Aquatic Mammals 2010, *36*(3), 248-261, DOI 10.1578/AM.36.3.2010.248

Comparative Survivability of *Tursiops* Neonates from Three U.S. Institutions for the Decades 1990-1999 and 2000-2009

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Abstract

Animal managers from three institutions that hold *Tursiops truncatus* participated in a workshop directed at documenting survivability of *Tursiops* neonates (birth to 30 d of age) in their managed populations. Key information was generated for the period 1990 through 2009 for the three organizations. Included in the findings are (1) documentation of the total live births, total fatalities, and causal factors of neonate losses; (2) recommendations for optimizing animal management procedures through standardized monitoring and husbandry intervention techniques, resulting in the best possible survivability of neonates; and (3) comparison of neonate survivability between the years 1990 to 1999 (78.2% of live births) and 2000 to 2009 (90.6% of live births), the latter decade representing progressing improvements in survivability resulting from recommended animal management procedures.

Key Words: *Tursiops*, neonate, survivability, monitoring, intervention

Introduction

Since 1989, the North American Marine Mammal Public Display and Research Community has looked exclusively to internal reproduction management for recruitment of *Tursiops truncatus* into resident population stocks. Facility animal managers have prioritized reproductive husbandry along with the required utilization of these animals toward core functions (e.g., show presentations, interactive programs). In achieving progressive successes in reproduction, animal managers have communicated freely among colleagues to share collective experiences. Currently, the population of *T. truncatus* in public display and research facilities (member institutions of the Alliance of Marine Mammal Parks and Aquariums [AMMPA]) is self-sustaining and growing. AMMPA members further contribute toward optimal reproduction management of populations by annually accounting for resident stock numbers, including losses to mortalities and additions due to reproduction, as well as delving into statistical studies of population demographics. From the collective experience of animal managers and through the initial AMMPA demographic studies, it is known that, for *Tursiops*, mortalities of neonate calves up to Day 30 postparturition accounts for the largest rate of loss to the population as compared to any other demographic age category. Yet, despite knowing this detail, there remains a relative absence of published, or otherwise communicated, information on the numbers of births lost in this time frame (and there are no published data on neonate losses in wild populations); the causes of losses or what measures may have been undertaken by facility animal managers that have proved beneficial; and what might therefore be useful to the community in furthering additional neonate survivability.

This paper is the result of a workshop including representatives from Dolphin Quest Inc. (with facilities on Hawaii, Oahu, and Bermuda), SeaWorld Parks and Entertainment (with facilities in San Diego, California; San Antonio, Texas; and Orlando, Florida), and the U.S. Navy Marine Mammal Program in San Diego, California. These facilities are known to have experienced success in increasing neonate survivorship through education, preventative and proactive management, and intervention with neonates for which failure to meet acceptable developmental criteria were observed. Each organization shared data on neonate survivability during the first 30 d postparturition as well as participated in an open dialogue on topics relating to experiences in maximizing survivorship during this period of time. Additionally, data provided included survivorship of *Tursiops* live births through 1 y of age. For wild dolphin population biologists, the 1-y threshold marks the survivorship of calves and the point in which study animals are included within the overall population database in long-term studies (Wells, 2003).

Materials and Methods

The workshop participants focused on neonate losses in the first 30 d following parturition, specifically as fatalities in Day 0 to 1, fatalities in Days 2 to 7, and fatalities in Days 8 to 30. With a focus on identifying specific husbandry management recommendations, the goal of the workshop was to establish whether there is a causal bias for each of the time frames noted. Data presented in Table 1 include the collective reproduction history from the years 1990 through 2009 for the three organizations.

The three organizations reported an accumulative total of 249 live births. Losses after live births within the first 30 d postparturition amounted to 37 neonates, including 13 in the 0 to 1 day time frame, 9 in the 2 to 7 day time frame, and 15 in the 8 to 30 day time frame. As expected, the causes of mortalities in these time frames were very much related to the critical developmental processes that are occurring in each period. Within the 0 to 1 day time frame, the majority of losses were accountable from trauma (n = 6) and failure to thrive (n = 3). The trauma was primarily resulting from maternal or conspecific aggression at or immediately after birth (e.g., novelty, threat, social displacement). Failure to thrive within this short time frame was considered a result of poor birth condition (e.g., immature neonate). At the 2 to 7 day time frame, the majority of losses were from failure to thrive (n = 5), this condition resulting primarily from nutritional failure or insufficiency. Within the 8 to 30 day time frame, infection (e.g., bacterial pneumonia in most cases) played the primary cause of mortality (n = 10), presumably resulting from a combination of failure to thrive nutritionally and, associated with this, poor physical condition and a poorly developing immune function. Altogether, survivability through the first 30 d of life in this study amounted to a considerable 85.1% of total live births. Survivability through 1 y of age included 201 calves in this dataset, or 80.7% of total live births.

With the overall goal of identifying methods of increasing survivability of neonates, the workshop group focused on the following three areas of neonate husbandry management that, through discussion of experiences, were determined to represent the most productive action areas for prioritization in this work:

I. *Monitoring*–Establish mom/neonate monitoring methodologies, including normalcy criteria for each.

A. *Nursing*–Monitoring of neonate nursing is the most important determinant of calf wellness. In order to assess nursing performance, the mom/calf pair must be reliably observable at all times (e.g., water must be clear enough and enclosure size must not be so large that direct viewing is not possible). In facilities that depend on natural light, monitoring may be limited to daylight hours.

