Introduction

Members of the species Orcinus orca, the largest member of the family Delphinidae (Rice, 1977), have been observed in all oceans and seas of the world (Leatherwood and Dahlheim, 1978). Research on the population biology, movements, and abundance of Orcinus orca in the waters around Vancouver Island, British Columbia by (Bigg et.al., 1976 and Bigg, 1982) revealed 30 pods containing a total of 260 whales. Pods are stable family groups composed of subpods, which consist of an adult female and her offspring (Bigg, 1987). There are two resident communities and one transient community ranging from southern Puget Sound to Queen Charlotte Sound. Individual orca are recognized through the use of photo-identification (Bigg,et.al, 1976 and Bigg, 1982). Ford and Fisher (1982) discovered the presence of distinct vocalizations and dialects among pods. Behavioral budgets have been compiled by Ford (1982) and Osborne (1981) on the northern resident community. Jacobsen (1986) has provided a detailed ethogram of the pods in the northern community. The purpose of this study was to compile a temporal budget of surface behaviors of pods in the northern resident community in Johnstone Strait, British Columbia and add to or modify the ethogram provided by Jacobsen (1986).

METHODS

Study Area

Johnstone Strait is a deep, narrow, steep-sided, glacially carved channel separating the northeastern coast of Vancouver Island from mainland British Columbia. The study area is located at the western end of Johnstone Strait (Fig.1). The strait, along with two other passages, forms a key entrance in the migration route of Pacific salmonid species to major river systems on the British Columbia mainland (Thomson, 1981). The majority of coastline within the study area is characterized as having numerous deep, narrow cracks, small coves and beaches, interspersed throughout. Robson Bight Ecological Reserve is located in the central portion of the study area.

Data Collection:

Behavioral observations were recorded from July 20th to August 27th 1987. The majority of observations were made from a 4.2 m inflatable boat with a 25 hp motor. Two shore stations were used to a minor extent for data collection. The rocky peninsula on the southern end of Boat Bay was used because the elevation (8-15 m) of the site provided an excellent view of the eastern portion of the study area. A cliff, 60 m in height, located west of Boat Bay, was also used as it provided a view of the majority of the eastern

