Herd composition and behaviour of white whales (*Delphinapterus leucas*) in two Canadian arctic estuaries

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White whales occupy the Nastapoka River and Cunningham Inlet estuaries in north-eastern Canada each summer. They arrive at the Nastapoka in late June and at Cunningham in mid-July, where numbers build to maxima of 260 and 1750, respectively. Distribution of whales in both estuaries is influenced mainly by the state of the mixed semi-diurnal tides and, to a certain extent, by river outflow and date. Few adult males appear to be present in the estuaries, the herd being composed mainly of females with calves and weaned juveniles. Limited evidence suggests that the basic social units of herds are matrilines consisting of adult nursing females accompanied by older female offspring. The age structure of the herd changes seasonally with an increasing proportion of nursing pairs. Behaviour was grouped into four activity classes. These are descriptive and are not intended to imply functions, which remain somewhat obscure. Much of the nearshore behaviour appears to be related to the processes of shedding old skin and growing of new epidermis. Strong philopatry and physiological dependence of white whales on estuaries indicate that these are important habitats which must be managed and preserved in order to conserve the species.

Key words:
White whale, beluga, *Delphinapterus leucas,* herd composition, behaviour.

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Introduction

Each summer certain estuaries and smaller stream outlets in northeastern Canada are visited by white whales, *Delphinapterus leucas*. During periods of several days and weeks, the whales expose themselves to water that is warmer and fresher than the ocean. Some of these sites are traditional places of summer aggregation for large numbers of white whales. It appears that these assemblages consist largely of females and their calves, and evidence indicates that the same animals return to the sites from year to year (Caron & Smith 1990). This site fidelity to areas where white whales appear to undergo a synchronous moult (St. Aubin *et al.* 1990), and where newborn calves are nurtured for the first month of a prolonged lactation period (Doidge 1990), strongly suggests that these sites are seasonally a critical part of their habitat.

All estuaries share the common features of low salinity and relatively warm waters, but vary in their size and bathymetry and the degree to which they provide opportunities for observing the behaviour of the whales in them.

We describe and compare the composition of the herds and behaviour seen at two different estuaries: the Nastapoka River in eastern Hudson Bay and Cunningham Inlet on the north coast of Somerset Island. The Nastapoka is a small estuary, which during our studies was hunted on most weekends by Inuit from communities along the eastern Hudson Bay coast. In contrast Cunningham Inlet is a much larger area, somewhat enclosed from the sea, which is totally undisturbed by hunters or traffic.

Materials and methods

In both study areas white whales were observed from a position 6 m above water level atop aluminum towers,

NASTAPOKA RIVER
QUEBEC

HUDSON
BAY

5   4   3   2   1

OBSERVATION
TOWER

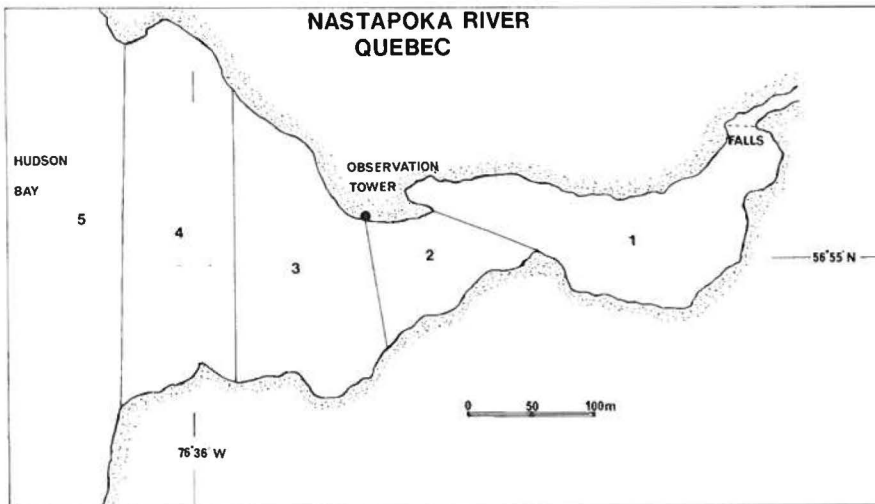FALLS

56°55'N

76°36'W

0   50   100m

Figure 1. Study area at the Nastapoka River, eastern Hudson Bay, Canada.

and at Cunningham also from a 32-m high observation hut on the adjacent shoreline (Figs 1 & 2) (Sjare & Smith 1986). Binoculars, spotting telescopes and cassette tape recorders were used during these observations.