Monitoring of Nursing Workshop Comments:

1. *Start of Nursing*–Nursing typically begins sooner after birth than previously considered. Most neonates begin nursing within 8 h of birth (Figure 1).
   - Some females do not begin nursing until after placental delivery (typically at around 6 h postpartum). Some, however, begin nursing hours before discharging their placenta.
   - Concern for unsuccessful nursing begins at 12 h. Workshop participants agreed that consideration for nutritional intervention should be considered no later than 24 h if consistent nursing has not been observed (Figure 3).

Table 1. Neonate survivability (< 30 d postpartum), 1990-2009

Calf survivability stats	Numbers	Percentage	Cause of mortality
Total live births	249		
Live births living < 30 d	37	14.9	
Day 0 to 1	13	5.2	6 = trauma; 3 = failure to thrive; 2 = infection (intrauterine); 2 = unknown
Days 2 to 7	9	3.6	5 = failure to thrive; 3 = infection; 1 = unknown
Days 8 to 30	15	6.0	10 = infection; 4 = malnutrition; 1 = maternal trauma
Live births living > 30 d	212	85.1	
Live births lost > 30 d and < 1 y	11	4.4	13 = causes not documented in this report
Total live births living to > 1 y	201	80.7	

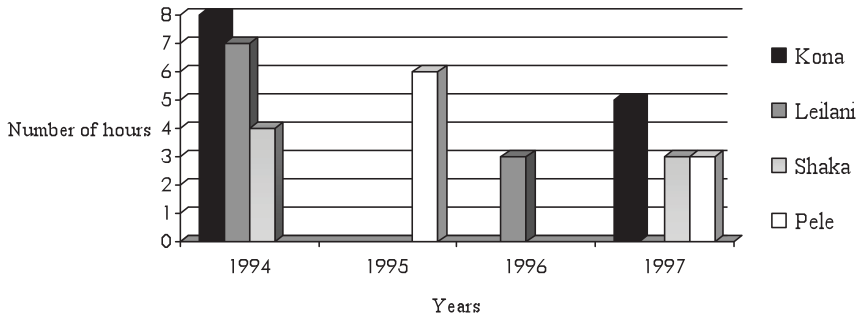

Figure 1. Time (in h) to first confirmed nursing after birth in *Tursiops* calves ($n = 8$) (Courtesy of Dolphin Quest)

- When considering thresholds for unsuccessful commencement of nursing, consider experience of the mother dolphin (with more experience there is less tolerance for no nursing past 12 h). With inexperienced mothers, some additional time may be allowed to initiate nursing, providing that progress can be documented. After 24 h, however, there is a critical need for the neonate to receive sustenance, including colostrum, from early milk production.

2. *Monitoring Methodologies*
   - Nursing frequency, duration, and accumulated nursing s/h are typically monitored from birth and for at least the first 2 wks postpartum (Figure 2). The goal is to establish a numerical dataset that is useful for developing trend analyses.
   - It was agreed that most neonates follow a predictable trend over the first 2 wks postpartum of accumulated seconds of nursing per hour (Figure 3). From this nursing performance curve, we can speculate, for example, that the numbers depicted in Figure 2 are compatible with a neonate that is up to 3 d of age. Note that at around Days 7 through 10, the accumulated time of nursing can drop to otherwise surprisingly low numbers (e.g., as low as 8 s/h). This appears to represent an efficiency factor, both for calf nursing proficiency as well as what is likely a peak in the mother's milk production. Nursing performance outside of this trend curve can be an indicator of problems with the calf and/or the mother.
   - It was noted that nursing in the first week or more follows what appears to be a satiation / hunger cycle that repeats two to three times each hour. Hunger is observed as consisting of three to five nursing events, one immediately after the other (hunger), followed by satiation, typified by an absence of nursing for 15 to 20 min (satiation).
   - Facility animal managers judge that intervention may be advisable when neonate nursing performance fails to follow normal monitoring patterns.

B. *Conformation/Weight Gain*—The calves are born relatively thin, and they appear to lose weight over the first several days, presumably due to a very high caloric demand, along with several days required for developing nursing efficiency. However, by Day 3, there should be the beginning of a notable weight gain (as usually judged by physical conformation), resulting in what is considered as "normal" baby dolphin conformation by Day 10 (Figure 5).

Confirmed Nursing Data Sheet

Date 26/3/08	0600 h	0700 h	0800 h	0900 h	1000 h	1100 h	1200 h	1300 h	1400 h	1500 h	1600 h	1700 h	Ave.
Pele calf total Nursing s/h	0.0	0.0	35.0	126.0	49.0	69.0	66.0	100.0	62.0	34.0	91.0	77.0	59.1
Pele calf ave. Nurse duration	0.0	0.0	2.9	4.5	4.5	5.3	6.0	4.5	3.1	3.8	5.1	3.7	3.6
Pele calf # nurse Bouts/h	0.0	0.0	12.0	28.0	11.0	13.0	11.0	22.0	20.0	9.0	18.0	21.0	13.8

Figure 2. Measurement and documentation of nursing events and parameters used to monitor nursing (Courtesy of Dolphin Quest)

