

**Effects of Tidal Current Phase on the Distribution and Abundance of Rhinoceros Auklets
(*Cerorhinca monocerata*) in Cattle Pass, Washington**

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Abstract:

The distribution and abundance of Rhinoceros Auklets is related to the tide cycle. I examined the effects of tidal currents phase on the distribution and abundance of the Rhinoceros Auklets through land-based surveys of the waters within Cattle Pass, Washington. Auklets aggregated in large groups inside Cattle Pass during flooding tides. During the slack high tide numbers dropped to intermediate levels, and then declined during ebbing tides and remained very low until the next flooding tide. During flooding tides the birds aggregated in the north end of the pass where prey availability was highest. Low abundance during the ebbing tide was attributed to high prey concentrations in the south end of the pass outside of the survey area. Auklets strongly preferred the center of the pass, where the main current flowed, over the calmer water closer to shore. This study shows the importance of the tide cycle in influencing the daily movements of Rhinoceros Auklets.

Keywords:

Cattle Pass, San Juan Channel, alcids, Rhinoceros Auklet, *Cerorhinca monocerata*, tidal currents, tide cycle

Introduction:

Tidal currents are a key factor in determining the spatial distribution of seabirds in coastal nearshore waters. Currents influence copepod abundance and distribution, which in turn influence the abundance of fish (Zamon 2003). Species of Alcidae forage in deeper water than most other piscivorous seabirds and avoid slack water (Holm and Berger 2002). The Rhinoceros Auklet (*Cerorhinca monocerata*), a piscivorous alcid, forages predominantly in marine waters that are >20 m deep and have strong tidal currents that concentrate their prey (Wahl and Speich 1994). Rhinoceros Auklets have two large breeding colonies in the inner waters of Washington

State, one on Protection Island and one on Smith Island, and forage relatively close to these colonies in areas of strong tidal current during their summer breeding season (Wahl and Speich 1994). In contrast to many piscivorous species, Rhinoceros Auklets are abundant and easy to locate, making them ideal to study the effects of tidal current on the distribution patterns of piscivorous seabirds in coastal waters.

Cattle Pass is the narrowest point of San Juan Channel, and is located at the juncture between the northern end of the channel and the Strait of Juan de Fuca (Fig. 1). Cattle Pass has strong tidal currents due to its position between these two waters, narrow width, and steep sides (Zamon 2002). Large aggregations of piscivorous seabirds are found at this site during the summer due to the large concentration of prey (Zamon 2003). Nesting Rhinoceros Auklets aggregate in this area and feed mainly on Pacific sandlance (*Ammodytes hexaptures*), a species of fish that depends on copepods that are concentrated by strong tidal currents. Non-foraging auklets form rafts of 20-40 birds or larger where birds float in close proximity to each other without diving (Grover and Olla 1983).

My objective was to assess variation in the spatial distribution of Rhinoceros Auklets in response to changes in tide phase. I chose Cattle Pass to study the effects of tidal current phase on auklets because of its strong tidal currents and high density of auklets during the summer months. High abundance of Rhinoceros Auklets in Cattle Pass during fast flood tides has been documented, however, their spatial distribution inside the pass related to the tidal cycle is not known (Zamon 2003; Spatz 2007). In this study, I demonstrate the strong correlations of Rhinoceros Auklet abundance and distributions on tidal currents by surveying the birds during a full tide cycle in Cattle Pass.

Methods:

Study Area

I conducted this study during 12-20 August 2011 in Cattle Pass located in the southern end of San Juan Channel, Washington (Fig. 1). Observations were conducted from Avenue Point ($48^{\circ}27'N$, $122^{\circ}57'N$) on the east shoreline of San Juan Island, which provides a clear view of Cattle Pass.

Surveys

I conducted land-based surveys of Rhinoceros Auklets in Cattle Pass over a period of seven days. I conducted 33 surveys in total. I used a spotting scope set at 15 \times magnification to initially locate birds; greater magnifications were used to conduct counts as needed.

The survey area was divided into nine unequal-sized spatial sectors based on easily identifiable landmarks and three tidal zones (west of main current, main current, and east of main current); these are the same sections and zones used by Zamon (2003). Surveys were conducted by counting all Rhinoceros Auklets on the water in each section and tidal zone. I started each survey in section 1 and moved through sections in sequence, counting birds from the furthest end of section to nearest. For each auklet sighted, I recorded whether another bird of any species occurred within approximately 5 m. A group was defined as >1 birds.