Both scan and focal animal sampling (Altmann 1974) were used to enumerate and document whale behaviour (Caron & Smith 1990). We compiled an ethogram of both nearshore (Smith *et al.* 1992) and offshore behaviour using these two sampling methods.

The sampling period at the Nastapoka was from 20 July to 13 August in 1983 and from 21 June to 2 September in 1984. Sampling at Cunningham was in the years 1980–1987 between mid June and 15 August.

Regular observations were made at 0900, 1100, 1300, 1500, 1700, 1900 and 2100 hr. These included total counts of white whales in the inlet. Scan and focal samples were taken during the intervening hours whenever the opportunities were available. Speed estimates of travelling white whales were made from the 32-m high observation point at Cunningham Inlet using vertical and horizontal angles from a theodolite and a stop watch.

At the Nastapoka tidal height was read from a tide gauge accurate to 5 cm, located in a small adjacent bay approximately 100 m from the observation tower. Water temperature was recorded from a temperature probe fixed to the bottom of the estuary in the middle of quadrat 3 and was relayed to a YSI tele-thermometer in the tower. Wind speed and wind direction were read from a portable weather station. Other factors influencing observations such as the state of the water surface, water clarity and light conditions were recorded on an ordinal scale of 1 to 4. A value of 1 indicated a choppy water surface, opaque water and strong glare, 4 indicated calm and flat surface, clear water and diffuse light. A count index variable, on an ordinal scale of 1 to 4 (worst to best), was created to measure the observer's confidence in the count value, which also represents a subjective measurement of observer fatigue.

The environmental variables were: the total number of whales present in the estuary at the time of observation, the time elapsed since the return of the first whale to the estuary after an evacuation, the time elapsed since the last hunt, and the median position of the distribution of the herd in the estuary. All variables were recorded immediately after the observation sessions. Sessions were of variable length depending on the number of whales present; they lasted until all whales had been counted in the study area.

Age structure of the herd was documented by recording the size categories of animals during the scan samples. Calves were assigned to different length categories based on the body length in proportion to that of accompanying or adjacent adult white females, and these length categories were in turn assigned to age classes (Caron & Smith 1990: table 1). Adult males were identified by their large size and heavy lateral musculature.

In constructing the ethogram we have in most cases employed terms previously used in descriptions of the activities of cetaceans. We purposely avoided implying functions in our terminology.

Study sites

The Nastapoka estuary is located at 56°55'N, 76°36'W on the east side of Hudson Bay. The estuary is only 1.3 km long, measured from the river mouth, which opens to the ocean, to a 30 m-high waterfall. It runs east-west and is 0.2 km at its widest (Fig. 1). Maximum tidal amplitude in the estuary was 5.2 m during June to August. Salinities and temperatures taken at mid-tide in the estuary during July and August ranged from 0 to 15 ppm and 6.6°C to 16.1°C. Because of its topography Lamothe (1983) classified this as a submerged delta estuary, but our measure-
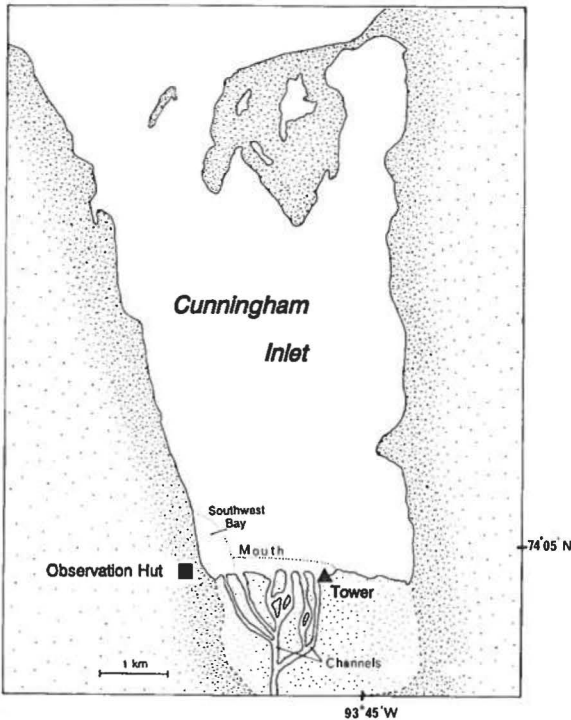
Figure 2. Study area with observation points at Cunningham Inlet on the north coast of Somerset Island, N.W.T., Canada.

ments indicate two distinct water masses which categorize it as a salt wedge estuary (Pickard 1979).