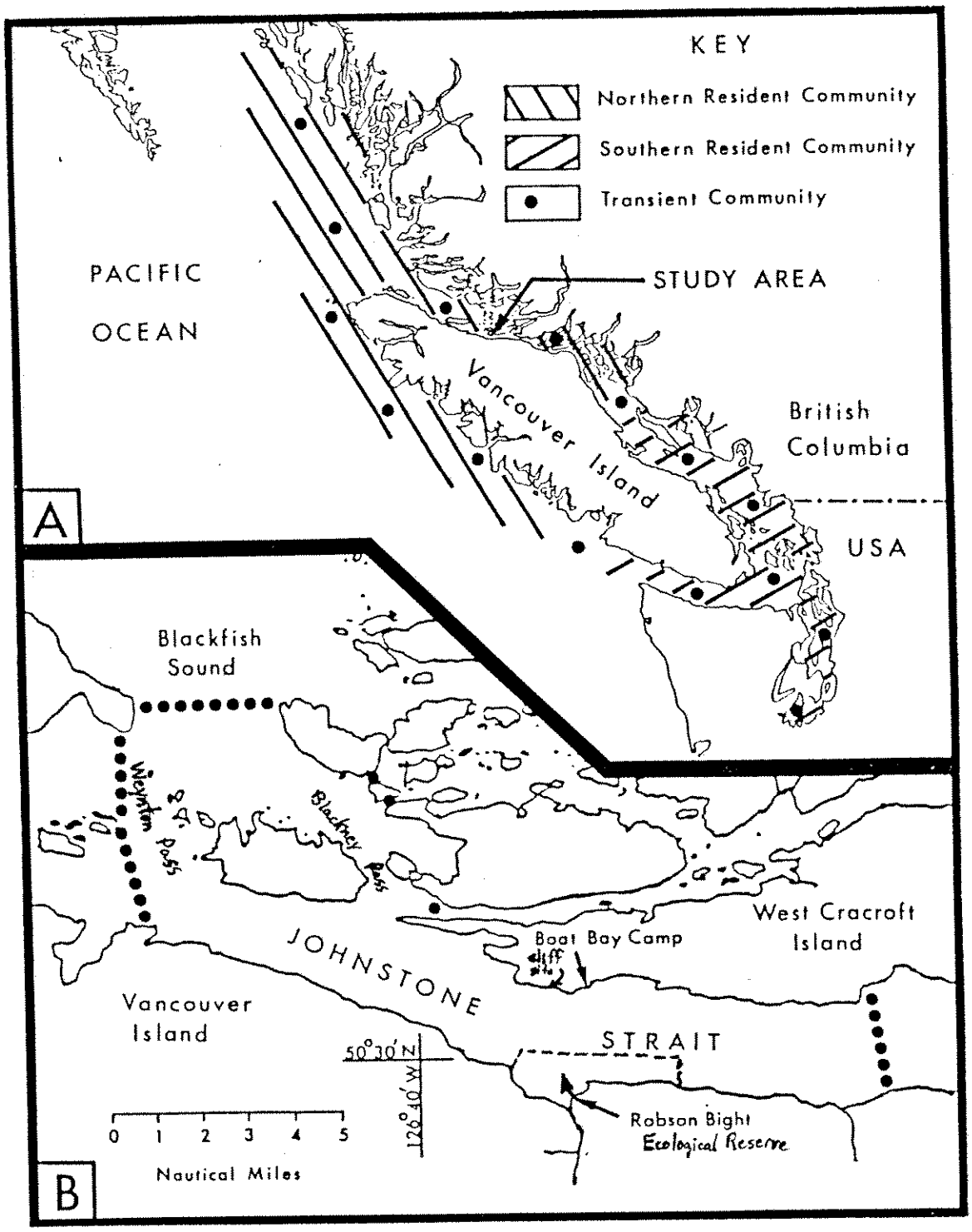

Fig.1 (A) A map showing the home ranges for the Northern and Southern resident communities, plus the range of the transient community and (B) a map of the study area. The dots in Fig.1 (B) represent the boundaries of the study area.

and western portions of the study area. Radio contact was maintained with other research teams and commercial whale watching vessels in the area to obtain orca sightings. A hydrophone deployed from the Boat Bay peninsula was used to monitor orca acoustic activity. If orca were vocalizing, it would indicate that they were either in or near the study area. The hydrophone was especially helpful on days with low visibilty due to fog, or on windy days when surface conditions made sightings difficult. A boat hydrophone was used to monitor and record acoustic activity.

The goal was to identify all orca groups in the study area and to observe and record their surface behaviors. A group of whales was approached from the side at a distance appropriate for identification purposes; such a group became the focus for data collection. The focal group was observed during daylight hours continuously until the group left the study area, weather prohibited further observation, or a new group moved into the study area. Whale movements and milling sites were recorded on maps in the field. Surface behaviors were recorded in the field by constructing coded sentences through the use of a behavioral coding system (Table 1) used by Osborne (1986). Coded sentences were constructed to describe each of the observed surface behaviors (Fig. 3-7).