My surveys were timed to cover the greatest possible range of tidal phases. All tidal phases were covered at least three times; however, surveys covering all 8 tidal current phases consecutively were taken only on two days. Predicted values for tidal current were obtained from the software program Mr. Tides 3 for the San Juan Channel (South Entrance) station. At the survey site I kept an observational log of tidal phases and speed to correlate with predicted values. No discrepancy was found between the predicted tidal current phases and observations made at the site. I divided the tidal cycle into eight tidal phases: slack low, slow flood 1, fast

flood, slow flood 2, slack high, slow ebb 1, fast ebb, and slow ebb 2 (Fig. 2). I only conducted surveys when the whole survey area was clearly visible and free from fog, with relatively calm seas (Beaufort Sea State ≤ 3).

Results:

Variation in total abundance of Rhinoceros Auklets in Cattle Pass correlated with differences in tidal current phase. Mean abundance of Rhinoceros Auklets was highest during the fast flood and slow flood 2 phases (Fig. 3). At both of these phases the mean number of auklets was > 100 . Mean number of birds was at a level 20-80 individuals through the next four phases, from slack high to slow ebb 2. The mean number of birds continued to decrease, reaching lowest values below 20 birds during slow ebb 1 and Slow 4. This apparent trend is strong but differences were not statistically significant.

A complete one-day survey covering a full tidal cycle on 20 August 2011 showed a very similar pattern of Rhinoceros Auklets abundance (Fig. 4). During the early morning fast flood and slow flood 2 phases abundance was > 200 birds. It decreased to 20-80 birds during slack high, slow ebb 1 then dropped below 20 birds through the end of the cycle. As the current increased with the evening flood tide abundance rose to 60-180 birds during the fast flood and slow flood 2 phases. The relatively lower abundance observed during the evening flood tide may have been because current speeds were lower than during the morning flood.

Rhinoceros Auklets were primarily seen in groups of other birds of the same species and rarely with other species or alone (Fig. 5). As the number of Rhinoceros Auklets in Cattle Pass increased with the tidal currents the total number of auklets in Rhinoceros Auklets only groups also increased. The number of single auklets or auklet groups did not increase as more auklets

entered the area. The majority of auklets surveyed were in groups of >1 with no other species within 5 m. The number of auklets single or in other species groups did not increase in proportion to the total number of auklets.

Spatial distribution of Rhinoceros Auklets in Cattle Pass was related to tidal current phase (Figs. 6a, 6b, & 7a-j). During fast flood and slow flood 2 auklets were concentrated in sections 1, 2, 3, and 4 in the north end of the pass and section 7 in the south end of the pass. During slow ebb 2, slack low, and slow flood 1, auklets were located in low numbers primarily in the center of the pass in sections 3, 4, 5, and 6. Auklet distribution was not consistent between the fast flood phases surveyed at either end of the tide cycle. Surveys from the morning fast flood showed auklets concentrated in the center current area in sections 1, 2, 3, and 4. Surveys from the afternoon fast flood showed auklets concentrated in section 7, with only a small number seen in sections 1, 2, 3, and 4. Regardless of tidal current phase, no auklets were found in section 9 and only three auklets total were found in section 8.

Auklets were found primarily in the center tidal current area throughout all tidal current phases and regardless of the section they were located in. During periods of low abundance numbers of auklets in the center and east current zones were more even. The number of auklets in the east current zone (C) and west current zone (A) did not increase in proportion to the total number of auklets in the pass. When out of the center current zone (B) auklets were primarily located on the east current zone (C) and rarely in the west current zone (A).