Peak discharges of the Nastapoka River occurred in June to September (468.6 m³/sec) with an average monthly discharge of 268 m³/sec over 20 years (Lamothe 1983).

Cunningham Inlet is on the north coast of Somerset Island, Northwest Territories at 74°05'N, 93°45'W. The inlet is 7.5 km long with a maximum width of 5.2 km; it thus covers a much larger area than the Nastapoka estuary

(Fig. 2). The head of the inlet consists of a 3.2 km-wide delta deposited by the Cunningham River, which has a drainage area of some 2600 km². During the unmeasured maximum outflow in July, the Cunningham River enters the inlet via two major channels. Since 1980 these channels have changed position several times due to sediment deposits and ice scouring.

Cunningham Inlet has a maximum depth of 42 m. Tides during July and August range from 0.8 to 2.1 m in mean maximum amplitude. In July there is strong vertical stratification throughout the inlet. A marked halocline exists from the surface to a 3 m depth (3 to 30 ppm), and there is an even more pronounced thermocline (6–8°C at the surface to 1° to 8°C at 3 m of depth) (Morrison & Taylor 1978). Stronger and more frequent winds in August turn the Inlet into a partially mixed estuary.

Results

Seasonal occupation and numbers

In eastern Hudson Bay the shore-fast ice usually breaks up by mid-June. In 1984, when observers were present prior to the arrival of white whales, the animals were first observed in the Nastapoka estuary on 23 June and were still present on 2 September when our observations ended. Maximum numbers counted at the Nastapoka were 245 on 27 July 1983 and 260 on 25 August 1984. During 1984, herd size gradually increased during July and August, then started to decrease into September.

In the high arctic, the ice along northern Somerset Island, adjacent to Cunningham Inlet, begins to break up in early July. Even when most of Cunningham Inlet remains ice-covered, except for the area melted by the river outflow, white whales penetrate into the inlet. In seven seasons the date of first occupation varied from 8 to 21 July and in five seasons the date of departure varied from 3 to 16 August. Annual dates of these events are

Table 1. Spearman rank correlation coefficients between the environmental factors and the median position of the white whale herd in the Nastapoka estuary in 1984.

Environmental factor	Correlation Coefficient (!R!)	Probability of a greater !R!	Number of Observations
Tide	0.39845	.0001	349
Total count	0.33728	0.0001	351
Water surface	0.32272	0.0001	351
Estuary time	0.23086	0.0001	272
Hunt time	0.21195	0.0004	272
Wind speed	0.16976	0.0014	351
Wind dir. (Sine)	0.14865	0.0053	351
Water clarity	0.12183	0.0224	351
Count index	0.11870	0.0262	351
Temperature of freshwater	0.11371	0.0332	351
Time of day	0.06737	0.2080	351

Table 2. Contingency table of the age structure of the Nastapoka herd in different quadrats (Q) of the estuary during the 1984 season using scan sampling. A deviation statistic Z was calculated for each cell and compared with the critical value of Z (3.0256) given a significance level of 0.05. Cell values which are significantly different from the expected value are marked with an asterisk.

Age class	Q1 Obs. (percent) Z statistic	Q2 Obs. (percent) Z statistic	Q3 Obs. (percent) Z statistic	Q4 Obs. (percent) Z statistic
Neonate	1278 (20.5%) 2.8693	2486 (19.9%) 1.8354	1258 (17.6%) *3.2546	1369 (18.2%) 2.0722
1/2	931 (15.2%) 0.4266	1992 (16.0%) 1.6207	1125 (15.8%) 0.7899	1074 (14.3%) 2.5852
2/3	649 (10.6%) 1.9505	1581 (12.7%) *4.1051	888 (12.5%) 2.5527	671 (8.9%) *7.2206
3/4	606 (9.9%) *7.1721	1773 (14.2%) *4.4626	1045 (14.7%) *4.2657	814 (10.8%) *5.0958
White	2663 (43.5%) 2.7609	4644 (37.2%) *7.9141	2818 (39.5%) 2.4331	3584 (47.7%) *8.6139

$X^2 = 342.4939$, DF = 12, $P < 0.005$.

directly influenced by the timing and pattern of ice break-up in the adjacent Barrow Strait, which is quite variable from year to year (Prinsenberg & Bennett 1987, Gorman 1988). Cunningham Inlet was occupied by white whales for periods varying from 27 to 38 days each summer (N = 5 seasons). Peak numbers ranged from 760 to 1750 whales, and the seasonal daily peaks varied from 17 July to 7 August (N = 7 seasons).