Table 1. The definitions and coding system used to describe the surface behaviors of orca encountered in Johnstone Strait, British Columbia. (from Osborne, 1986)

BEHAVIOR CLASS	CODE	CATEGORY AND DEFINITION
POD STATUS	ASB	ASSEMBLAGE: More than one pod.
	POD	POD: One complete family unit with a stable membership.
	OTH	OTHER: Less than one pod, a lone whale, etc.
SOCIAL UNITS	GRP	GROUPED: All whales present are in a single homogeneous group.
	PSG	POD SUBGROUP: An aggregation of 2 or more whales, less than the sum of all whales present, containing members all from the same pod.
	MSG	MIXED SUBGROUP: An aggregation of 2 or more whales, less than the sum of all whales present, containing members from more than one pod.
	IND	INDIVIDUAL: A single whale by itself.
INDIVIDUAL SPACE	LOO	LOOSE: Individuals are approximately 5 meters or more apart.
	THT	TIGHT: Individuals are 0.5 to 3 meters apart.
	TCT	TOUCHING: Whales are in physical contact.
ACTIVITY LEVEL	FAS	FAST: Moving at approximately 6 knots or more (the whales are usually "porpoising" high out of the water when surfacing).
	AVR	AVERAGE: Moving at approximately 4 knots or less.
	SLO	SLOW: Moving at approximately 2 knots or less.
	STA	STATIONARY: Whales are motionless at the surface.
ORIENTATION	DIR	DIRECTIONAL: Moving with a nearly constant heading.
	NON	NON-DIRECTIONAL: Moving without an apparent heading.
SPECIFIC BEHAVIORS	SPL	SPLASHING: Any purposeful breaking of the water's surface with an appendage (excluding rising to the surface for respiration and "breaching" or "spy-hopping").
	BRE	BREACHING: A whale jumps vertically out of the water landing with a horizontal splash of at least 1/3 of its body.
	SPY	SPY-HOP: A whale rises vertically from the water exposing the rostrum and the eyes. The whale then slips back into the water in the same vertical plane.
	PEN	PENILE: A whale is observed with an erect penis.
	PRY	PREY: A food species is observed in the mouth or otherwise in the immediate vicinity.
ACOUSTIC ENVIRONMENT	SIL	SILENCE: Individuals are not producing any phonations.
	CLK	ECHOLOCATION CLICKS: Individuals are producing echolocation clicks and no other types of phonations.
	PHO	CLICKS AND OTHER PHONATIONS: Whales are producing phonations that include more than echolocation clicks.
INDIVIDUAL COMMENTS	M	MALE: An adult male.
	F	FEMALE: An adult female.
	C	CALF: A small young whale usually accompanied by an adult female.
	(A-X)	INDIVIDUAL ALPHA-NUMERIC DESIGNATION.
SENTENCE CONJUNCTIONS	&	PERIPHERAL: Behavioral outlier to the majority of whales present.
	/	OCCASIONAL: Occurence of non-continuous (sporadic) behavior.
	.	STOP: Go to next time period and/or encounter.

ENCOUNTER# :_____ DATE: FORAGING POD(s)_____

TIME	TIDE	POD STATUS	SOCIAL UNITS	INDIVIDUAL SPACE	ACTIVITY LEVEL	ORIENTATION	SPLASHING	BREECHING	BELLY-UP	SPYHOP	PENILE	PREY	RUBBING	ACOUSTIC ENVIRONMENT	SENTENCE CONJUNCTIONS	COMMENTS
		OTH	PSG	LOO	AVR	DIR	+	-	-	-	-	+	-		.	
		OTH	PSG	LOO	SLO	NON	+	-	-	-	-	+	-	PHO	.	
		OTH	PSG	LOO	SLO	DIR	-	-	-	-	-	+	-		.	

Fig. 3 Examples of coded sentences indicating foraging behavior.

ENCOUNTER# :_____ DATE: TRAVEL POD(s)_____

TIME	TIDE	POD STATUS	SOCIAL UNITS	INDIVIDUAL SPACE	ACTIVITY LEVEL	ORIENTATION	SPLASHING	BREECHING	BELLY-UP	SPYHOP	PENILE	PREY	RUBBING	ACOUSTIC ENVIRONMENT	SENTENCE CONJUNCTIONS	COMMENTS
		ASB	GRP	THT	AVR	DIR	-	-	-	+	-	-	-		.	
		ASB	GRP	THT	FAS	DIR	-	-	-	+	-	-	-		.	
		OTH	PSG	THT	SLO	DIR	+	+	+	+	-	-	-		.	

