The Elasmobranch Husbandry Manual:

Captive Care of Sharks, Rays and their Relatives

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Chapter 19

Physiological and Behavioral Changes to Elasmobranchs in Controlled Environments

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Abstract: Stress is defined as a stimulus acting on a biological system and the subsequent behavioral and physiologic reaction of that system (Pickering, 1981). Minimizing potential stress to elasmobranchs in a controlled environment will increase their survivorship. Parameters that can indicate the presence of stress include inappetence and anorexia, evasive or avoidance behavior, and changes to any of the following: skin coloration, ventilation, swimming behavior, feeding behavior, blood parameters, and steroid titers. Stressors may be divided into two basic categories, abiotic and biotic. Abiotic stressors include spatial constraints, transport and handling, compromised water quality, lighting, electromagnetic fields, and vibrations. Biotic stressors include species compatibility, sexual conflict, interactions with divers, inappropriate nutrition, and disease-producing pathogens. Multiple observations of animals throughout the day will allow an understanding of baseline parameters, facilitating comparison to unusual behaviors or changes in physical appearance that may indicate the presence of stressors. Careful assessment of "stressful" situations is recommended as stress responses may be of a generic nature and "snap" judgments can result in ill-informed husbandry decisions. Once a stress stimulus has been positively identified, every effort should be made to modify or eliminate it quickly. Chemico-therapeutic intervention may be required if an animal has been injured or is immunosuppressed.

The concept of biological stress has many definitions in the scientific literature and it is difficult to establish a single, comprehensive definition. All definitions of stress, however, share the common premise of a stimulus acting on a biological system and a subsequent behavioral and physiologic reaction of that system (Pickering, 1981). Stress is regarded as any stimulus that is sufficient to unbalance the internal environment (homeostasis) of an organism. Stressors can include hyperactivity, physical injury, and modification of the external environment (Smith, 1992), as well as diving activities and interaction with humans during capture, transport, and other husbandry procedures.

This chapter will examine behavioral and physiological parameters that may used as indicators of stress, comment on pre-disposing abiotic and biotic factors, and suggest techniques to moderate the effects of described stressors.

CLINICAL SIGNS

Minimizing potential stress to elasmobranchs in a controlled environment will increase their survivorship. To control stress it is important to first quantify natural behaviors and physiology in the wild, and compare these norms to observations of reactions in captive situations.

Murru (1990) states that it is important for animals maintained in controlled environments to exhibit as close to "normal" activity as possible. One must therefore understand the natural ecology and sociobiology of the species concerned to better understand clinical signs indicative of stress.

Parameters that may be used as potential indicators of stress include skin coloration, ventilation, swimming behavior, evasion or avoidance, feeding behavior, anorexia, and physiological changes. This list highlights the importance of monitoring elasmobranch behavior and of recognizing how it may be affected by environmental changes. Further, it points to the importance of documenting behavioral and clinical observations prior to, and during, changes to controlled environments. This information will be useful in developing a course of action to avoid stress, mitigate reactions, and prompt appropriate corrective treatments, where required.

Skin coloration

Epidermal hyper- or hypo-coloration (i.e., acute darkening or fading of the skin) is symptomatic of stress and may be characterized by general color changes to the entire body or manifest as a blotchiness of the skin. Rajiformes exhibit similar responses but, in addition, often display dark lines that run sagittally from the spine to the distal tip of the pectoral fins.

Hypo-coloration of the epidermis may be attributed to the effect of increased levels of catecholamines on melanocytes and the vasoconstriction of peripheral blood circulation (Cliff and Thurman, 1984). An additional biochemical reaction to catecholamines is the mobilization of glucose. Changing skin color may therefore indicate to what degree glucose redistribution has occurred and, indirectly, the depth of stress experienced by the animal (Smith, 1992).

Ventilation

There are two basic methods of breathing, or ventilation, used by sharks: obligate ram ventilation and active ventilation. Some species of sharks, such as nurse (*Ginglymostoma cirratum*), sand tiger (*Carcharias taurus*), whitetip reef (*Triaenodon obesus*), and leopard (*Triakis semifasciata*) sharks have demonstrated the ability to use both modes of ventilation. Ventilation rates may vary both inter- and intra-specifically under different environmental conditions.