Factors influencing distribution

In both estuaries the daily pattern of distribution of white whales was strongly influenced by tides. Generally white whales moved farthest into the estuaries as the tide rose and either dispersed into offshore areas or left the estuary completely as the tide ebbed.

At the Nastapoka the median position of the white whale herd was most influenced by the state of the tide. Other influencing factors included the total number of whales present (total count), the water surface condition (water surface), the time of day (estuary time) and amount of time elapsed after the last hunting disturbance (hunt time) (Table 1).

At Cunningham white whales dispersed into the deeper waters of the Inlet on the ebb tide and could still be seen by observers, but we could not verify whether some left the Inlet completely. Analyses on factors influencing the number of whales in the mouth quadrat of Cunningham Inlet, which is analogous to the inner quadrats of the Nastapoka site, indicate that date had the greatest influence on whale numbers during 5 years of systematic observations. The importance of the other factors were highly variable. Both river flow and tide influenced the number of whales in the mouth and channel quadrats.

The upper channels of the Cunningham River can only

be reached by the whales on a rising tide. Date had a noticeable influence on numbers in the channel, especially since it was related to high tides which occurred in the latter part of July.

Herd composition and social groups

At the Nastapoka estuary, where in 1984 our data set was sufficiently large, 19% of the herd consisted of neonates, 15% were yearling (1/2 length) calves, 24% were older juveniles (2/3 and 3/4 length) and 42% were white adults (Caron & Smith 1990: table 2). The sex ratio of adults was calculated by assuming that: (1) since the gestation period is >1 year, nursing neonates and 1/2 length calves (yearlings) must each have one mother present in the Nastapoka herd, and (2) since lactation lasts for up to 2 years, an adult seen with a 2/3 length calf (2 or 3 years old) was assumed to be that calf's mother. The sum of neonates, 1/2 length calves and white animals with 2/3 length calves gave a conservative estimate of 35% sexually mature females. A small percentage of large grey animals accompanied by neonates and therefore assumed to be sexually mature (3%) was subtracted, giving 32.1% adult white females. Subtracting this from the total whites in the area gives a maximum estimate of 10% adult males, and an adult sex ratio of 1 (male): 3.2 (females) in the Nastapoka estuary.

Age structure in the Nastapoka varied between quadrat areas. Juvenile (2/3 and 3/4 length) age classes penetrated higher upstream while large, solitary adults individuals were most often found at the seaward end of the estuary. Females with neonates and yearlings (1/2 length) were most frequent in the middle quadrats (Table 2).

Age structure also varied seasonally, with a decrease of the juvenile age class (2/3 and 3/4 length) in mid-summer

Table 3. Contingency table of the age structure variation of the Nastapoka herd over the 1984 season. The dates listed are mean values of dates for blocs of equal sample size. A deviation statistic Z was calculated for each cell and compared with the critical value of Z (3.0256) given a significance level of 0.05. Cell values which are significantly different from the expected value are marked with an asterisk.

	17 July	7 August	20 August	29 August
Age class	Obs. (percent) Z statistic	Obs. (percent) Z statistic	Obs. (percent) Z statistic	Obs. (percent) Z statistic
Neonate	1455 (17.4%) *3.9657	1733 (20.4%) 2.5837	1670 (20.0%) 1.6840	1542 (18.9%) 0.6223
1/2	1143 (13.7%) *4.2544	1474 (17.4%) *4.5117	1257 (15.1%) 0.7863	1254 (15.4%) 0.0187
2/3	1484 (17.8%) *14.2083	736 (8.7%) *8.4982	547 (6.6%) *17.3304	1022 (12.5%) 3.0170
3/4	910 (10.9%) *5.1238	1226 (14.4%) *4.2706	1029 (12.3%) 1.0690	1077 (13.2%) 1.1922
White	3355 (40.2%) 1.6985	3310 (39.0%) *3.5317	3844 (46.1%) *6.7856	3259 (40.0%) 2.0206

$X^2 = 703.7002$, DF = 12, P < 0.005.

and a sharp increase towards the end. Neonates and yearlings were fewer during the first quarter, but reached constant levels for the remainder of the season (Table 3).