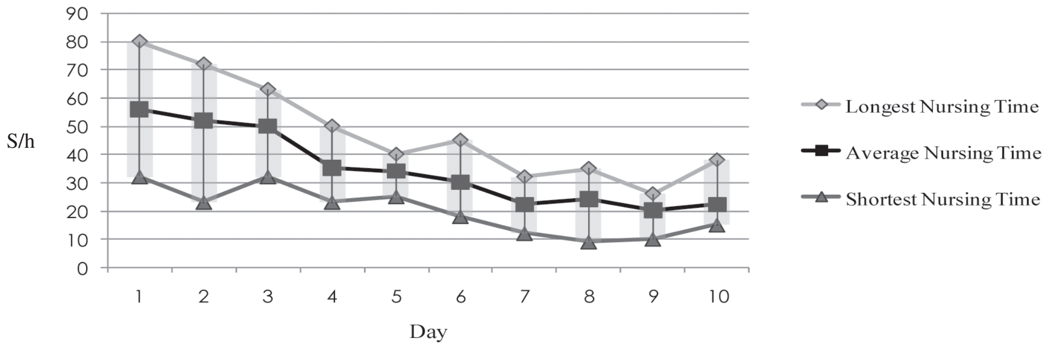

Figure 3. *Tursiops* neonate nursing performance in s/h during the first 10 d after birth (n = 8) (Courtesy of Dolphin Quest)

Figure 4. A calf exhibiting inadequate weight gain on Day 14 (at the start of intervention management) (Courtesy of Dolphin Quest)

1. Visual indicators of relative weight gain/loss include presence or absence of concavity in the fat pad behind the skull (referred to as "peanut head"), presence or absence of visible lateral spinus processes at the peduncle area (immediately in front of the insertion of the flukes), and the presence or absence of abdominal swelling that occurs with the consumption of milk.
2. Filling of the "peanut head," peduncle, and abdominal enlargement occurs at about 7 to 10 d postpartum.
3. Failure of the above visual developments can warrant intervention (Figure 4).
4. Weight gain statistics for normal neonates/calves examined at < 60 d old are included in Table 2. As there is a substantial range of birth weights under normal birth conditions, weight gains/losses must be assessed using a measured baseline weight for each subject neonate. From this data, the average weight gain/d was 0.2 kg (0.46 lb).

C. *Skin Phasing*—When *Tursiops* neonates are born, their skin color is typically dark gray, almost black. Through the first 2 wks

Table 2. Neonate weight gain (< 60 d) (Courtesy of Dolphin Quest and U.S. Navy Marine Mammal Program)

Animal	Age (d)	Girth cm (in)	Length cm (in)	Calc wt kg (lbs)*	Scale wt kg (lbs)	Gain/d kg (lbs)
Madeline	<1	--	--	--	18.6 (41.0)	--
Slooper's calf #1	2	--	114.8 (45.2)	--	18.2 (40.0)	--
Slooper's calf #3	2	--	--	--	20.9 (46.0)	--
Slooper's calf #2	9	--	--	--	18.6 (41.0)	--
Bermudiana	15	68.6 (27.0)	--	--	25.5 (54.0)	--
Bermudiana	46	77.5 (30.5)	--	--	31.8 (70.0)	0.24 (0.52)
Nea	18	76.2 (30.0)	--	--	28.2 (62.0)	--
Nea	55	83.8 (33.0)	--	--	36.4 (80.0)	0.22 (0.49)
Halia	20	71.9 (28.3)	121.9 (48.0)	21.7 (47.8)	21.5 (47.4)	--
Halia	37	74.9 (29.5)	128.3 (50.5)	25.0 (54.9)	24.6 (54.2)	0.20 (0.44)
Hua	20	69.9 (27.5)	114.3 (45.0)	19.1 (42.0)	--	--
Hua	33	72.4 (28.5)	118.1 (46.5)	21.5 (47.2)	--	0.18 (0.40)
Luna	29	83.8 (33.0)	--	--	29.1 (64.0)	--

*Formula for calculating weight: [length (cm [in]) × girth (cm [in])^2] / 800 (The Marlin Club of San Diego, n.d.)

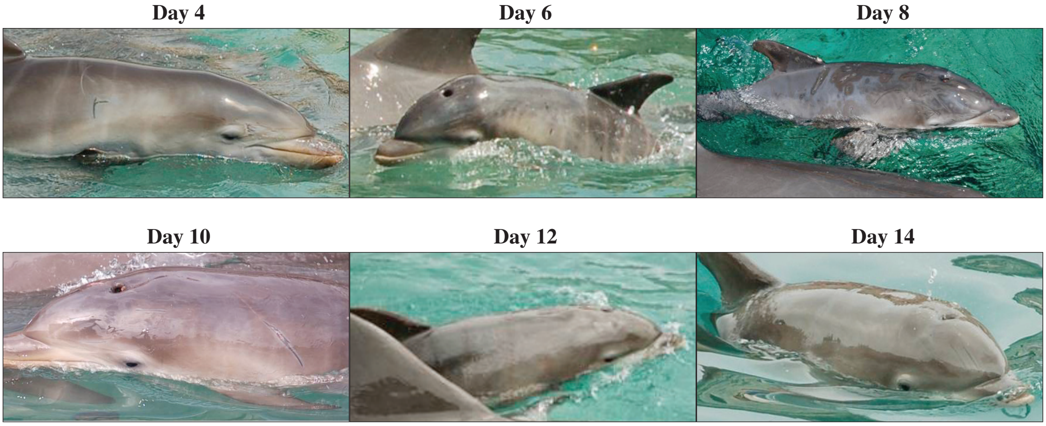

Figure 5. Normal progression of skin mottling and appearance of weight gain (Courtesy of Dolphin Quest)

of growth and development, the neonate's skin can be observed to progress to a light gray dorsally and white/pink ventrally, with a distinct white "donut" shaped zone around each eye. During this 2-wk period, the skin progresses through a mottling phase, presumably indicating peeling off of the dark newborn skin layer(s). This mottling occurs in all neonates, and its presence, and progression to completion, appears to occur in a documentable time frame that also marks initial weight gain (see B above).