Discussion:

During this study, tide direction had a significant effect on the total abundance of Rhinoceros Auklets within Cattle Pass. Auklets aggregated in large groups inside Cattle Pass during flooding tides, dropped to intermediate numbers during the slack high, and then declined

during ebbing tides occurred and remained very low until the next flooding tide. This pattern of abundance by tidal phase was in close agreement with the pattern reported by Zamon (2003), who used the same spatial survey area as I did. Aggregations of birds typically correlate with higher abundance of prey. In Cattle Pass prey availability is highest during fast moving flooding tides. Strong currents force plankton and bait fish that are prey for Rhinoceros Auklets into the water column (Zamon 2000). Further, flooding currents have been found to concentrate plankton and bait fish inside Cattle Pass (Zamon 2000). Low abundance during slack tides is probably because weaker currents lead to lower prey availability. In contrast, low Rhinoceros Auklets during fast ebbing tides is probably because the birds have moved south out of the pass following the prey (Spatz 2007).

Tidal phase patterns also influenced the distribution of Rhinoceros Auklets in Cattle Pass. As the flooding tide progressed larger and larger numbers of birds aggregated in the north end of the pass. They stayed predominantly in the center current zone riding the current that was heading north. Zamon's (2003) findings indicate that seabird prey is concentrated at the north end of the pass by the current flowing fast through the narrows during flood tides. As the flood current decreased, the number of auklets in the pass diminished. Some may have moved farther north out of my viewing area, however many were seen flying south back through the narrows towards Strait of Juan de Fuca. Expected increase in numbers at the south end of the pass at the beginning of the next flooding was not observed, possibly because my observational site did not extend far enough south. On one occasion, build up of Rhinoceros Auklets in the north end of the pass was noticeably slower on the second of two consecutive floods tides. This may have been because current speeds during the second flood were much slower. Time of day is unlikely

to be a factor since Rhinoceros Auklets do not have a diurnal-based activity pattern (Holm and Burger 2002).

During flooding tides when there are large numbers of Rhinoceros Auklets present, the majority of these birds are in the flowing current in the middle zone of Cattle Pass; very few birds were in the calmer waters on the sides of the channel. Rhinoceros Auklets might prefer the mid channel because they are actively feeding in these waters or because they are passively riding the current. In either case this pattern is consistent with the findings of previous studies that have shown auklets prefer deep waters with strong currents (Grover and Olla 1983; Wahl and Speich 1994; Holm and Burger 2002; Zamon 2003; Spatz 2007). The center current zone is the deepest part of the pass and the area where the main current flows (NOAA Chart 18434). The lack of other species with Rhinoceros Auklets may be due to differing depth and current requirements (Holm & Burger 2002; Spatz 2007). This is supported by my observation that Common Murres, which share similar depth and current preferences, were the only species found in groups with Rhinoceros Auklets (Spatz 2007). That the two species were not seen together more often is likely because of the relatively low abundance of Common Murres in comparison with Rhinoceros Auklets.

This study adds fine-scale detail for the effects of tidal current phases on Rhinoceros Auklets to the overall understanding of seabird movements within Cattle Pass. Future research connecting distribution of Rhinoceros Auklets inside Cattle Pass with the areas north and south of the pass during a tide cycle would be valuable.

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Zamon, JE. 2003. Mixed species aggregations feeding upon herring and sandlance schools in nearshore archipelago depending on flooding tidal currents. *Marine Ecology Progress Series* 261: 243-255.

Figures and Tables:

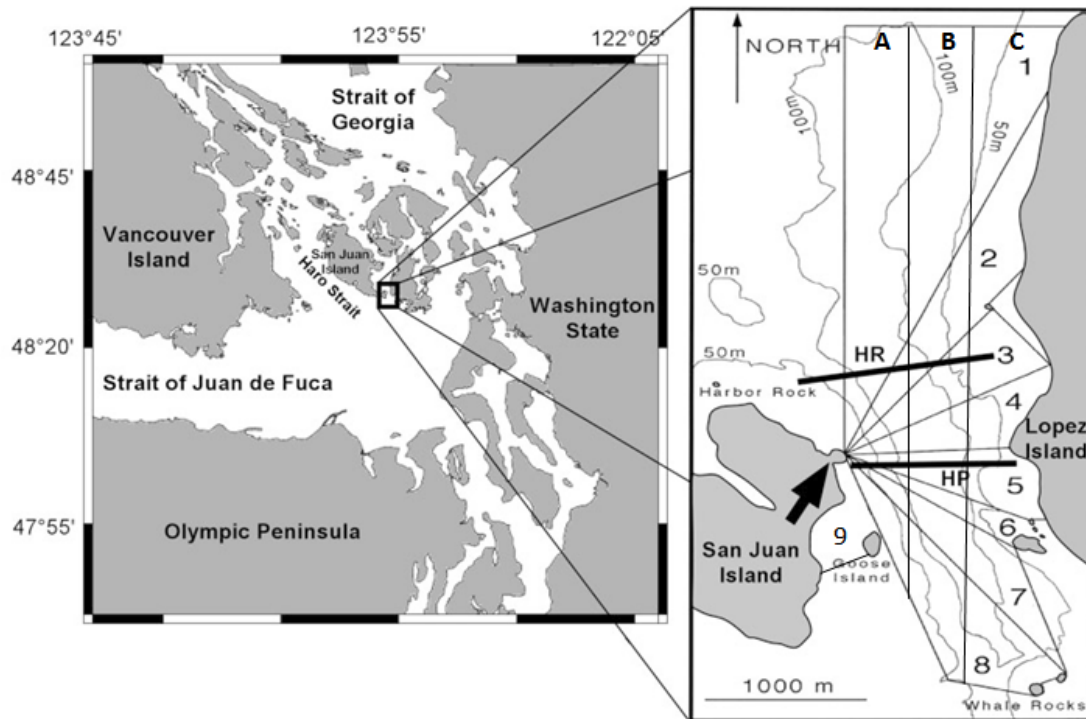


Figure 1. Map of study site. Sectors 1-9 are divided by stable landmarks. Tidal zones A, B, and C correspond to west of main current flow, main current flow, and east of main current flow when current is fast. Arrow indicates survey site (Modified from Zamon 2003).

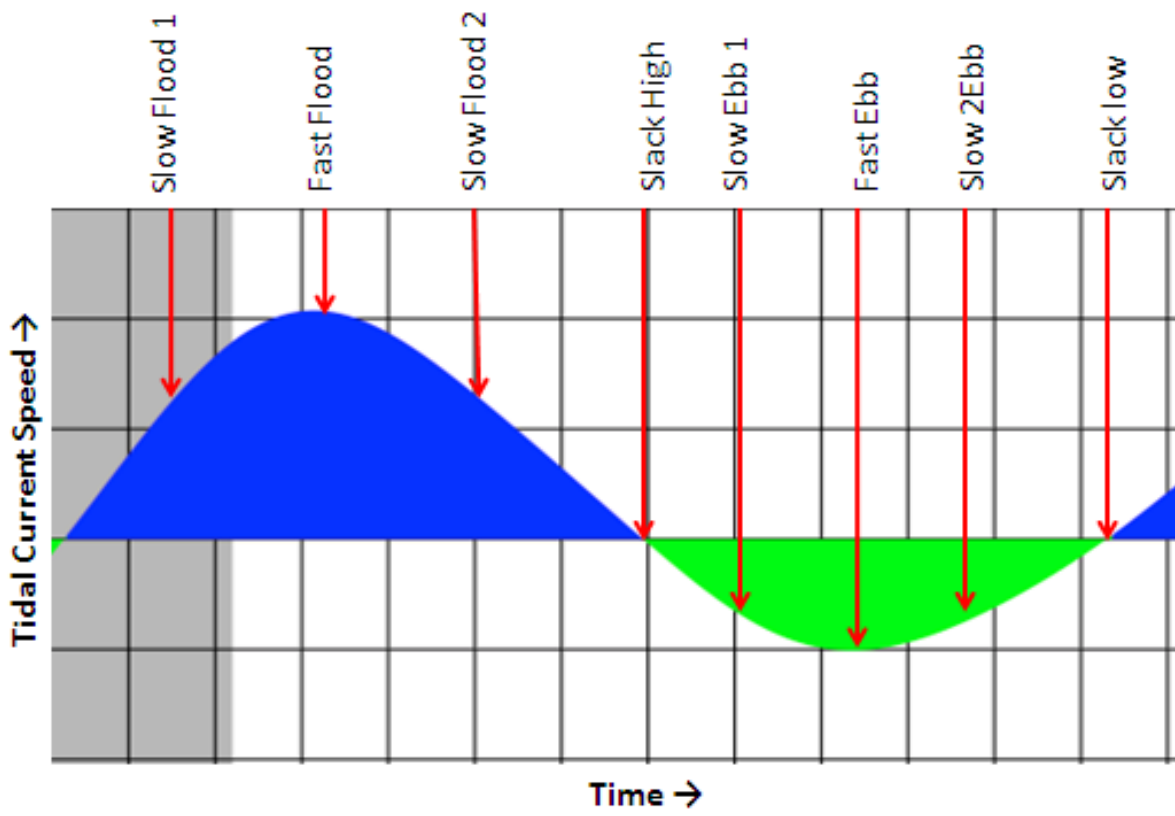


Figure 2. Tidal phase survey points representing a full tidal cycle.