At Cunningham Inlet during 1980–87 we obtained age structures from two quadrats analogous to the Nastapoka river: the mouth and channel quadrats. We also documented the age structure in Southwest Bay quadrats, a quiet part of the inlet outside of the influence of flowing fresh water, which had no counterpart in the Nastapoka study area.

Males were infrequently seen at Cunningham and were noted usually as groups consisting of 10–15 large white adults. These pods appeared to be transient and would come and go throughout the period of estuarine occupation by other white whales.

Comparing all the quadrats at Cunningham Inlet using an analysis of variance revealed no significant differences in the age structure (F = 0.6074, P > 0.6947). A seasonal trend of an increasing 0+ age group for individual years of 1980, 1981, 1982 and 1983 was significant (F = 37.88, P < 0.0001), as were the combined suckling calves (0+ and yearling calves) for all years together (F = 12.60, P < 0.0011).

Focal samples seem to indicate that females with young calves actively avoid contact with adult males in the nearshore areas. To investigate this relationship we examined the effect of adult male presence on the neonate-to-adult female ratio and the suckling calf (neonate and 1/2 length) – to the adult female ratio. Surprisingly there was a significant positive relationship between both ratios and the presence of adult males (F = 13.82, P < 0.007 and F = 5.92, P < 0.0193, respectively). Further regression analysis, which sought to remove the influence of date on this relationship, showed a much weaker relationship of neonates to the presence of males (F = 0.346, P = 0.91), but a significant effect on the

percentage of yearling calves (1/2 length) (F = 4.38, P < 0.0432).

Ethogram

The ethogram describes the action patterns in four classes of activity: locomotor, non-locomotor and comfort, emergent and surface, and interactive (Table 4).

Locomotor behaviour of white whales involves normal swimming, often with synchronous diving and surfacing when whales are travelling in groups. Swimming speeds measured at Cunningham Inlet, usually when adult whales were travelling in a directed manner toward the offshore areas, varied from 0.9 to 8.1 km/h (Fig. 3).

In shallow water and in areas occupied by large numbers of whales the usual swimming pattern would often be altered. Instead of rolling gently to the surface, only the blowhole only would emerge from the water as a whale raised its head to breathe.

Leaping, often called porpoising, occurred very infrequently and for only short periods at the beginning of quick swimming. It was seen occasionally at Cunningham Inlet, when a sudden mass movement out of river channels occurred (Sjare and Smith 1986). In the Nastapoka this behaviour was also observed when whales were fleeing from Inuit hunters.

Skimming is used to describe white whales swimming with their heads out of the water. White whales are the only northern cetacean species with unfused cervical vertebrae (Kleinenberg et al. 1969) similar to the platanistoid river dolphins (Martin 1990). This allows white whales to raise their head completely clear of the water. Individuals have been seen to swim in this position for up to 30 minutes in Cunningham Inlet. Our impression was

Table 4. Ethogram of white whale behaviours seen at the Nastapoka River estuary and Cunningham Inlet, Northwest Territories.