Abnormal ventilation rates can be used as an indicator that some physiological or environmental stressor exists. It is important to understand the ventilation technique used by a species and to document ventilation rates under different circumstances. Examples of different circumstances include: at rest, actively swimming (including cruising, rest-glide, and recovery phases), the presence of divers, during feeding, during courtship, post-acclimatization, post-physical exam, and throughout transport. Information documented during different conditions will provide baseline data against which changed ventilation rates can be compared.

Changes to ventilation during stress will depend on the mode of ventilation normally employed by an elasmobranch. For active ventilators, movements should be relaxed and fluid, and at a reasonably constant rate. Obligate ram ventilators should have their mouth slightly open, and the gill slits partially flared, with minimal movement of the jaw or gills. Changes to ventilation may be indicated by the rate, orientation, and/or degree to which the mouth, gill slits, and spiracles open and close.

The degree of increase or decrease in ventilation rate may be slight or profound, depending on the condition of the animal and/or the stress stimulus. Stressed sharks have been observed ram ventilating with their mouth agape and gill slits flared more than normal. This behavior may be coupled with an increased swimming speed. Heavy or forced ventilation is evidenced by a stronger pumping of the gill slits or spiracles (i.e., a profound, "squeezing" of the gill slits or spiracles is observed). A pumping of the mouth and an increased ventilation rate may also be observed. Shallow or weak ventilation is characterized by a decrease in the magnitude that gill slits and spiracles open during ventilation cycles. Shallow or weak ventilation is usually associated with a decreased ventilation rate; however, it may occur independently or with an increased ventilation rate.

Changes in environmental conditions (e.g., a pulse of poor water quality) may cause an animal to temporarily minimize the water contacting its gills by "protecting" them. Protection of the gills is indicated by a severe decrease in ventilation rate, the mouth, gill slits, and spiracles remaining closed. Another stress response is ram ventilation accompanied by "coughing" or "jaw popping" (i.e., moving the jaw forward in the same manner adopted during feeding), often followed by several forced ventilations.

Swimming behavior

Swimming behavior can indicate stress in elasmobranchs and should be regularly monitored, especially when any change in environmental conditions occurs. Swimming behavior indicative of stress can include any of the following: constant, rapid swimming; quick or "jerky" maneuvers; slow, labored swimming with exaggerated lateral head movements; head above and tail below the horizontal plane, in some cases with the head out of the water; poor navigation (i.e., colliding with exhibit decoration, walls, or other animals); quick movements up through the water column followed by powerless gliding to the bottom of the exhibit; and swimming in tight circles or "looping".

Swimming behavior can be influenced by buoyancy, especially in the sand tiger shark. This species is unique in that it retains air in its stomach to regulate buoyancy. Sand tigers are normally neutrally buoyant, able to hang almost motionless in the water column. When stressed, the ability of a sand tiger to regulate the amount of air in its stomach can be compromised. This reaction can be caused by the physical trauma associated with invasive husbandry activities. If there is too much air in its stomach, the sand tiger may be observed near the surface struggling to swim down through the water column. Alternatively, the shark may be observed floating "belly up" at the surface, or occasionally upside down on the bottom of the aquarium. Too little air in the stomach will cause the shark to be negatively buoyant and sink to the bottom. The shark may be observed swimming laboriously, body angled, with the head up and tail down. This type of swimming behavior may be followed by periods where the shark "rests" on the bottom. If fatigue is extreme, the shark may remain on the bottom for long periods of time, dorsal, lateral, or even ventral side up.

Swimming behavior can be influenced by poor water quality. For example, sand tiger sharks exposed to toxic volatile organic compounds exhibited erratic swimming behavior, swimming slowly and resting intermittently on the bottom of the exhibit (Rasmussen et al., 2000).

Evasion or avoidance

Another indicator of stress in captive elasmobranchs is their evasion or avoidance of specific areas or animals, whereby the subject actively swims away from the stimulus in question. In the case of normally conspicuous benthic species, they may suddenly go into hiding indicating the presence of a disagreeable stimulus.