1. Typical progression runs from Days 6 to 14. By Day 6, mottled skin is starting to appear; by Day 8, mottling is very clear; by Day 12, very little mottling remains; and by Day 14, mottling is completely gone (Figure 5). Delays in mottling disappearance can be an indicator of poor neonate development.
2. One workshop participant noted that in colder water (e.g., 12.7 to 18.3° C [55 to 65° F]), the above described skin mottling phase is delayed as much as 2 wks later than at "tropical" temperatures, commencing between Days 20 to 30. In these cases, the process still takes about 1 wk to 10 d in length to complete.

D. *Respirations*—All workshop participants monitor respiratory statistics in time allotments of 5 min. It is advised that due to some variability, 5-min monitoring periods be repeated up to three times, then averaged. It was noted that periods in which the neonate calf is engaged in play or when swimming at the surface of the water, as when in very shallow water, be rejected for data use as respiratory rates accelerate disproportionately during such activities.

1. Normal range for neonate respiratory rate is 12 to 25 resps/5 min, with some workshop participants considering up to 30 resps/5 min as acceptable.
2. Neonates that start swimming deeper immediately following birth exhibit benefits in respiratory function. Persistent surface swimming for newborns is considered an indicator of poor health.
3. Participants noted the importance of mother dolphins diving their newborn calves to as deep as possible as early as possible. This is a favorable observation.
4. It was further observed that respiratory rate can serve as an important indicator of neonate health status. Of particular importance is that, while swimming together, neonate respiratory patterns generally match that of the mothers. Any consistent deviation warrants concern and probable need for husbandry intervention.

E. *Behavior*—While mother dolphins in the wild maintain their neonates in very close proximity, most likely due to the very real threat of predation, mothers in public display/research facilities have no such threat and, as such, are much less insistent upon a tight physical presence with their calves. Therefore, neonates learn quickly to explore their environment, engage in play, and are regularly observed interacting with their mothers in all sorts of tactile behavior. This is normal, and it should be progressive throughout the first weeks and months of life.

1. Observations should be made for maternal/neonate interactions that could be indicative of problems. Neonate independence generally begins at around Day 7 or 8, and this should increase over time. An absence of independent behavior from the neonate,

or regression toward less independence, may be an indicator of a decline in health of the calf, warranting intervention.

2. In consideration of aggression exhibited by the mom toward her calf (that may result in life-threatening trauma), it is important to have a plan for removing the opportunity for the mom to express undesirable behaviors toward her neonate. This is especially true when first-time mothers are involved as aggression is far more prevalent in these animals, especially within the immediate postparturient period. In these cases, aggressive instinct can play out on a new arrival. In such cases, a change in environment (e.g., lower pool water level) can change the context of the threat thereby shifting it from the calf to the environment. In other situations in which the mom is threatened by a social situation, for example, the least dominant, or most susceptible, element (e.g., the neonate) becomes the target. In such cases, removing the mom/neonate from the adverse social environment can solve the problem.
3. Maternal aggression (possibly related to frustration by the mother) that is observed past 1 wk of age can be a sign of problems with the neonate and may warrant husbandry intervention.

F. *Urination/Defecation*—Documentation of urination may be missed without very clear water and intense concentration by viewers. Fecal depositions, however, are easily observed and should be noted.

1. Frequency of defecation, color, and consistency are important to monitor. Fecal excretions should be observed by Day 3 and may be seen several times each hour. Feces should be a thick liquid, light grey in color, and should not float or exhibit gas bubbles.
2. Urine may be observed, and it should not be dissimilar from the mother's urine.

G. *Maternal Food Intake*—In order for the mother dolphin to provide sufficient nutrition to her neonate calf, she must increase her food consumption in calories. Typically, food consumption totals postpartum increase to 50% or more over typical baseline food consumption for maintenance.

1. Expectation for full increase in food consumption often takes up to a week (Figure 6).
2. Moms that bulked up in weight (e.g., greater than 54.4 kg [120 lbs] of weight gain prior to birth) may be slower to reach the full 50% increase food consumption target.
3. Food intake peaks at about the same time milk output peaks (e.g., Days 7 to 10). By this time, the calf's nursing efficiency has also peaked. Any delay, or failure, in this critical developmental process can be a serious threat to a neonate's ability to survive.
4. Participants recommended providing moms with the option of an on-demand feeding schedule throughout the 24-h d. This maximizes windows of feeding.
5. Methods and styles of feeding may be altered to accommodate particular needs of the mother (e.g., food trails, handfuls at once without stopping, etc.).

II. *Intervention*—Describe what conditions, including physical environment and specific handling protocols, successfully have been utilized for safe and effective handling of neonates during intervention procedures.

Intervention requires that the neonate be handled under restraint conditions. There has been a historical resistance, almost a rule, that neonates and calves under 1 y of age not be handled. This has come from experiences in which

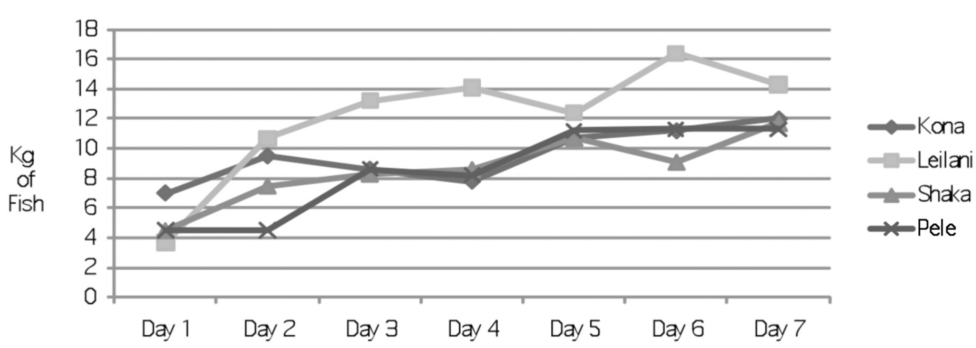

Figure 6. Fish consumption of mother (kg of fish/d) in first week following parturition in *Tursiops truncatus* (Courtesy of Dolphin Quest)

neonates and calves have been lost from acute cardiorespiratory failure while being restrained. Nevertheless, as noted above, by far the highest rate of *Tursiops* loss occurs within the first 30 d following birth and, as such, this time represents an opportunity to increase neonate survivorship through intervention in face of clear evidence (from monitoring) that a neonate is regressing. Clearly, if intervention is to become a medical/husbandry option, the safety problem of handling neonates and calves had to be solved.