| Activity Class	Action pattern	Description
Locomotor	Normal swimming	Forward motion with the blowhole region of the head exposed and a gentle roll of the back above the surface during breathing.
	Head raising	Raising only the head and blowhole clear of the surface to breathe while moving forward.
	Leaping (porpoising)	During fast movement forward. Projecting the anterior end of the body and re-entering head-first during the initial thrust of the sequence. Never done frequently; never prolonged.
	Skimming	Slow forward swimming with the neck bent upwards, lifting the full face, including the underside of the jaws, above the surface of the water.
	Side swimming	Moving forward with body oriented laterally to the water surface.
	Back swimming	Moving forward with the dorsum towards the sea bottom.
Non-locomotor and Comfort	Sounding	At the initiation of a prolonged dive the body bends sharply downward midventrally, exposing the mid-dorsum, but not raising the flukes above the surface.
	Sounding with tail up	Initiation of a prolonged dive with flukes and caudal peduncle appearing above the surface.
	Mud stirring	In depths of several meters or more diving to contact the sea bottom and rubbing all parts of the body. Mud is often seen to adhere briefly to the body after such dives.
	Partial Stranding	In a normal swimming position while in full contact with the bottom. Parts of the dorsum are continuously exposed to the air including the blowhole. Occasional lifting of the flukes and head, or both, completely clear of the water. Whales can be completely motionless or actively rubbing on the substrate in this position.
Surface and Emergent	Breaching	Projecting the body in a forward motion obliquely out of the water and falling on the water surface on the side, front or back.
	Spinning	Breaching in a forward motion and spinning through at least 270° before reentering the water.
	Body slapping	Emerging vertically and falling backward slapping the water with the back often repeatedly.
	Spy hopping	Raising the head and neck vertically out of the water.
	Pitch poling	In the same position as a spy hop, but with rotation around the axis of the body.
	Tail standing	Raising the body vertically out of the water to the area posterior to the flippers and maintaining position briefly by vigorous tail movement.
	Tail waving	Moving the tail (caudal peduncle and flukes) from side to side above the water surface with the rest of the body submerged.
Interactive	Head bobbing	Moving the head up and down above the water surface.
	Head slapping	Hitting the water surface with the chin and throat.
	Flipper slapping	Hitting the surface with the ventral surface of the flipper.
	Tail slapping	Striking the surface with the ventral surface of the flukes.
	Mouthing	Touching, biting or holding any part of another whale with the mouth. These are often head to head or head to genital region contacts.
	Head butting	Pushing or butting against other whales with the head.
	Milling	Active interactions, often among juveniles, involving chasing, rolling and tumbling. Most often seen in shallow areas 2–4 m deep and also involving contact with the sea bottom.
	Sexual activity	During close contact usually involving milling behaviour. Erections are seen.
	Riding	Usually neonates or yearlings position themselves over the backs of adult females and probably benefit from the laminar flow to maintain their position.
	Suckling	Both neonates and yearlings are seen to dive repeatedly to the genital area of adult females, which usually maintain a normal swimming position, but sometimes turns slightly sideways. Usually observed in quiet nearshore areas away from other whales.
	Carrying objects	Carrying objects either in their mouths or on their heads or backs.
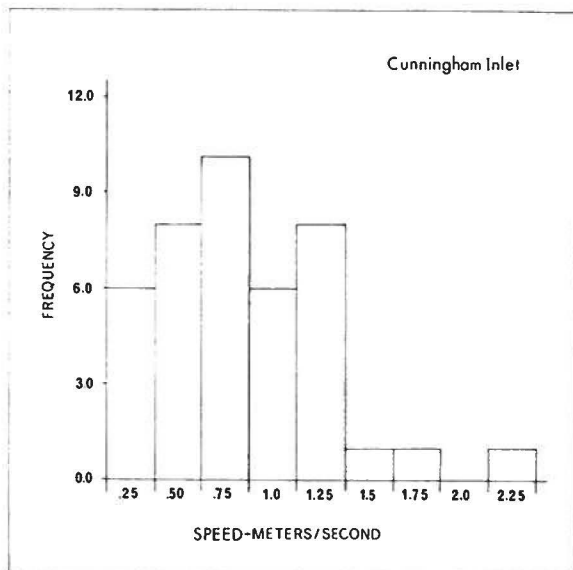
Figure 3. Speed of adult white whales (N = 41) swimming in a directed manner within Cunningham Inlet, N.W.T., Canada.

that this occurred more frequently in groups of whales that had just arrived in the estuary, but we cannot verify the impression with data.

Both side swimming and back swimming occurred only for short intervals and could only be seen when white whales were in the shallow waters near the observation points. In most cases these postures were assumed as the white whales visually investigated and sometimes echolocated on hydrophones or the observation tower. Back swimming may have involved the rubbing of the dorsal skin on the sea bottom.

Prolonged dives were observed offshore in Cunningham Inlet in water depths of up to 42 m. Focal samples, of what was presumed to be the same whale, revealed two types of action pattern which we have called sounding. The most common was when whales initiated a dive with a pronounced midbody bend exposing the mid-dorsum above the surface. Less frequently a sounding also resulted in the caudal peduncle and flukes breaking the surface. Neither of these action patterns is thought to be distinct enough to indicate unequivocally that a prolonged or deep dive has begun. We caution that more detailed observations are needed in order to use such action patterns as indicators of feeding or foraging dives.