Over time, many animals fall into repetitive swimming patterns. If a change in the environment occurs, this may cause the animal to change its pattern or avoid a particular area within the exhibit. This behavior is usually caused by an array of factors that can be broken into two basic categories, biotic and abiotic. Examples of biotic factors include changes to social structure and species composition, changes to husbandry practices, and the presence of sick or injured animals. Examples of abiotic factors include changes to exhibit décor, changes to water flow, mechanical vibrations, etc. Animals affected by any one of these stimuli may actively avoid the source of stress. Careful observation of evasive behavior will provide clues as to the problem and how it may be remedied.

Evasive behavior may be observed during feeding sessions, whereby aggressive species are the cause of a stressful environment and other animals avoid the feeding station or are inhibited from taking food. Some animals may avoid a feeding station if activities outside the exhibit produce a lot of visual or auditory stimuli. Improper feeding techniques (e.g., the method of presenting food items) can be a source of stress for elasmobranchs and cause them to avoid the feeding station. For example, attempting to feed a smalltooth sawfish (*Pristis pectinata*) with "snake tongs" can create a stressful situation as the animal cannot readily access the food. The animal may therefore subsequently avoid the feeding station and displace other animals in their quest for more readily available food.

During mating season, females of some species of elasmobranch may be observed with bite wounds and lesions on their pectoral fins, on their body adjacent to the pectoral fins, or near the gill slits. Females experiencing these injuries have been known to avoid males and/or areas frequented by males, and may even avoid feeding stations, becoming temporarily anorexic.

Anorexia

A decrease in food intake, total loss of appetite, and other changes to normal feeding behavior may be an indicator of stress in some shark species. Feeding behavior can be characterized in a number of different ways including pre-feeding, feeding technique, post-feeding, amount and type of food consumed, and time required to consume a normal ration. Behavior during feeding sessions should be well understood and documented for each specimen so that meaningful comparisons can be made if and when changes occur.

Fish in controlled environments become conditioned to normal operating regimes within and around their exhibit. Animals will frequently alter their swimming pattern and speed just prior to and/or during feeding sessions. If an elasmobranch is less excited than usual at the beginning of a feeding session, it may be suffering from some form of stress. Stressed animals may not take food as readily as usual or may require more time to come to a feeding station. Dropping food items, decreased or increased consumption rates, deviations in the way food is accepted, and refusal to consume normal daily ration are all possible indicators of stress.

If anorexia is not addressed quickly, changes in body form may occur (e.g., concave abdomen, head wider than axial girth, prominent pelvic girdle, etc.). In the case of Rajiformes the dorsal surface above the coelomic cavity, proximal to the spine, may become concave.

Some elasmobranchs exhibit seasonal changes to diet and daily ration, which could be misdiagnosed as stress. Food intake should be well documented so that such seasonal trends are not misunderstood.

Physiological responses

Different conditions or stimuli can cause physiological responses indicative of stress. These conditions include: capture, restraint, transport, confinement, exposure to heavy metals or volatile organic compounds, and changes to water quality parameters (e.g., temperature, salinity, etc.). Physiological responses to stress can be identified, and to some degree quantified, using blood pictures (i.e., hemograms and serum chemistry) (Stoskopf, 1993), as well as measurement of the corticoid 1 α-hydroxy-corticosterone (Idler et al., 1969; Kime, 1977; Manire et al., 1999; Manire et al., 2001).

Capture and transport

Cliff and Thurman (1984) studied the effects of stress, during capture and transport, on the blood of juvenile dusky sharks (*Carcharhinus obscurus*). Samples were taken within two minutes of capture on hook and line, 10 minutes post-hyperactivity, 30 minutes post-transport (i.e., 60 minutes post-capture), and three, six, and 24 hours post-capture. Potassium (principally an intracellular cation) rose significantly but returned to baseline levels within 24 hours. Total serum magnesium increased and remained high during the post-stress period, and total and ionized serum calcium levels rose and returned to baseline levels within 24 hours. Although variable, creatinine kinase concentrations generally remained high during post-stress periods. Blood lactate, blood glucose, and serum osmolality were elevated, while pH declined.

In addition to changes in blood chemistry, stress associated with capture and restraint may elicit a complex group of physiological responses involving circulatory, respiratory, endocrine, and muscular systems. Examples include hypoxia, respiratory and/or metabolic acidosis, cellular damage, etc. (Manire et al., 2001). In extreme cases mortality can result.