Fig. 4 Examples of coded sentences indicating travel behavior.

ENCOUNTER# :_____ DATE: RESTING POD(s)_____

TIME	TIDE	POD STATUS	SOCIAL UNITS	INDIVIDUAL SPACE	ACTIVITY LEVEL	ORIENTATION	SPLASHING	BREECHING	BELLY-UP	SPYHOP	PENILE	PREY	RUBBING	ACOUSTIC ENVIRONMENT	SENTENCE CONJUNCTIONS	COMMENTS
		OTH	PSG	THT	SLO	DIR	-	-	-	-	-	-	-		.	
		ASB	GRP	TCH	SLO	DIR	+	-	+	-	-	-	-		.	

Fig. 5 Examples of coded sentences indicating resting behavior.

ENCOUNTER# :_____ DATE: SOCIALIZING POD(s)_____

TIME	TIDE	POD STATUS	SOCIAL UNITS	INDIVIDUAL SPACE	ACTIVITY LEVEL	ORIENTATION	SPLASHING	BREECHING	BELLY-UP	SPYHOP	PENILE	PREY	RUBBING	ACOUSTIC ENVIRONMENT	SENTENCE CONJUNCTIONS	COMMENTS
		ASB	GRP	LOO	SLO	NON	+	+	+	+	-	-	-		.	
		OTH	PSG	THT	STA	NON	+	-	+	+	-	-	-		.	
		ASB	GRP	THT	SLO	DIR	+	+	+	+	-	-	-	PHO	.	

Fig.6 Examples of coded sentences indicating socializing behavior.

ENCOUNTER# :_____ DATE: RUBBING POD(s)_____

TIME	TIDE	FOC STATUS	SOCIAL UNITS	INDIVIDUAL SPACE	ACTIVITY LEVEL	ORIENTATION	SPLASHING	BREECHING	BELLY-UP	SPYHOP	PENILE	PREY	RUBBING	ACOUSTIC ENVIRONMENT	SENTENCE CONJUNCTIONS	COMMENTS
		ASB	GRP	THT	STA	NON	+	-	-	-	-	-	+		•	
		OTH	PSG	LOO	SLO	NON	-	-	-	-	-	-	+		•	

Fig. 7 Examples of coded sentences indicating rubbing behavior.

For instance, in (Fig. 3) examples of coded sentences indicating travel behavior are given. Upon recording travel behavior, I evaluated each behavior class and assigned a particular code based on their definitions (Table 1). Thus, the combination of codes in a specific sequence forms a coded sentence indicating travel behavior.

Data Analysis

Combinations of coded sentences joined by sentence conjunctions comprised individual time blocks. Each main behavior category was then sorted from the data by grouping time blocks containing consistencies in sentence composition (Osborne, 1986). Time blocks for each category were then summed and the total percent occurrence was calculated (Fig.2).

RESULTS

The study resulted in 128 hrs of recorded observations. Five main categories of surface behavior were recognized in the orca that visit Johnstone Strait during the summer months. In the following presentation, I provide a brief description of each of the main categories in the context of how each was recognized by me and present variations in certain behaviors where they occur.