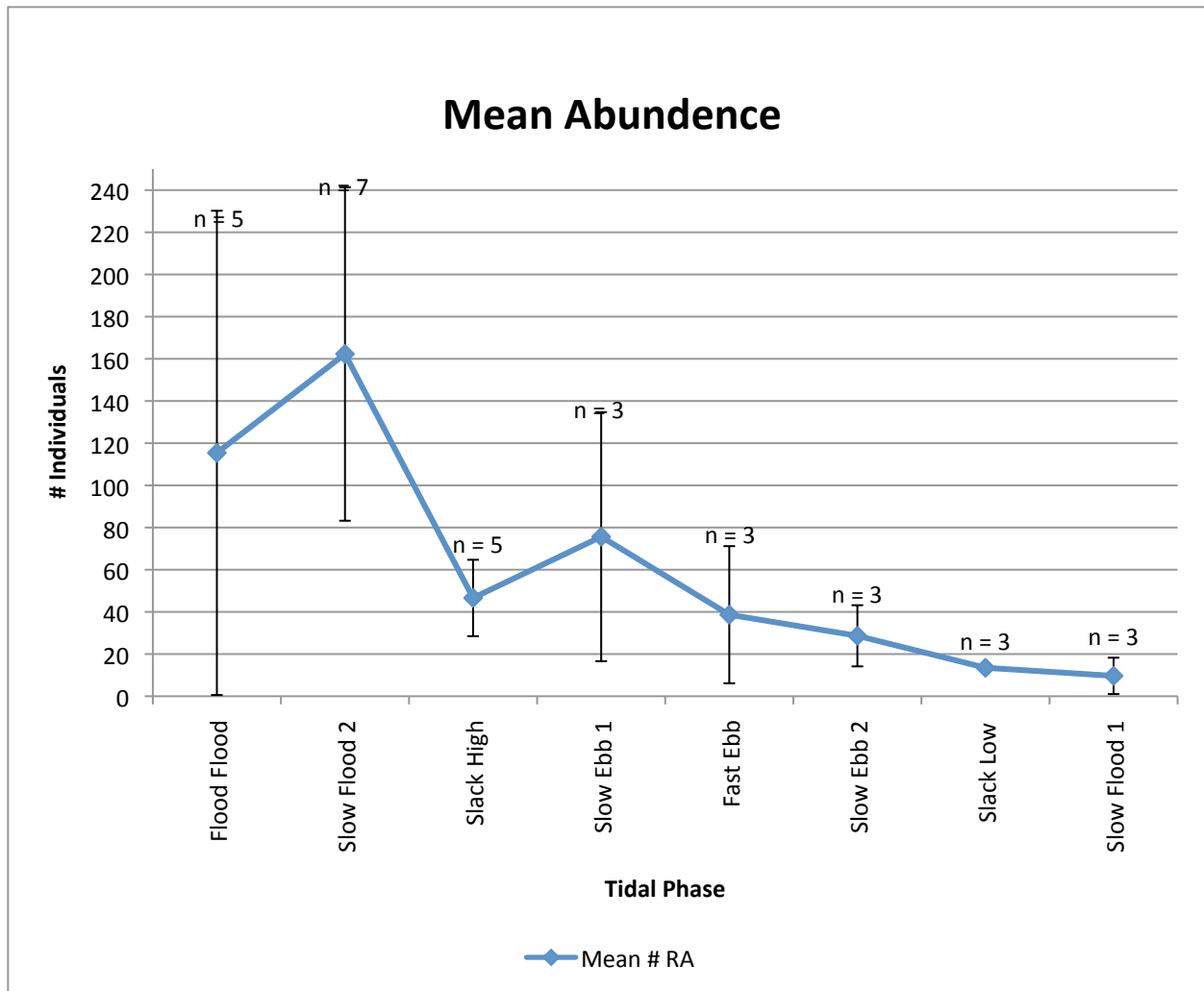


Figure 3. Mean abundance of Rhinoceros Auklets in Cattle Pass by tidal phase. Mean # of birds, standard deviation, and total # of surveys taken at each point reported. Includes all surveys taken between 12-20 Aug. 2011.