Heavy metals

Torres et al. (1986) examined blood chemistry in the smallspotted catshark (*Scyliorhinus canicula*) during both confinement stress and exposure to zinc. Significant decreases in erythrocyte counts (RBCC), hematocrit (Hct), hemoglobin (Hb), leucocrit (Lt), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentrations (MCHC) were observed in “stressed” sharks. Mean corpuscular volume (MCV) did not change and a significant increase in glucose was observed. Animals exposed to 80 mg l^{-1} zinc for 24 hours exhibited significant decreases in Hb, MCH, MCHC, and plasma glucose, and elevated Lt and RBCC, suggesting that exposure to heavy metals can influence blood chemistry.

An additional study examined the affects of copper exposure on smallspotted catsharks. Decreased RBCC and Hct was observed at the lowest concentration (i.e., 2 mg l^{-1} copper II). At higher concentrations (i.e., 4 mg l^{-1}, 6 mg l^{-1}, 8 mg l^{-1}, and in particular, the near-lethal concentration of 16 mg l^{-1}) a general reduction of all blood parameters was observed (Tort et al., 1986). Liver composition (i.e., protein, glycogen, and lipid levels) was not affected by copper exposure over the duration of the experiment.

Volatile organic compounds

Volatile organic compounds can infiltrate water and cause clinical and physiological signs of stress, and in some extreme cases even death. Rasmussen et al. (2000) recently examined a situation where two moribund sand tiger sharks exhibited stressed swimming behavior. Liver samples taken from stressed bony fish (i.e., swimming frantically and jumping from the water surface) from within the same exhibit revealed the presence of a number of volatile organic compounds. Water samples taken shortly after the observed stressed behavior revealed the presence of many volatile organic compounds (e.g., acetone, tetrahydrofuran, 2-butanone, 1,1,1-trichloroethane, methyl isobutyl ketone, toluene, and 1,2,3-trichloro-propane). All other tested water parameters were within normal limits. It is believed that the volatile organic compounds damaged the gills of the sand tiger sharks and ultimately resulted in their death. The most likely source of these toxic compounds was fumes produced during the application of a waterproofing compound on the walls of a nearby exhibit (Rasmussen et al., 2000).

Water quality

Temperature (Spotte, 1992) and salinity fluctuations (Claiborne, 1998) should be minimized as they can disrupt acid-base homeostasis and osmotic pressure in elasmobranchs. Maintenance of internal pH (acid-base homeostasis) occurs through two processes: internally between blood and tissue, and externally by transference between the animal and its surrounding environment. Nursehound (*Scyliorhinus stellaris*) subjected to a sudden water temperature increase of 10°C displayed a rapid decline in pH, a rise in physiologic carbon dioxide (CO_2), and an elevated concentration of blood bicarbonates (HCO_3^-). Bicarbonate was simultaneously released into the surrounding seawater (Spotte, 1992). Physiological reactions were inversed when nursehound were subjected to a water temperature decrease of 10°C.

Salinity fluctuations can potentially cause stress in elasmobranchs. Plasma sodium chloride (NaCl) concentrations are normally lower than that of seawater in chondrichthyan fishes. However, the presence of urea and trimethylamine oxide (TMAO) means that elasmobranch plasma is hyperosmotic to the environment. Urea aids the osmotic challenge that sharks would otherwise face in the marine environment, while TMAO counteracts the potentially toxic effects of high blood urea (Karnaky, 1998).

Odor of urea

Some elasmobranchs produce a strong odor, reminiscent of urea, when subjected to stress, whether they are in or out of the water. Evans and Kormanik (1985) found that stress, associated with handling and anesthesia, was followed by a significant and transient increase in the efflux of urea across the branchial epithelium of spiny dogfish (*Squalus acanthias*). In small aquariums the urea odor may be more easily identified, due to lack of dilution. Examples of this phenomenon have been observed in small exhibits containing yellow (*Urobatis jamaicensis*), southern (*Dasyatis americana*), and Atlantic (*Dasyatis sabina*) stingrays. During handling, the urea odor may be produced rapidly as has been observed in lemon (*Negaprion brevirostris*) and bull (*Carcharhinus leucas*) sharks. A sandbar shark (*Carcharhinus plumbeus*), recently bitten by another shark, was observed to reek of urea and was assumed to be stressed, as other stress indicators were observed (i.e., hypo-coloration and anorexia). The urea odor will usually dissipate once the causative stress stimulus has been removed; this may be rapid, or may take several days.