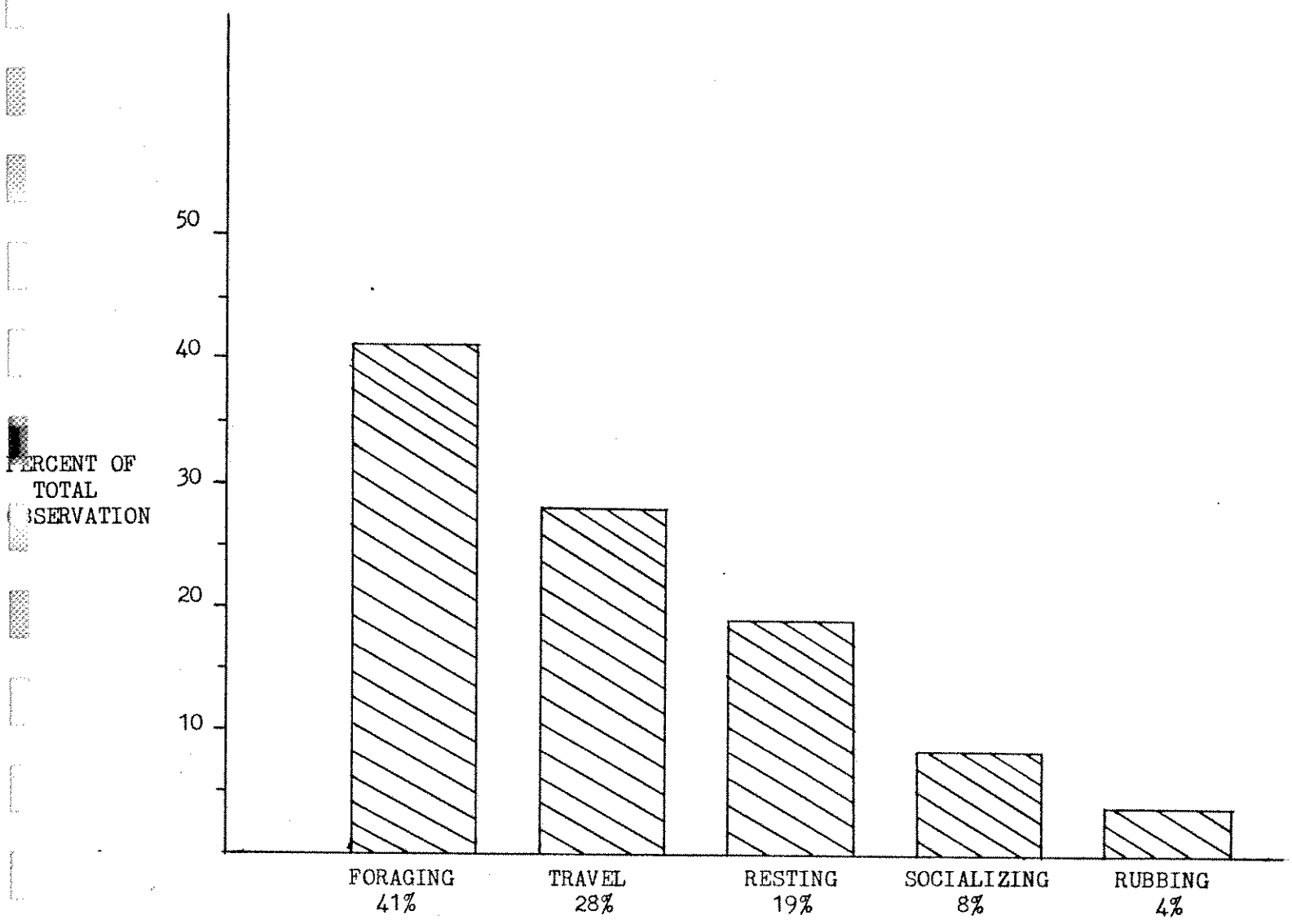

Fig.2 A histogram showing total percent occurrence of categories of surface behaviors in the northern resident community of killer whale pods that visit Johnstone Strait, British Columbia. Sample size equals 128 hr of observation during July and August 1987.