Mud stirring in water depths of several metres or more appears to be directly involved with abrasion of the skin surfaces during the moult process, but feeding cannot definitely be excluded. Partial stranding in the flowing fresh water of the river channels is also related to rubbing of the skin surfaces on the abrasive substrates (St. Aubin et al. 1990, Smith et al. 1992). Occasionally animals which have lingered too long on an ebbing tide in shallow water strand completely. Usually they are left in a pool 10–30 cm deep, with parts of their bodies continuously exposed to the air. Sometimes they are left in deeper pools where they can submerge completely, but cannot escape to the sea. On the several occasions when we observed white whales completely stranded out of the water, they were all able to escape on the next high tide. It did not appear that exposure to elevated ambient air temperatures resulted in burning or desiccation of the skin, and the whales remained vigorous throughout the maximum 18 hours of stranding. Infrequently such strandings result in mortality from predation by polar bears (Ursus maritimus; Smith & Sjare 1990).

Behaviour classified as surface and emergent occurred in the deeper areas of the estuaries. Although many other white whales were in the estuaries, our observations of these action patterns were of single whales. These patterns have been described for other cetaceans. They have rarely been noted for white whales in captivity (Defran & Pryor 1980), possibly because of the limited depth of the aquarium tanks.

Interactive behaviour was documented near our observation points in the inshore areas, but it could also be seen offshore. Slapping of the water surface with various parts of the body was common and occurred when animals were close to each other and during interactions such as chasing or rubbing. Visual signalling was probably involved in close, head to head encounters, in which up and down movements of the heads were seen. Actual contacts involved use of the mouth to touch, hold or bite parts of another whale. Head butting observed in the nearshore areas of Cunningham Inlet commonly involved groups of adult male white whales. It infrequently resulted in "rosette formation", previously described for such species as the sperm whales (Physeter catodon; Nishiwaki 1962).

Neonate and yearling calves remained close to their mothers at all times. Occasionally we were able to follow triads of adult females with either a neonate or a yearling accompanied by a larger grey animal. On two such occasions we observed the white adult, which we presumed to be the mother, leave her neonate in the care of the large grey individual. Because of the large number of whales and the lack of individually identifying characteristics, we could not obtain much information on these groups which might be family units.

Both neonates and yearlings appear to benefit from the laminar flow effect created by their mothers' swimming. The smaller calves remain in the area above the dorsal ridge as far back as the beginning of the caudal peduncle, as their mother swims about one meter below the surface. Neonates breathe more frequently than their mother and are able to take quick breaths without actively swimming (Williams et al. 1992) simply by changing the angle of their tail surfaces while being passively propelled.

In nearshore areas close to our observation points, neonatal, yearling and possibly 2+-year-old calves were seen in position to be suckled. It was usually difficult to

ascertain whether nursing actually occurred because it is such a brief event (Hewlett 1978).

White whales near shore were seen to carry inanimate objects both in their mouths and on their backs. Whales held flat stones in their mouths on several occasions while swimming in the river channels of Cunningham Inlet. They also carried objects, on the backs and near the head region, including planks and other flotsam. This might relate to succorant maternal behavior in response to perinatal mortality (Smith & Sleno 1986).

Almost all of the action patterns were observed in both study areas. Only the stranding, mud stirring and carrying of objects were missing from the behaviourial repertoire at the Nastapoka River.

Discussion

In appearance and size the Nastapoka and Cunningham Inlet estuaries are quite different. Within the small area of the Nastapoka, white whales are constantly exposed to the significant river outflow and are never far from the open ocean. At Cunningham Inlet they are able to move from the delta areas of fast-flowing river water to quieter and warmer waters within the enclosed inlet, and yet remain somewhat distant from the open sea areas of Barrow Strait.

Because of these different sighting conditions, our documentation of detailed action patterns was different at the Cunningham Inlet and Nastapoka estuaries. The rubbing behaviour, for example, which appears to be a principal action pattern related to the mouth and channel areas of Cunningham Inlet (Smith et al. 1992), could not be easily detected in the deeper fast-flowing waters of the Nastapoka. It was probably occurring there since epidermal moult was clearly evident (St. Aubin et al. 1990), but the rubbing behaviour (Smith et al. 1992) was almost totally obscured. We would also expect this behaviour to occur in other estuaries, such as those of western Hudson Bay and the Mackenzie River, where sighting conditions, because of lack of good observation points or muddy waters, prevent close observations.