Corticosteroids

Early studies into elasmobranch blood worked on assays to identify and measure the principal corticoid 1α-hydroxycorticosterone (1α-OH-B) (Kime, 1977; Idler et al., 1969). Idler et al. (1969) studied the corticoid 1α-OH-B in 15 species of elasmobranch because initial experiments indicated that cortisol and/or corticosterone were the principal plasmatic corticosteroids. More recent studies with bonnethead sharks (*Sphyrna tiburo*) found no change in corticosterone concentrations during acute or chronic stress (Manire et al., 1999).

Manire et al. (1999) examined the possible role of 1α-OH-B in reproduction of bonnethead sharks and the Atlantic stingray. A significant difference in corticosterone concentrations was observed between male and female bonnethead sharks, but no difference was observed between immature and mature sharks. Additionally, significant differences in corticosterone concentrations were observed during various reproductive stages in mature males and females of both bonnethead sharks and Atlantic stingrays.

Recent attempts at producing 1α-OH-B in elasmobranchs have been unsuccessful and assays for this steroid have not been developed. This is an area that merits further investigation (Manire, 2001).

PREDISPOSING FACTORS

Successful husbandry and increased survivorship of animals in aquariums must be built on their environmental and physiological requirements (Murru, 1990). Stress factors that affect these requirements may be divided into two basic categories, abiotic and biotic. Abiotic stressors are characterized by the absence of life or non-biological factors independent of living organisms and biotic stressors pertains to life or ecological factors due to the interactions of living organisms (Wallace et al., 1981). Abiotic factors include spatial constraints, transport and handling, water quality, lighting, electromagnetic fields, and vibrations. Biotic factors include species compatibility, sexual aggression, interactions with divers, nutrition, and pathogens.

Abiotic factors

Spatial constraints

Spatial constraints in controlled environments have the potential to be stressful, particularly for pelagic elasmobranchs. The size and shape of an exhibit has a direct impact on the behavior of animals therein. If an exhibit is too small it has the potential to limit swim patterns, restrict courtship behavior, and increase aggression between and within species. Within an elasmobranch exhibit, corners having an angle of $\leq 90°$ are considered dead space to a swimming shark, making navigation difficult, consuming valuable energy reserves, and creating unnecessary distress (Murru, 1990). Similarly, excessive currents within an exhibit may provoke overexertion, elevating metabolic rates and resulting in anaerobic respiration. Prolonged periods of anaerobic respiration will ultimately become stressful for an elasmobranch.

Transport and handling

Many elasmobranchs have succumbed to stress induced during transportation. Careful handling on capture, proper pre-transport staging (Murru, 1990), a good transport regime, and a swift acclimatization period with minimum stress (Smith, 1992) are all important components of a successful transport. Likewise, manipulation of elasmobranchs during physical examinations should be swift and impose the least possible stress to the animal under scrutiny.

Water quality

The most important environmental stressor appears to be exposure to poor water chemistry, or sudden changes thereof (Spotte, 1992). Poorly designed life support systems (LSSs) may not adequately remove particulates and toxic metabolic byproducts from the water, or achieve suitable gas balance (in particular oxygen concentrations), resulting in physiological stress to the animals within an exhibit.

Sudden changes to salinity, temperature, pH, oxygen concentrations, and environmental hypercapnia (increased CO_2) will all affect acid-base homeostasis (Eckert and Randall, 1983; Spotte ,1992; Claiborne, 1998), as well as causing other types of stress responses in elasmobranchs. Nitrogenous compounds (ammonia, nitrite, and nitrate) are toxic to elasmobranchs (Spotte, 1979). A buildup of nitrogenous wastes can result in signs of a neurological challenge (Stoskopf, 1993).

