PRACTICAL CONSIDERATIONS FOR SUPPORTIVE NUTRITIONAL CARE OF ELASMOBRANCHS.

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Introduction

Inappetence / anorexia is not always a sign of a clinical disease process in progress. Anorexia in elasmobranchs (sharks, skates, and rays) can be caused by a variety of factors ranging from injury, inappropriate water quality, environmental disturbance, and social organization to temperature changes, season or life stage, and manifestation of typical foraging behavior. The challenge is to determine, as accurately as possible, the main cause of the anorexia and whether intervention is necessary. In some cases, intervention may take the form of altering the ingredients or physical form of the diet. In other cases, assist feeding may be needed. In all cases, clear nutritional goals prior to the initiation of diet alteration and methods for follow up assessment are needed. The goal is a self-feeding animal, consuming a diet appropriate for its life stage and physiology.

When and Why to Intervene?

Prior to a move, animals can be purposefully fasted in order to insure appropriate water quality (and animal health) during the transport. Neonate animals or animals transported from a different habitat or facility may exhibit a period of inappetence or anorexia post-birth, hatch, or transport, and utilize body stores to meet nutrient needs during that period.[5]

During periods of anorexia, some loss of body condition can be expected, and body condition changes can indicate when intervention may be necessary. Experimentally fasted lemon sharks lost 1.0% of bodyweight (BW) per day.[2] Periods of anorexia between 3 months (sandtiger sharks, *Carcharias taurus*) and 5 months (tiger shark, *Galeocerdo cuvier*), followed by commencement of normal feeding, have been reported.[5] The maximum allowable period of anorexia for an elasmobranch can be based on individual body condition, health status, available diagnostic measures, and the discretion of husbandry staff involved. Sea World has used a 4-6 week timeline to begin force feeding mature elasmobranchs.[5] Additionally, a loss of 5% of body weight is a suggested threshold for assist feeding, if body weight measurements are available.

Methods to evaluate condition change in elasmobranchs are not well-established. Simple body weight measurements are often not easily acquired. Assessment of body condition based on visual observation (wrinkles, concavities, and protrusions caused by weight and condition loss) is often the best available tool to assess weight loss. These observations are based on species and individual animal. When blood samples are available, reference "normal" values for circulating metabolites are sparse.[3,7,11] When available and practical however, these values provide thresholds for metabolites such as glucose, creatinine, total protein, and others as guides for initiation and use of supportive therapies. Blood metabolites can be influenced by capture and handling stress.[3]

Normal feeding behavior also can be influenced by capture and handling. There is a definite cost-to-benefit relationship when considering a decision to handle an anorexic animal. Knowing how an animal responds to handling (easily handled, changes or does not change post-handling behavior, etc) is important to consider prior to making a decision to be more invasive.

The goals of intervention can be numerous and often complementary. The ultimate goal is to get an animal to self-feed in an appropriate manner for its physiological state (growth, maintenance, reproduction, healing). This goal is often the summation of a series of smaller goals: the animal receiving enough energy to resume normal behaviors, to heal an injury, to maintain itself, to begin natural foraging behaviors, and to resume self-feeding after a period of minimized handling (no additional invasive feeding effort). In each case, clear, progressive goals should be established, as well as parameters to objectively measure success.

How to Intervene?

In general, the elasmobranch gastrointestinal (GI) tract is characterized by a short, wide, and straight esophagus leading to a j-shaped stomach.[4,9] The intestine is characteristically short, containing one of four different configurations of folded intestinal mucosa and submucosa (spiral intestine) to increase absorptive surface and retention time. When considering assist feeding, the portion of the GI tract anterior to the pyloric region of the stomach is the primary target.

In some cases, offering novel items or familiar items (previously presented) in a novel way will encourage animals to feed. Whole food items for voluntary consumption can be offered floating or swimming in the water column, or via tongs, skewers, or some other feeding device safe for the animal. Live food items can be used initially, followed by a step-wise transition back to a more appropriate option. When such approaches do not work, a more invasive approach may be needed.

When items are assist fed, it may be necessary to reduce particle size in order to fit through the esophageal sphincter leading to the stomach. In the case of this paper, the difference between "force feeding" and "tube feeding" is in form. "Force feeding" is considered the provision of whole food items or items with slightly reduced particle size (i.e. whole capelin or capelin chunks), and "tube feeding" is the provision of a blended formula or gruel. A tube can be used for either approach, the only difference is in physical form. When tube feeding, the nutrient content and physical consistency of the formula is most important. The goal is to deliver nutrients needed in the amount and form that will flow through a tube of the appropriate diameter and length. Equally important, the equipment used must be the appropriate length, diameter, and physical form to insure safe and appropriate placement inside the animal and for adequate delivery of the desired formula.