Foraging

Foraging accounted for 41% of all observations. It is recognized as a loose directional formation of subpods and individuals with periods of non-directional milling. On those occasions when whales were observed entering Johnstone Strait through Weynton or Blackney Pass, the group diverged into subpods. Some subpods foraged along the Hanson and Cracroft Island shore, while others traveled on a diagonal course to forage along Vancouver Island shore. Upon reaching a distance approximately 1 km east of Robson Bight, the whales changed directions and foraged westward back along shore. Subpods were often observed foraging along shore in a parade fashion, typically spaced approximately two minutes apart. Adult males were most often observed foraging further offshore in deeper water, while juveniles and cow/calf pairs tended to forage closer to shore.

Cooperative foraging was observed on two occasions. The first instance involved two cow/calf pairs that entered a small cove. A short milling session ensued and ended with the pairs chasing prey out through the kelpbed located at the mouth of the cove. An adult female entered rapidly from the side presumably to intercept the prey. In the other instance a pair of orca encountered a fish in a small cove while foraging at night. One whale pursued the fish while the other stationed itself at the eastern end of the cove.

As the pursuing whale chased the fish back to the center of the cove, the other whale moved in, causing the fish to veer out into the strait. The fish was presumed to be captured as its bioluminescent trail disappeared, as the whales stopped vocalizing and continued foraging westward.

Milling is a non-directional movement by an individual or a group of whales and is associated with encountering prey. Sites where milling most often occurred include: coves; kelpbeds; near peninsulas; tidal rips; stream mouths; and in deeper water (usually by adult males). Whales often engaged in various percussive behaviors (e.g. breeching or fluke slaps) as they approached any of the geographic locations listed above. Behaviors associated with milling include: turning dives; porpoising; high arch dives; and speed swimming at the surface. Underwater monitoring through the use of the boat hydrophone showed that milling sessions tended to include high levels of acoustic activity.

Undulations in place begins with the whale orienting its head to the shore, and then proceedds to arch its back and then straighten the body out creating a wave of water to be pushed toward shore. Only adult females were observed exhibiting this behavior. Milling activity occurred prior to sessions involving undulations in place on 5 of 6 occasions. The duration of undulating activity ranged from 5-25 minutes, during which time the whales did not undulate

continuously. A whale would undulate continuously up to one minute, then the whale floated or milled for 1-2 minutes and then resumed undulating.

Two occasions when undulating behavior was observed provided evidence for the purpose of this behavior. In the first instance the female was oriented toward a tide pool on a flat shelf of rock. She undulated in place, forcing a wave of water up into the pool. On the second occasion, the female was oriented toward a long, narrow, crack that bottomed out on a shelf of rock. The shelfs on both occasions prevented the whales from moving any closer to shore. A subsequent investigation yielded one 30+lb king salmon from each location. The fish in the tide pool was found with its abdominal surface facing up and motionless, and the fish found in the crack was in the same position as the first but was moving slowly. No visible marks were seen on either fish other than scrapes on the head from banging into the rocks.

Travel

Travel accounted for 28% of all observations. It is recognized as the directional movement of an entire group of whales along a straight line course either in a loose formation where individuals are several meters apart or in

tight formation. Traveling within Johnstone Strait occurs at three distinct speeds. The rate of slow travel averages 2-4 kn, medium travel 4-6 kn, and fast travel 6 kn+ (Jacobsen, 1986). Instances when slow travel occurred varied from after a period of rest, (where the whales often engaged in socializing behavior), after a period of average travel (where they slowed down before deploying into foraging), to occasions after a foraging session. The degree of percussive behavior engaged in during average travel varied from total absence, to times where the whales were quite active while traveling to meet a group of whales entering the strait from the north. In fast travel, the whales were typically in tight formation and upon surfacing would porpoise out of the water. Percussive behavior was usually absent during periods of fast travel.

Resting

Resting accounted for 19% of all observations. The orcas swim at 2-4 kn while resting (Jacobsen, 1986). Whales form resting lines perpendicular to the direction of movement and are either in contact with one another or within 1-2 m of their immediate neighbor. Respirations were highly synchronized and percussive behaviors were generally absent when resting. However, splashing occurred typically when whales were in a transition from resting to foraging.