As with many problems, the resolution to this one has come via breakthrough experiences that effectively have changed the problematic paradigm. Two situations accounted for this resolution. First, dolphin calves recovered from beach strandings were successfully rehabilitated through the development of digestible formulas and formula delivery protocols, providing for opportunities to experience safe methods for handling these animals (Townsend, 1999; Townsend & Gage, 2000).

Table 3. Neonate hematology averages (< 30 d) (Courtesy of Dolphin Quest and U.S. Navy Marine Mammal Program)

			Neonate age		
	Tests	Units	Day 7 (N = 6)	Day 15 (N = 5)	Day 30 (N = 5)
CBC	WBC	x 10 (9)/L	10.2	7.4	7.7
	RBC	x 10 (12)/L	3.9	3.5	3.4
	Hgb	g/dL	15.4	13.0	12.0
	Hct	1/L	45.5	42.5	36.5
	MCV	fL	116.5	109.0	114.1
	MCH	pg	39.4	37.2	37.0
	MCHC	g/dL	33.8	34.5	34.1
	Neutrophil	%	76.2	70.4	65.0
	Bands	%	0.4	5.4	1.8
	Lymphs	%	13.4	14.6	21.6
	Monos	%	8.0	7.8	3.5
	Eos	%	1.8	8.8	9.2
	Platelets	x 10 (9)/L	182.0	No data	No data
	Sed Rate	mm/h	6.0	12.0	4.0
CHEM	Glucose	mg/dL	140.2	132.7	143.0
	ALB	g/dL	4.0	2.3	4.6
	BUN	mg/dL	52.0	51.3	46.3
	Creatinine	mg/dL	0.7	0.7	0.8
	Sodium	mEq/L	156.0	154.0	153.6
	Potassium	mEq/L	4.4	2.1	3.9
	Chloride	mEq/L	110.4	55.6	113.7
	CO_2	mEq/L	30.6	15.7	25.6
	Calcium	mg/dL	10.2	5.5	7.2
	SGOT (AST)	IU/L	114.4	91.6	115.0
	SGPT (ALT)	IU/L	18.8	18.5	10.5
	Alkaline phosphatase	IU/L	No data	1,899.4	2,716.8
	Bilirubin, total	mg/dL	0.1	0.1	0.1
	Total protein	g/dL	No data	4.0	5.6
	Uric acid	mg/dL	0.2	1.5	0.2
	Phosphorus	mg/dL	6.7	No data	7.5
	LDH, total	IU/L	474.0	1,294.0	702.3
	Gamma GT	IU/L	44.8	No data	20.0
	Iron, total	µg/dL	294.2	156.7	110.1
	TIBC	µg/dL	No data	No data	575.0
	% saturation	%	No data	No data	19.0
	Fibrinogen	mg/dL	No data	No data	254.0
	CPK	IU/L	497.0	No data	No data
	Reticulocyte count	%	No data	4.5	4.6
	Globulin	g/dL	1.6	1.3	No data

Second, several of the facilities represented in the workshop have made decisions to handle neonates, both for routine medical check-ups, the development of healthcare databases, and the establishment of "norms" on hematology and morphometrics as well as for interventions in problematic neonates. One facility (Dolphin Quest) performs routine physical examinations on neonates and calves beginning at age 15 d and continuing monthly throughout the first year of life. Another (the U.S. Navy Marine Mammal Program) performs physical examinations on neonates at 1 wk of age. Hematology databases for ages 7 d, 15 d, and 30 d are presented in Table 3.

Critical factors in enabling animal managers to safely handle neonates are presented below:

A. *Physical Space*—To safely handle neonate dolphins, the physical space in which the process occurs is extremely important to the ultimate successful outcome. If a handling procedure requires moving the mom/neonate pair into a different physical space, stress may be eliminated or reduced through conditioning early gating. Where gates must be passed in order to position a mother and her neonate into the appropriate physical space, it is important to know that within the first week after birth, moms and their neonates gate relatively easily, especially if the target space is one in which the mom has familiarity and trust.

1. Avoiding excitement and struggling is paramount to safe handling of neonates. This is facilitated by restricting handling of neonates to shallow water (0.3 to 0.9 m [1 to 3 ft]) and approaching the situation efficiently yet calmly. Still, until the neonate is habituated to being handled, it must be collected and physically restrained in order to be examined and treated. In shallow water, this process can be greatly facilitated by using a physical barrier (crowding panel or taut, small mesh net) that restricts spatial proximity to that occupied by the handlers. Figure 7 depicts four physical space configurations that meet the requirements of this delicate procedure (**Note:** Lift bottom enclosures are generally smaller than ideal for neonates. Preconditioning of mother is especially important here.)