Herd structure at the two estuaries in our study appears similar. Adult males, which appear to maintain tight pods of 10–15 individuals, are a small component of the estuarine aggregations. They appear to remain in estuaries only for short periods compared with the younger whales. Focal samples indicate that adult females, especially those with neonates, avoid close contact with large males in the nearshore areas of the estuaries. Age-structure data, however, do not support this conclusion, but instead point to a positive correlation of adult males, at least with the number of female-yearling pairs. Date appears to play a large role in this correlation, with adult males and female-neonate pairs both increasing as the season progresses.

In both areas the proportions of females with suckling calves, both neonates and yearlings, increases as the sea-son progresses. No calving or behaviour which could be associated with parturition has ever been observed in either estuary and we conclude that births occur prior to the females' arrival in the nearshore waters. This conclusion is consistent with evidence from other recent studies of reproductive cycles which indicate that the season of births is between April and July (Heide-Jørgensen & Teilmann 1994, Doidge 1990a). The argument that estuaries provide a thermal advantage for calving (Sergeant 1973) has been refuted by Doidge (1990b).

The difficulty of following individuals, pairs or groups in crowded estuaries has resulted in a low yield of information on herd structure. The close association of calves with their mothers for two and possibly more years is obvious. There are strong indications that adult-neonate pairs are accompanied by large grey calves who might assist in the care of the newborn or yearling calves. The sex of large grey animals was usually not discernible to the observer. However, in one instance we were able to attach satellite transmitters to a large white female and a large grey female captured together in a river channel, where they had become entrapped together on the ebbing tide. These animals stayed together for at least 21 days as they travelled away from Cunningham Inlet in the Barrow Strait area. Location data during this period indicated that they remained together as they travelled over a considerable distance both offshore and in coastal areas. All of the 5 unaccompanied grey calves captured at Cunningham Inlet during our satellite tagging program have been females ranging in length from 250 to 340 cm. These data might be taken to indicate that the basic herd structure is along matrilines similar to those suggested for other long-lived cetacean species (Baker et al. 1990, Bigg et al. 1990, Hoelzel et al. 1991).

The functions of individual behavioural patterns are difficult to understand. Surface observations of behaviour, occurring offshore at some distance from the observer, are subject to misinterpretation. These surface observations usually consist of what essentially is the beginning of an underwater behaviour, providing weak data from which to infer functions. Even the simple observations of sounding will not give quantitative data on foraging effort for studies of energetics. These answers are more likely to be provided by the application of telemetry (Martin & Smith 1992) in combination with physiological measurements and a detailed knowledge of regional biological oceanography (Welch et al. 1992).

Marine mammals remain elusive to researchers attempting to understand how they thrive in the oceanic environment. Our restricted windows of access for observing such species, coupled with their great mobility through vast unpopulated areas, makes the research task difficult. The period of estuarine aggregation provides only a glimpse of how white whales behave and of the composition of their herds. The important late winter period when mating and calving occur (Heide-Jørgensen & Teilmann 1994, Doidge 1990a) will remain obscure for some time to come. It is vital, however, to underline the

importance of estuaries as areas of particular biological significance. These are areas of traditional occupation where fidelity to site is strong (Caron & Smith 1990) and is probably developed through a learning process, in animals which remain in family groups over a prolonged period. The strong dependence of white whales on specific estuaries, which appear to be limited in number, has led to the depletion of many populations in Canada (Finley *et al.* 1982, Pippard 1985, Reeves & Mitchell 1989, Richard 1991) and the extirpation or cessation of use of at least one large estuarine area of aggregation at the Great Whale River (Francis 1977, Finley 1982) and possibly one other in Ungava Bay (Smith & Hammill 1986, Reeves & Mitchell 1989).

White whales are the most vulnerable of arctic marine mammals under present harvest regimes and should be the subject of continuing conservation action. Five of seven Canadian white whale stocks are considered either endangered, threatened or vulnerable (Finley *et al.* 1982, Pippard 1985, Reeves and Mitchell 1989, Richard 1991, International Whaling Commission 1992, Doidge & Finley in press). The strong philopatry of discrete white whale stocks to specific estuaries makes them subject to severe overexploitation and loss of critical habitat, both major ingredients of past man-mediated ecological disasters.

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