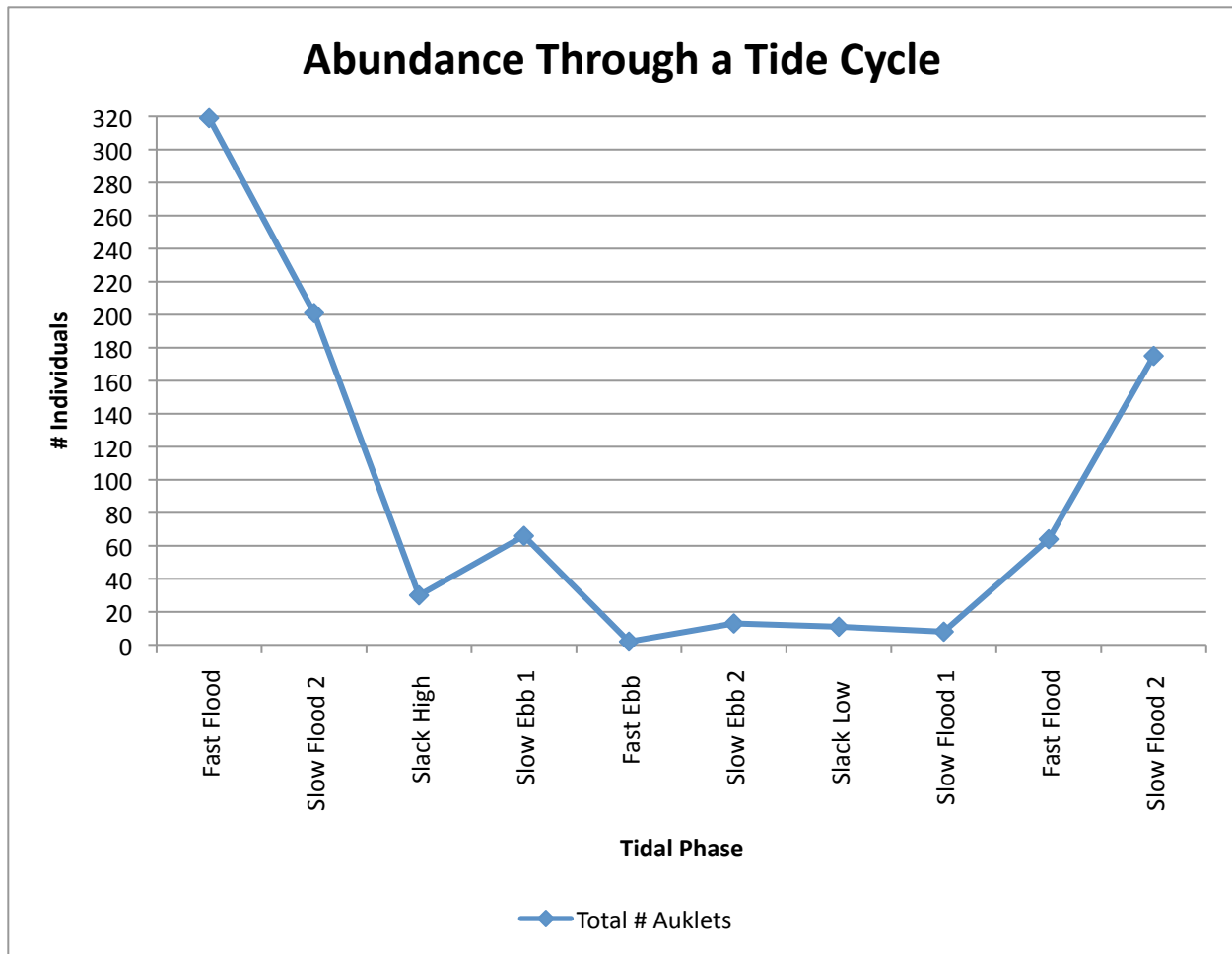


Figure 4. Total abundance of Rhinoceros Auklets in Cattle Pass by tidal current phase for a consecutive set of surveys taken during a one day period. Surveys taken on 20-Aug. 2011.