B. *Maternal Preconditioning*—The mother dolphin is totally responsible for the reaction that a neonate has to a given novel situation. Because of this, behavioral conditioning of

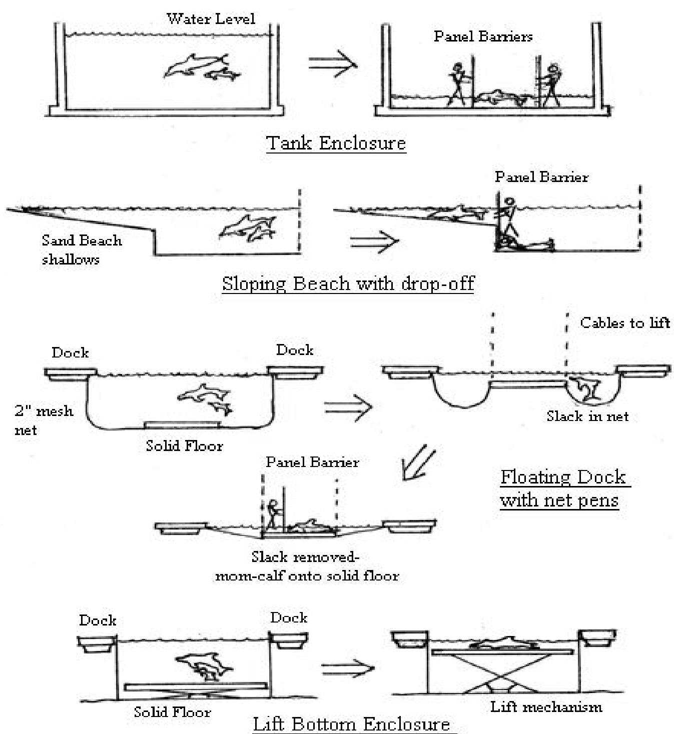

Figure 7. Strategies for creating limited space for successfully handling neonates (Courtesy of Dolphin Quest)

the mother can be very effective in driving the perception and reaction by the neonate to any given circumstance.

1. Mother dolphins can readily be preconditioned to the physical space as well as to capture and restraint procedures prior to giving birth. This facilitates familiarity to the procedure and engenders trust in the mom that fight and/or flight are not necessary. As such, the neonate follows the mom in remaining calm during the procedure. It is worth noting here that neonates (and moms) accommodate to handling very quickly (three or four approximations in most cases) so long as the procedure is done without aversion (e.g., struggling, extreme excitement, fear, extreme discomfort).

C. *Neonate Collection and Restraint*—By taking proper precautions, neonate and calf restraint can be accomplished safely and, as a learning tool, lead to remarkable accommodation with very few number of trials.

1. The foremost requirement of handling is to facilitate whatever procedure is to be accomplished while preventing shock and cardiorespiratory arrest in the neonate.
2. If possible, the neonate should be retained within the water at all times (see Figure 8).
3. Keep mom and calf face to face and within proximity for physical contact, vocalizations, and sight.
4. Be prepared to abort a session if neonate is not displaying baseline behavior.
5. Use heart rate to determine duration of session. Heart rates outside of threshold norm (90 to 120 beats per minute [bpm]) or those that change significantly during the session are indicators of a problem.
6. Additional warning signs of neonate distress include arching; extreme struggling; irregular breathing rate; short, weak, shallow, and/or rapid breaths; opening mouth; air passing through mouth; and vomiting.
7. Comfort can be provided to the restrained neonate using undulating movements and by keeping its eyes below the water surface.
8. If requirement exists to lift neonate out of the water, approximate the procedure over a few days to create familiarity with it. Any out of water procedure should be as brief as possible.

III. *Intervention*—Describe husbandry management intervention procedures that the workshop facilities representatives have found useful in restoring productive maturation of neonates.

In a regressing, or failing, neonate, intervention often offers the option of last resort. As noted above, the earlier in the regression process the decision for intervention can be made, the better the prospect for successful medical and/or husbandry outcome. There is now an

Figure 8. Handling mom and neonate in shallow water and limited space (Courtesy of Dolphin Quest)

increasing body of knowledge and experience in intervention management, including nutrition supplementation, medical management, considerations for immune supplementation, and establishing targets for weight and morphometric parameters. Below are some elements discussed by workshop participants:

A. *Nutritional Supplementation with Formulas*—In the event that nutritional supplementation or total neonate management is required, "artificial" formulations are necessary. While milk can be obtained from the mother dolphin, or from other available lactating females, obtaining sufficient mother's milk to sustain a neonate is highly unlikely. However, if a neonate fails to nurse at the outset, milking the mother may provide essential colostrum.

B. *Formula Composition*—Two formulas are presented in Table 4. When considering formula use in neonates, it is critical that certain key factors are taken into account including the following:
   1. *Caloric Content of the Formula*—This information, taken in context to the known caloric requirement of neonates at approximately 200 kcal/kg/d, will determine the daily volume of formula that must be delivered.
   2. The formula must be digestible. Therefore, use a proven formula. The formula must be liquid enough to pass by gravity through the feeding tube.
   3. The formula delivered must contain the required calories in no more that 50 ml of

Table 4. Calf milk formula composition (Courtesy of Dolphin Quest and Busch Entertainment Corp.)