Lighting

Lighting levels may present a potential stress to elasmobranchs in aquariums. Light intensity, light quality, and photoperiod influence the ability of a fish to make vitamins, navigate throughout its surroundings, and reproduce (Moe, 1992). Although there is no scientific study to support this claim, it is possible that inappropriate photoperiods, and/or a lack of crepuscular periods of low illumination, may cause some degree of stress in elasmobranchs. The sudden lighting of an exhibit from complete darkness to high illumination, or vice versa, is certainly not recommended as elasmobranchs react suddenly and erratically to such changes. A “night”-light employed during nocturnal periods, to simulate the moon, will decrease predation of smaller fishes and sharks by larger sharks, reducing stress to the former.

Electromagnetic fields

The electrical fixtures within an aquarium building produce electromagnetic fields that may stress elasmobranchs and ultimately impact animal health. Exposure to excess electromagnetic fields has been hypothesized as a contributor to head and lateral line erosion (HLLE) and general poor health (Goertz, pers. com.). Spiny dogfish, and to a lesser extent, the dusky smooth-hound (*Mustelus canis*), have been observed swimming with their head out of the water when stressed. It has been hypothesized that low levels of electricity within the exhibit were responsible for this behavior.

Vibration and acoustics

The immediate environment surrounding an aquarium may be exposed to vibration and noise (high-frequency vibration) from LSS equipment and husbandry activities. These vibrations may be conducted into an exhibit and cause stress to the elasmobranchs therein. Swimming behavior consistent with stress has been observed in elasmobranchs during periods of underwater maintenance, while restarting LSSs, and during instances of sudden loud noises from outside an exhibit.

Biotic factors

Species compatibility and sexual aggression

Species compatibility is an important part of the successful husbandry of elasmobranchs. Inter- and intraspecific species selection, animal size, and population density must be considered when determining the composition of an exhibit's population. It is important to ensure that growth rate and maximum size of a species is well understood to avoid placing animals in a confined and stressful environment. Courtship, often involving behavior where an elasmobranch bites and holds another with its teeth, may create stress in restricted environments. Lacerations of the pectoral fins and gill covers, resulting from sexual aggression and copulation, should be monitored closely to ensure they are healing without complication (Uchida et al., 1990).

Interaction with divers

Diving activities within an exhibit have the potential to cause stress responses in elasmobranchs, mostly related to navigation and swimming behavior. Divers, and occasionally bubble streams and noises created by the divers, represent an obstacle for sharks to negotiate, sometimes eliciting “flight responses”. As the shark attempts to evade the stimuli presented by divers it can swim into décor, other divers, walls, etc., and potentially damage itself or others (refer to Chapter 12 of this manual for more information about diving with elasmobranchs).

Nutrition

If elasmobranchs are over- or underweight it can cause physiological and behavioral stress. Underfed animals may be more aggressive and prey on cohabitants, making the environment stressful for smaller or less dominant animals.

Inappropriate food types, sizes, and feeding techniques can cause stress. It is therefore important to understand how each animal normally obtains its food and, where possible, to attempt to simulate this during feeding sessions. Having animals take food quickly can prevent aggressive animals from competing for the same food item. Food items that are too large may necessitate the animal to tear the food into smaller pieces, creating an opportunity for aggressive animals to compete for the same food item. In an extreme case, bull sharks have been observed “ramming” the stomach of sand tiger sharks, coercing them to spit out food fish and leave it available for the bull sharks to consume. Minimizing the work required to consume its daily ration, without excess competition with co-habitants, will alleviate potential stress. In elasmobranch exhibits containing different species, it may be necessary to set up several feeding stations where more than one person can feed the animals simultaneously. In this way, different groups of animals can be fed at specified locations, cutting down aggression and competition.

Goiter has been observed in a number of different elasmobranchs. Goiter is a physiological condition, usually related to nutrition, which may cause a compounding stress reaction in an elasmobranch. Goiter is described as a thyroid enlargement, due to hyperplasia and hypertrophy, caused by low aquatic iodine concentrations or goitrogenic agents that block the release of iodine from the thyroid gland (Crow et al., 2001). Goiter in elasmobranchs is usually characterized by a swelling of the posterior portion of the lower jaw.

Goiter can be seen as a round swelling within the buccal cavity and, if severe, externally on the ventral surface of the lower jaw. Profound goiter-induced changes to the jaw have been known to cause stress responses (i.e., changes to swimming patterns, changes to ventilation rate and depth, and anorexia).