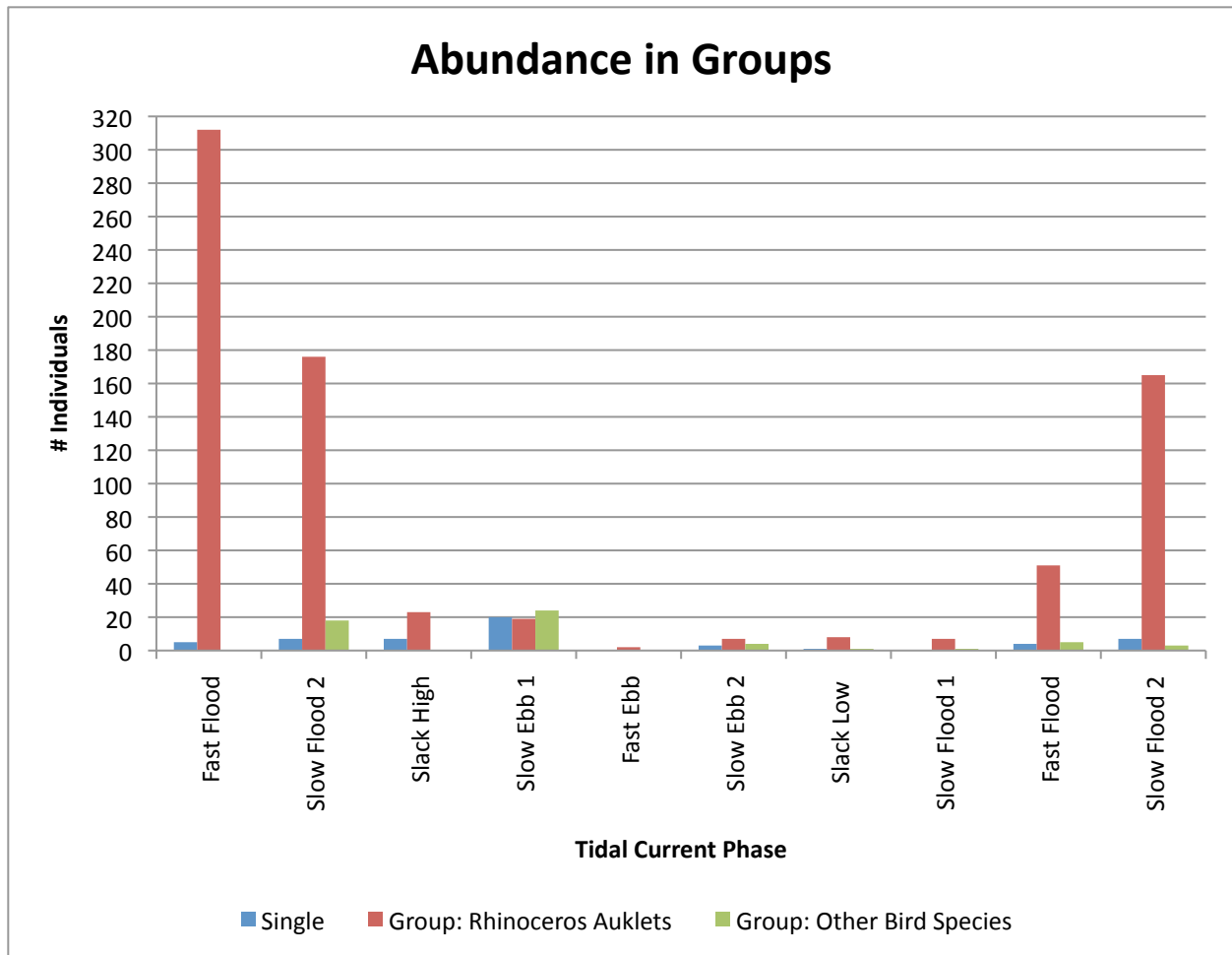


Figure 5. Total number of Rhinoceros Auklets observed signally, in groups of Rhinoceros Auklets only, and in groups with other bird species at each tidal current phase. Surveys taken on 20-Aug. 2011.