Ingredients	Dolphin Quest	Busch Entertainment Corp.
Herring – Fish fillet	750 g	1,135 g
(No skin, viscera [guts], spine, or head)		
Zoologic Milk Matrix 30/55	450 g	200 g
(Milk powder)		
Zoologic Milk Matrix 33/40	300 g	345 g
(Milk powder)		
Salmon oil	100 ml	50 ml
(Menhaden oil/Safflower oil)		
Heavy whipping cream	100 ml	200 ml
(Heavy cream/whipping cream)		
Water/Pedialyte	1,600 ml	2,200 ml
Lecithin	15 ml	8 g
(Granules)		
Taurine	500 mg	500 mg
Lactobacillus	3 tabs	
(Acidophilus)		
$DiCaPO_4$	75 g	5 g
(DiCalcium Phosphate)	(10 tabs)	(10 tabs @500 mg/tab)
Multivitamin	1/4 to 1/2 of tab	
Dextrose		30 g
Salt		18 g
Total volume (approx.)	3,300 ml	4,000 ml
Total calories (approx.)	2.21 kcal/ml	1.8 kcal/ml
	2,210 kcal/L	1,800 kcal/L
Calf requirements	3,000 Kcal/d	
@200 kcal/kg/d		
	Est. wt. = 15 kg	
Volume per feeding	1,357 ml/d	
	57 ml/feeding	
	@24 feedings/d	

volume per feeding. This is the maximum volume that can safely be fed to a neonate 1 wk of age. Increases in volume per feeding should be limited to very small increments. **Note:** It is important that initial tube feedings are administered with sufficient frequency to allow for adequate nutrition and hydration via small volumes. During the first week of life, risks associated with aspiration of milk or formula following a vomiting event are significant. During the first week, feedings of 20 to 30 cc administered every 30 min have worked well, whereas volumes as low as 35 to 50 cc have caused vomiting and aspiration.

4. Formula feedings are to be performed throughout a 24-h d in order to deliver the necessary calories in feeding volumes that are safe.
   - *Formula delivery*. Refer to Townsend (1999) or Townsend & Gage (2001) for complete reference on methods for formula delivery.

C. *IGG Immunity*—Newborn dolphins are believed to be immune incompetent at birth, depending entirely upon mother's milk (colostrum) as their sole source of immunity. This vulnerable state remains for at least until they are several weeks of age, and likely this dependency continues, at least partially, for as long as several months. As such, supplementation of IGG has been under investigation up to the present day. IGG has been purified from large volumes of dolphin donor blood and given via IM and oral administration. Results of such administrations have met with mixed results. Presently, purified IGG is not available commercially and, as such, we will hold further discussion.

D. *Medical Management*—Once intervention has been accomplished, and access to the neonate for medical assessment has been facilitated, the clinician's approach to diagnosis and treatment follow standard protocols, albeit procedures are limited in time and scope as discussed above.

1. *Hematology*—Because some facilities are routinely performing physical examinations on neonates, we now have a database on normal hematology for neonates less than 1 mo of age (Table 3), as well as normal weight gain and limited morphometric development for this age class (Table 2).
2. *Pharmaceutical Assistance*—At this point in time, use of medications in neonates is managed on the same mg/kg dosage basis as for adult dolphins. Consider the following:
   - Antibiotics cannot effectively be introduced to a neonate through mother's milk. Therapeutic levels cannot be achieved in this way due to dilution from limited excretion concentration into the milk.
   - Where possible, medications should be delivered IM or IV to provide assurance that dosage levels are being realized.
   - In consideration of neonate's likely immune incompetence, consider cidal antibiotics over those that function via static mechanisms.
   - In consideration of the likelihood of infection by microorganisms in a nutritionally compromised neonate, remember that because immune function is marginal, if existent at all, use of antibiotic treatments should be given high priority in treating neonates.
3. *Weight Gain*—In the first month of development, the neonate should be gaining approximately 0.18 kg (0.4 lb) of body weight/d (Table 2).

Table 5. Neonate survivability: (A) 1990 to 1999 vs (B) 2000 to 2009

	A 1990 to 1999		B 2000 to 2009	
Calf survivability stats	Numbers	Percentage	Numbers	Percentage
Total live births	110		139	
Live births living < 30 d	24	21.8	13	9.4
Lost Day 0 to 1	6	5.5	7	5.0
Lost Days 2 to 7	8	7.3	1	0.07
Lost Days 8 to 30	10	9.09	5	3.4
Live births living > 30 d	86	78.2	126	90.6
Live births lost > 30 d to 1 y	7	6.4	6	4.3
Total live births living 1 y or longer	79	71.8	120	86.3

E. *Surrogacy*—In the situation of an orphaned neonate, there have been a number of successful surrogacy attempts (Ridgway et al., 1995; Messinger et al., 1996; Gaspar et al., 2000). Some helpful remarks are as follows:
   1. Choose a mother/calf pair in which the calf is 18 mo of age or older. In such cases, the calf can be weaned at a moment prior to when the neonate is introduced. Be prepared to abort the attempt if the transition appears to be unsuccessful.
   2. Another option is to introduce the neonate to a multi-female scenario in the hope of facilitating a willing match.
   3. There have been a number of reported relactation incidents in nonlactating females. A few of these have performed successfully as surrogate mothers.

Results

Because the database for this analysis has spanned two full decades (1990 to 2009), the authors decided to break out the two decades of data into 10-y spans (1990 to 1999 and 2000 to 2009). By so doing, we put to test the learning curve relative to the practices of neonate management detailed in this report (e.g., the noted practices were much more "practiced as standard procedures" in the decade beginning at 2000 than in the decade of 1990). Including the 2009 data, the two decades of survivability accumulated experience are presented in Table 5A (1990 to 1999) and 5B (2000 to 2009) below.