Socializing

Socializing accounted for 8% of all observations. Bouts in which socializing behavior was observed occurred on nine different occasions with durations ranging from 13 minutes to 2.5 hrs. Variations in social behavior depended on group composition and the number of whales involved. Groups engaged in socializing behavior varied sex and age class. In the following section, I provide examples of various social behaviors the whales engaged in and the context in which socializing occurred.

Allomaternal care was exhibited by an adult female with a group of three juveniles, while the mothers of two of the juveniles were foraging. Another instance involved a single pod that contains four adult males. While the adult males were foraging, the remaining members of the pod were observed rubbing their heads on one another and diving non-directionally in close proximity to one another. All male groups were observed shoving and diving over one another. The durations of three sessions were 1.5 hr, 2.0 hr, and 2.5 hr, and involved 30, 102, and 25 whales respectively. These sessions were characterized by various social changes in association, with chase sequences occurring between calves and juveniles and between adult males and juveniles. Periods of floating were also common on these occasions. Also, adult

males were observed moving from subpod to subpod swimming behind adult females. This activity is thought to be a sipping behavior where the male is testing the estrus condition of the female (Jacobsen, pers. comm.).

Rubbing

Rubbing behavior accounted for 4% of all observations. The primary rubbing area consists of a short section of coastline where the bottom is composed of large deposits of small, smooth circular stones. These stones are found in shallow water at the base of steep rocky coastline or in small coves where they form beaches. The method in which a whale typically rubs on the stones is," by making contact with the side of the head first and as it swims forward arches the body to progressively make contact with posterior portions of the back and sides (Jacobsen,1986)." Other variations in posture assumed by the whales that were observed include: orienting the abdominal surface to steep rocky shoreline in order to make contact with the shore as the orce glides along rubbing its ventral surface, or orienting the ventral portion of the whale to the surface in shallow water to rub various portions of the dorsal surface.

Discussion

The importance of Johnstone Strait as a core foraging area for orcas of the northern resident community (reflected by the arrival of pods in the are coinciding with the return of salmon) is becoming better understood as long term studies in this region continue. The orca frequent this area during the summer months not only to forage, but also to socialize (Bigg, pers. comm.). The total percentage occurence of rubbing activity in this study equated to 5.0hr of observation. However, research conducted in July and August 1987 with 24 hr surveillance showed a total of 139 hr of rubbing (Briggs et.al., 1988). The wide discrepancy in the total number of hours where rubbing was observed is due to a differnce in methods. Briggs method involved 24 hr observation at the primary rubbing area, whereas in my method rubbing was only observed if the focal group being observed chose to engage in rubbibg behavior. The findings by Briggs et, al. indicates that rubbing accounts for a significantly higher percentage of the behavior budget than was revealed by my study. The function of undulations in place was previously unknown prior to this study. It is now highly probable that the whale undulates in an attempt to flush fish it has trapped from areas on the shoreline where it is physically impossible for the whale to reach. The size of the trapped fish on two occasions and the durations of undulating sessions suggest, from an energetics standpoint,

the importance of exploiting these large fish while they are available. The question of whether or not seasonal variations in foraging during the summer months in the strait exist remains to be answered. An attempt at addressing this question may be to conduct a study comparing the number of whale hours spent foraging with seasonal fluctuations in abundance of salmon. A study of this nature may be difficult at best, as fisheries data reflects a management bias and does not provide an accurate representation of the numbers of salmon moving through the strait at any particular time. The documentation of milling sites in this study illustrates area where the whales were frequently observed feeding. The importance of these observations may be to serve as baseline data for future management and development decisions pertaining to this region of Johnstone Strait.

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Special thanks goes out to Jeff Jacobsen, the man who introduced me to behavioral biology and was almost always around to field endless questions from me during the course of my project. Also, I would like to thank the orca of the northern resident community. May you someday thrive in an environment free of pollution and overfishing.

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