Pathogens

Disease can cause stress responses in sharks and rays (e.g., changes to ventilation rate and depth, swimming behavior, skin coloration, and feeding behavior). An infestation of the gills by monogeneans may cause a change in ventilation rate and depth, mimicking similar responses to other adverse environmental conditions. Internal parasites such as coccidia (*Eimeria southwelli*) have been known to cause skin discoloration, emaciation, coelomic cavity distention, and ultimately death in cownose rays (*Rhinoptera bonasus*) (Stamper and Lewbart, 1998). Other chapters, detailing different disease-producing organisms (refer to Chapters 24, 25, and 26 of this manual), provide more information about clinical signs that may be observed. From this information it is possible to interpret signs of disease-induced stress and develop appropriate management strategies.

TECHNIQUE TO ALLEVIATE POTENTIAL STRESSORS

A proactive approach to animal management is the key to successfully maintaining elasmobranchs. This approach requires planning during exhibit and LSS design; considered species selection; and, a careful acquisition, transport, and acclimatization process. Once animals have been acclimatized to their new environment, detailed record-keeping and strong communication skills are essential tools for keeping colleagues apprised of animal status, developing husbandry regimes, and thus increasing specimen survivorship. Multiple observations of animals throughout the day allow an understanding of baseline parameters, facilitating comparison to unusual behaviors or changes in physical appearance. Table 19.1 summarizes a number of behavioral, biochemical, and physiological changes in elasmobranchs that may be attributable to an exposure to stressors.

If an observed change to baseline parameters is attributed to stress, the next step is to determine causative stimuli. A careful assessment of any given situation is advised, as stress responses may be of a generic nature and "snap" judgments may result in ill-informed husbandry intervention. For example, parasitic infestations of the gills may elicit the same stress response as low dissolved oxygen concentrations. Regardless, observed stress responses should be investigated quickly. Often the determination of a stressor may require the observation of several different stress responses and other physical changes to an exhibit, piecing together clues somewhat like a detective investigating a crime scene. Once a stress stimulus has been positively identified, every effort should be made to modify or eliminate it. The course of action taken will be dictated by the source of stress. Chemico-therapeutic treatment may be required if an animal has been injured and/or immunosuppressed.

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Table 19.1. Behavioral, biochemical, and physiological changes observed in captive elasmobranchs that may indicate stress, showing possible stressors. I = parameter increases; D = parameter decreases; I+D = parameter may both increase or decrease; CO = specified condition observed; NC = no discernable change observed; UN = result unknown.

Observed change	Spatial constraints	Transport + handling	Temp. increase	Temp. decrease	Water quality changes	Heavy metals	Electro-magnetic field	Vibration	Courtship	Diver presence	Nutrition problems	Disease
Skin Coloration	CO	CO	CO	CO	CO	CO	CO	CO	CO	CO	CO	CO
Ventilation	CO	CO	CO	CO	CO	CO	CO	CO	CO	CO	CO	CO
Swimming Behavior	CO	CO	CO	CO	CO	CO	CO	CO	CO	CO	CO	CO
Evasion or Avoidance	CO	CO	CO	CO	CO	CO	CO	CO	CO	CO	CO	CO
Anorexia	CO	CO	CO	CO	CO	CO	CO	CO	CO	CO	CO	CO
Urea Odor	CO	CO	UN	UN	UN	UN	UN	UN	UN	UN	UN	UN
Potassium		I										
Magnesium		I										
Total and Ionized Serum Calcium		I										
Creatinine Kinase		I										
Blood Lactate		I										
Blood Glucose	I	I				D						
Serum Osmolality		I										
Acid - Base Homeostasis					CO							
pH		D	D	I								
Hypoxia		CO										
Hypercapnia				CO								
Respiratory and/or Metabolic acidosis												
Acidemia/Acidosis		CO	CO									
Alkalosis			I	D								
Cellular Damage		CO										
Erythrocyte Counts	D					I+D						
Hematocrit	D					I+D						
Hemoglobin	D					I+D						
Leucocrit	D					I+D						
Mean Corpuscular Hemoglobin	D					I+D						
Mean Corpuscular Hemoglobin Concentration	D					I+D						
Mean Corpuscular Volume	NC											

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PERSONAL COMMUNICATIONS

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