From these tables, we note that the decade of 1990 accounted for 110 live births compared to 139 live births for the three institutions in the decade of 2000. Of very high significance is the fact that neonate losses (30 d or less after birth) in the 2000 decade were 9.4% of the total live births compared to 21.8% in the decade of 1990. Further, losses in Day 0 to 1 were similar in the two time frames, but losses in the Days 2 to 7 (1) and 8 to 30 (5) in the decade of 2000-2009 were reduced by 66% from the earlier 10-y period. These two time frames are those in which the potential of successful medical/husbandry management are most likely to occur and also are best implemented. Clearly, this significant difference in greater neonate survivability in the more recent 10-y period can be attributed to better neonate and maternal monitoring and intervention husbandry procedure techniques.

Discussion and Conclusions

The Tursiops Neonate Survivability Workshop had three principle tasks with which to deal: (1) to establish a statistical standard for neonate (up to 30 d postpartum) survivability, using three experienced and successful reproduction public display/research organizations, which function with state-of-the-art animal management programs; (2) to define developmental parameters for this first month time period relative to critical time frame thresholds of 0 to1 d, 2 to 7 d, and 8 to 30 d; and (3) to establish means of determining that if a developing neonate begins to fail at any one, or multiples, of the defined and carefully monitored developmental parameters, could such information be obtained in a timely enough manner to provide for medical/husbandry intervention directed at salvage of a regressing neonate.

When considering the data in Table 1, including the differing causes of mortalities with respect to the three time frames (Day 0 to 1, Days 2 to 7, and Days 8 to 30), it becomes apparent that animal managers should be able to anticipate threats to neonates as they mature through each time frame and direct preventative management measures toward mitigating these, to the extent possible. For example:

Day 0 to 1 (Trauma and Failure to Thrive)—Take into consideration the social history for each parturient female, anticipating each animal's position in the dominance/submissive social structure, and thusly remove potentially problematic conspecifics from the mix. Likewise, for moms with a history of aggression toward newborns, or first-time moms, plans for removing a newborn immediately after birth, temporarily or permanently, should be prepared. As noted, failure to thrive, in this context, relates to newborns that are immature at birth. This condition can easily be anticipated by following fetal maturation and growth using diagnostic ultrasound. Using fetal thoracic diameter at the level of the heart (rib-to-rib measurement), fetuses at 15 cm or smaller at full term may be immature and may need special management attention after birth. Fetuses that are 17 cm or larger at full term (thoracic diameter) may be considered physically large and, therefore, more likely for stillbirth, dystocia, and/or birth-related trauma.

Days 2 to 7 (Failure to Thrive)—Establish close monitoring criteria so that a poor performing neonate, especially nutritionally, is identified early so that intervention opportunities with success are still possible. Use of harvested mother's milk AND prepared formulas have been successfully facilitated, including appropriate diagnostic and therapeutic considerations, particularly in the recent decade of 2000 to 2009.

Days 8 to 30 (Infection)—Same as above for Days 2 to 7. The plan for intervention should especially include diagnostic and therapeutic consideration for microbial infections.

There was clear consensus among the workshop participants that neonate development occurs within definable maturation benchmarks, including nursing performance, weight gain, respirations, skin color and mottling phasing, behavior, etc. By Days 7 to 10, most, or all, of these indicators can be assessed and/or measured to establish that a neonate is developing according to expectations or that concerns are warranted, with intervention potentially advisable. The workshop participants were in agreement that intervention for medical/husbandry assistance is an important and applicable procedure, and all agreed that in doing so, certain very specific protocols must be followed in order to assure safety to the neonate and mom, and also to handlers involved in the procedure(s). Among these safety-producing procedures are the following:

- Excitation of the neonate/mom pair must be avoided or limited. At no time should a neonate be chased in an attempt to capture it for restraint.
- Removing the neonate from the water is inadvisable and, if necessary, should be limited in time, with continuous monitoring of vital signs, particularly heart rate. Neonates are much less apt to suffer life-threatening stressor events when submersion in water includes holding the neonate with eyes below the water surface.
- The above conditions are best met by performing the handling procedure in shallow water (e.g., 0.9 m [3 ft] or less). In shallow water, handlers are more comfortable and effective, as both mom and calf are much easier to catch, and both are less likely to vigorously resist restraint (Figure 8).
- Excitation in the process of capture and restraint of the neonate/mom pair can be significantly reduced, if not eliminated, by preconditioning of the mom to the physical space and procedure in the months prior to parturition.
- At any time during an intervention procedure with a neonate, personnel must be willing and ready to abort the procedure if concerns for the status of the neonate are observed.

Each of the workshop participants related occasions in which intervention with a neonate in the first 30 d had resulted in successful redirection of a regressing situation. It appears clear that such actions, most of which have come with recent learning opportunities as noted in this text and illustrated in Table 5, have resulted in a significantly higher neonate survivability, with subsequent survival through to and beyond year one.

As noted above, the workshop participants all agreed that careful husbandry preparations for an impending birth, taking into account the particular history and needs of the mother; identifying problem areas of the enclosure; recognizing potential social threats to the birthing process, especially in first-time mothers; developing a well-thought-out plan for monitoring the development of the neonate with outlier thresholds clearly recognizable for each monitoring indicator; and having well-rehearsed protocols for husbandry management of mom and neonate should intervention become necessary, all represent preventative animal management and can lead to improved facility calf survivability.

Acknowledgments

The authors wish to thank the institutional managers who were fully willing and forthcoming in making 20 years of reproduction records openly available for this workshop and report. Without their support and encouragement, this analysis would not have been possible. These include Drs. Jay Sweeney and Rae Stone from Dolphin Quest Inc., Brad Andrews from SeaWorld Parks and Entertainment, and Mike Rothe from the U.S. Navy Marine Mammal Program. The authors wish to thank Ms. Natalie Acklin for her assistance and technical expertise in the development of this report.

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