Methodology

Giving anorexic animals an opportunity to self-feed on novel items prior to any additional intervention is recommended. Offering live food items may initiate feeding behavior in some animals. If the food item is not alive, manual manipulation of the food item for some elasmobranchs also elicits a feeding response. Anecdotal reports suggest that some diet additives[1] or items may elicit a feeding response in difficult or slow feeders (clam meat, salmon, bonito, sand lance, etc), but few have been adequately proven. Sometimes, soaking diet items in novel or distinctive fluids can increase foraging behavior (clam juice, krill juice, squid juice, etc). The duration of this period is based on animal condition, behavior, and any diagnostic measures available.

If self-feeding does not occur, or does not appear probable within a time frame that maintains animal health, an assist feeding approach can be adopted. Animal handling is invasive and potentially stressful, so the benefits of such handling should clearly outweigh the costs (maintaining hydration, prevent excessive weight loss, promote healing or recovery).

Initial assist feeding efforts for elasmobranchs may include tubing with freshwater (10 ml/kg as an estimate), which has been reported to stimulate feeding behavior. In coordination with fresh water, vitamin B complex (5-10 mg/kg when thiamin concentration is 100 mg/ml IM) also can be administered. Steroids (dexamethasone, 0.5 - 1.0 mg/kg IM and/or prednisilone, 0.5-2.0 mg/kg IM) can be included to help stimulate a feeding response, prior to attempting a more invasive approach.

"Force feeding" can be accomplished in one of two general forms - either a tong feeding method or via a tube. Whole fish can be clamped (head forward) in tongs and introduced into the mouth and esophagus of the elasmobranch (often using a bite block). Once the tongs are released, the fish continues to progress into the stomach. Another method involves filling a piece of flexible tubing (large red rubber catheter, Tygon or airline tubing, etc) with normal diet items that may or may not be reduced in particle size (i.e. krill may fit through the tube without reduction, but capelin may need to be cut). All air must be removed from the tube prior to insertion to avoid introducing it to the stomach, and impacting buoyancy. The length and diameter of the tube should be appropriate for the animal and food type in question. The leading end of the tube should be smooth and, in the case of pliable tubing, can often be rounded manually. The tube needs to pass through the esophagus and extend slightly into the cardiac portion of the stomach. A bite block (rigid pvc or stainless steel) can be used to keep the mouth safely open when passing the tube. In the case of smaller sharks and rays that are manually or chemically immobilized, appropriate tube placement can be determined by feeling the tube through the body wall as it passes through the esophagus into the stomach. In larger animals, gross measurement from the mouth to the predicted placement of the stomach (via palpation) may be helpful. In other cases, passing an endoscope into the stomach allows accurate tube length measurement as well as identification of the appropriate landmarks between the mouth and the stomach. Once appropriately placed, the food can be gently squeezed from the tube via a "plunger" that slides through the inside of the feeding tube. The plunging rod should be secured on the end to insure it does not pass completely through the feeding tube and into the animal. Often, premanufactured equipment does not exist for this purpose, and creativity is needed to assemble safe feeding mechanisms.

If medications are included, they should be placed between food items near the leading end of the tube or in the first fish offered (using the tong method). This prevents loss of medication, and insures they are delivered as close to the start of the feeding as possible.

The volume to feed using this method can be estimated based the animal's normal consumption in one feeding, but distension of the stomach also should be monitored to assess appropriate amounts. Several resources have been used to assess daily or weekly rations in elasmobranchs.[5] If an animal has not fed for a prolonged period, the amount of a normal daily ration may be more than the stomach can hold. Overfeeding can lead to regurgitation, which represents a net energy loss to the animal for the entire process (and possible loss of medications), so care should be made to observe distension while feeding.

Tube feeding is performed in much the same way as force feeding, but the food is processed via a blender or food processor into an appropriately consistent paste. Medications can be mixed in the blending process and incorporated into the formula. Care should be taken to insure medications will remain stable in the formula (i.e. efficacy may change when exposed to heat or cold prior to administration).

Assist feeding approaches have been successfully used to feed a variety of animals, including tassled wobbegong sharks (*Orectolobus dasypogon*), whale sharks (*Rhincodon typus*), bowmouth guitarfish (*Rhina ancylostoma*), and a variety of ray species, among others (Table 1).

Formula preferences are based on the foraging strategy of the animal, the previous food that was digested by the animal, and the caloric, nutrient, or medicinal needs of the animal. Tube formulas can be delivered via the same tubes (18 or 24 french red-rubber catheters or up to 3 cm Tygon tubing) as described for force feeding, and fitted to syringes or pumps to deliver the appropriate volume. Tube feeding elasmobranchs has been accomplished using syringes ranging from 10 to 450 ml, and several styles of pumps (grout pumps, bilge pumps, etc) for larger volume.

