagno, L.V.J. SHARKS OF THE WORLD, FAO SPECIES CATALOG. No. 125, Vol. 4, Part 1. FAO, Rome, 1984.

Compagno, L.V.J.; Ebert, D.A. Smale, M.J. GUIDE TO THE SHARKS AND RAYS OF SOUTHERN AFRICA. London, New Holland, 1989.

Gallup, G.G., Jr. Animal hypnosis: Factual status of a fictional concept. PSYCHOLOGICAL BULLETIN 81:836–853, 1974.

Gallup, G.G., Jr.; Nash, R.F.; Donegan, N.H.; McClure, M.K. The immobility response: A predator-induced reaction in chickens. PSYCHOLOGICAL RECORD 21:513–519, 1971.

Gruber, S.H.; Keyes, R.S. Keeping sharks for research. Pp. 373–402 in AQUARIUM SYSTEMS. A.D. Hawkins, ed. London, Academic Press, 1981.

Gruber, S.H.; Zlotkin, E. Bioassay of surfactants as shark repellents. NAVAL RESEARCH REVIEW 2:18–27, 1982.

Kreidl, A. Uber hypnose bei Fischen PFLUGER'S ARCHIVES OF GENERAL PHYSIOLOGY 164:441–444, 1916.

Lissmann, H.W. The neurological basis of the locomotory rhythm in the spinal dogfish (*Scyllium canicula, Acanthias vulgaris*). I. Reflex behavior. JOURNAL OF EXPERIMENTAL ZOOLOGY 23:143–161, 1946.

Mangold, E. Die tierische hypnose (Einschliesslich tonische tetanische und Totstell-reflex: Reactions- Akinese der Protisten). ERGELON PHYSIOLOGIE, 18:79–117, 1920.

Martini, F.H. The effects of fasting confinement on *Squalus acanthias*. Pp. 609–646 in SENSORY BIOLOGY OF SHARKS, SKATES, AND RAYS. E.S. Hodgson; R.F. Mathewson, eds. Arlington, VA, Office of Naval Research, 1978.

Schaefer, J.G. Beitrage zur Physiologie des Farbenwech sels der Fische. PFLUGER'S ARCHIVES OF GENERAL PHYSIOLOGY 188: 25–48, 1921a.

Schaefer, J.G. Uber den Lagerreflextonus von *Raja clavata*. BIOLOGICAL ZENTRABL 41: 291–295, 1921b.

Watsky, M.A.; Gruber, S.H. Induction and duration of tonic immobility in the lemon shark, *Negaprion brevirostris*. FISH PHYSIOLOGY AND BIOCHEMISTRY 8:207–210, 1990.

Whitman, P.A. TONIC IMMOBILITY IN JUVENILE SANDBAR SHARKS, *Carcharhinus plumbeus* (Nardo, 1827) (Pisces, Carcharhinidae). M.S. thesis, Univ. West Va., Morgantown, WV, 1984.

Whitman, P.A.; Marshal, J.A.; Keller, E.C., Jr. Tonic immobility in the smooth dogfish shark, *Mustelus canis* (Pisces, Carcharhinidae). COPEIA 3:829–832, 1986.

Zlotkin, E.; Gruber, S.H. Synthetic surfactants: A new approach to the development of shark repellents. ARCHIVES OF TOXICOLOGY 56:55–58, 1984.