Formulas

One of the main nutritional considerations for supportive care is providing animals enough energy to begin/resume self-feeding and/or heal from any injuries. Energy needs for elasmobranchs have not been clearly defined, although some data do exist for small and medium-sized sharks (<100 kg). For bull sharks (*Carcharhinus leucas*) maintained at Sea World (40 - 100 kg), mean metabolic expenditure per animal ranged from 4 to 5.7 kcals per kg per day (16.7 to 23.8 kJ per kg per day).[8] Those values were lower than those reported for juvenile free-ranging scalloped hammerhead sharks (*Sphyrna lewini*; <1 kg), which were noted to have high metabolic rates compared to other shark species studied (22.9 ± 3.6 kcal per kg per day, 96 ± 15 kJ per kg per day).[6] In aquarium environments, energy needs will be based on the life stage of the animal, its size and the size and environmental parameters of the enclosure, and the specifics of the situation. For example, larger animals in small enclosures expend more energy for locomotion than smaller animals in the same enclosure. A wide variety of formulas have been used, ranging from typical diet items being blended into a smooth slurry to specially made mixes reconstituted with water or electrolyte solutions (Table 1).

Formulas mixed with fresh water, electrolyte solutions, and different strengths of salt water have all been used in elasmobranches at the Georgia Aquarium. Osmoregulation in elasmobranchs involves a complex interaction of metabolic processes occurring in the gills, kidneys, and rectal gland. Elasomobranchs maintain urea in their tissues and blood at levels that would be harmful to most vertebrates. Trimethylamine oxide (TMAO) counters the protein de-stabilizing effects of urea in the tissues. Together, urea and TMAO add substantially to osmotic pressure within the animal, which minimizes metabolic effort to maintain hydration (internal environment is maintained slightly "saltier" than external environment, creating a gradient which causes the constant influx of fresh water). When selecting the fluid portion of the formula, consideration should be given to maintain osmotic balance. No standard formula is recommended universally. Selection can occur in response to observed clinical observations of the animal, measured circulating blood metabolites, and/or observations of pre-feeding stomach contents (if available).

Conclusions

Supportive nutritional care of elasmobranchs involves a stepwise approach to allow the animal to begin or resume self-feeding. There are a variety of methods and techniques to overcome anorexia, based on each individual situation. Relatively little quantitative work exists to delineate feeding volumes and nutrient compositions for assist feeding formulas. This, coupled with the wide array of elasmobranch species maintained in aquarium settings, makes the task of selecting the appropriate formula complex. Future research efforts are required to more adequately delineate the best practices based on the species and situation in question.

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Table 1. Example force and tube feeding preparations.*

Example	Ingredient	Processing	Equipment	Species Fed
1	Herring	0.5-1.0cm chunks	1m (L) x 1.5 cm (ID) tube with plunger, bite block	Bowmouth guitarfish (*Rhina ancylostoma*)
2	Mazuri Omnivore Gel (5Z94)[a]	Mixed with water, according to instructions	18 french red catheter, 60 cc syringe, bite block	Cownose rays (*Rhinoptera bonasus*)
3	Superba krill	No processing	3.5 m (L) x 2.5 cm (ID) tube attached to bilge pump	Whale shark (*Rhincodon typus*)
4	Mazuri Omnivore Gel (5Z94), blended krill, salt water, menhaden oil, pancreazyme[c], Mazuri Shark and Ray 2 tabs, vitamins C and B, dextrose solution	Blended until smooth	3.5 m (L) x 2.5 cm (ID) tube attached to bilge pump	Whale shark (*Rhincodon typus*)
5**	Hill's A/D, Emeraid[d], Nutrical[e], cod liver oil, pedialyte[f]	Blended well	24 french red catheter, 60 ml syringe	Blue-spotted rays (*Taeniura lymma, Dasyatis kuhlii*)
6**	Mackerel fillets, shrimp, nori, Nutrical, Mazuri VitaZu tabs, STAT liquid[g], cod liver oil	Blended well	24 french red catheter, 60 ml syringe	Blue-spotted rays (*Taeniura lymma, Dasyatis kuhlii*)

* Georgia Aquarium, unless noted.
** Thomas (2005).
[a] Purina Test Diet, St. Louis, MO, [b] Hill's Pet Nutrition, Topeka, KS, [c] Virbac Animal Health, Fort Worth, TX, [d] Lafeber Co., Cornell, IL, [e] Evsco, Buena, NJ, [f] Abbott Laboratories, Abbott Park, IL, [g] PRN Pharmaceuticals, Indianapolis, IN.