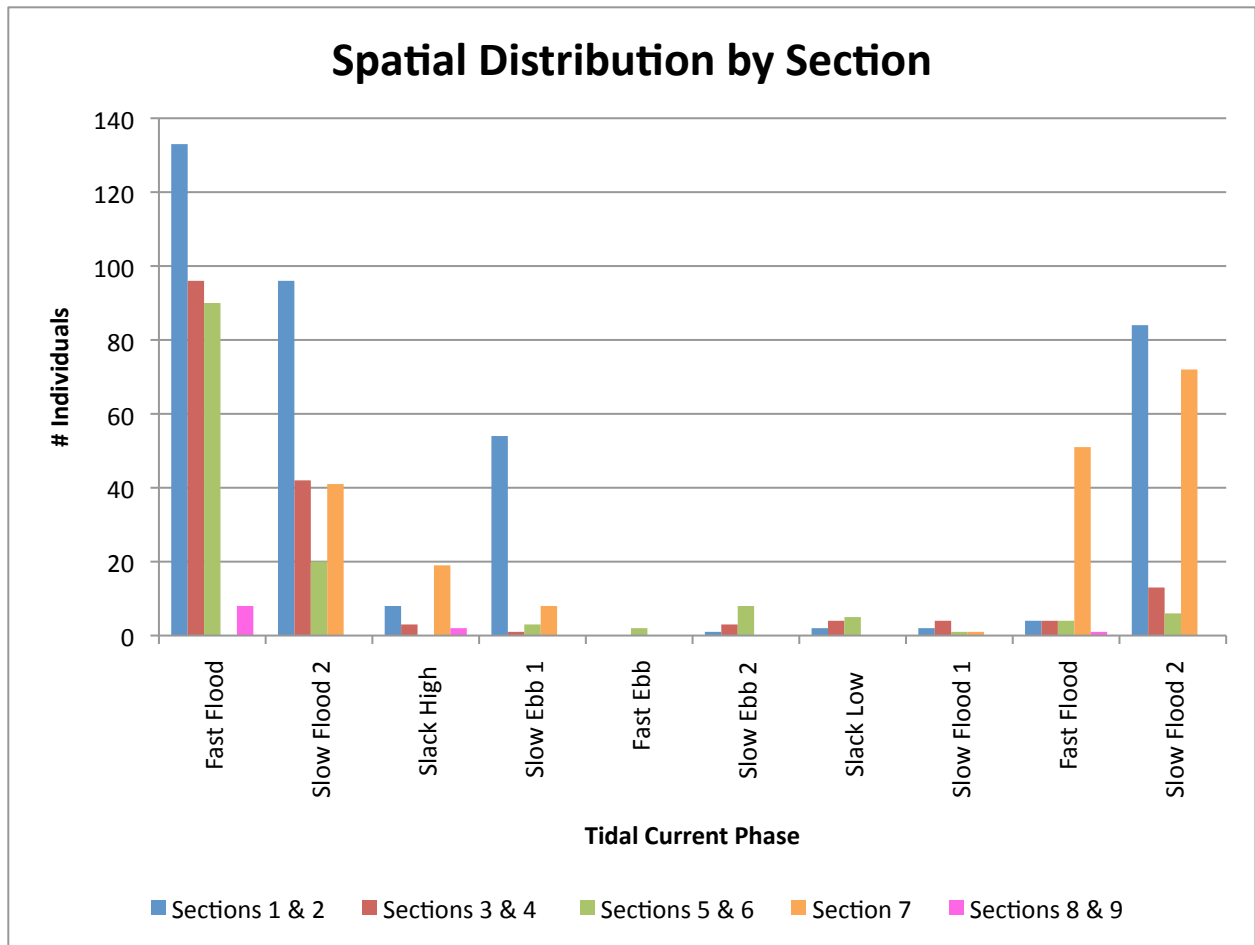


Figure 6a. Spatial distribution of Rhinoceros Auklets in Cattle Pass by sections. Sections are grouped based on similar distribution patterns in sequential sections. Surveys taken on 20-Aug. 2011.

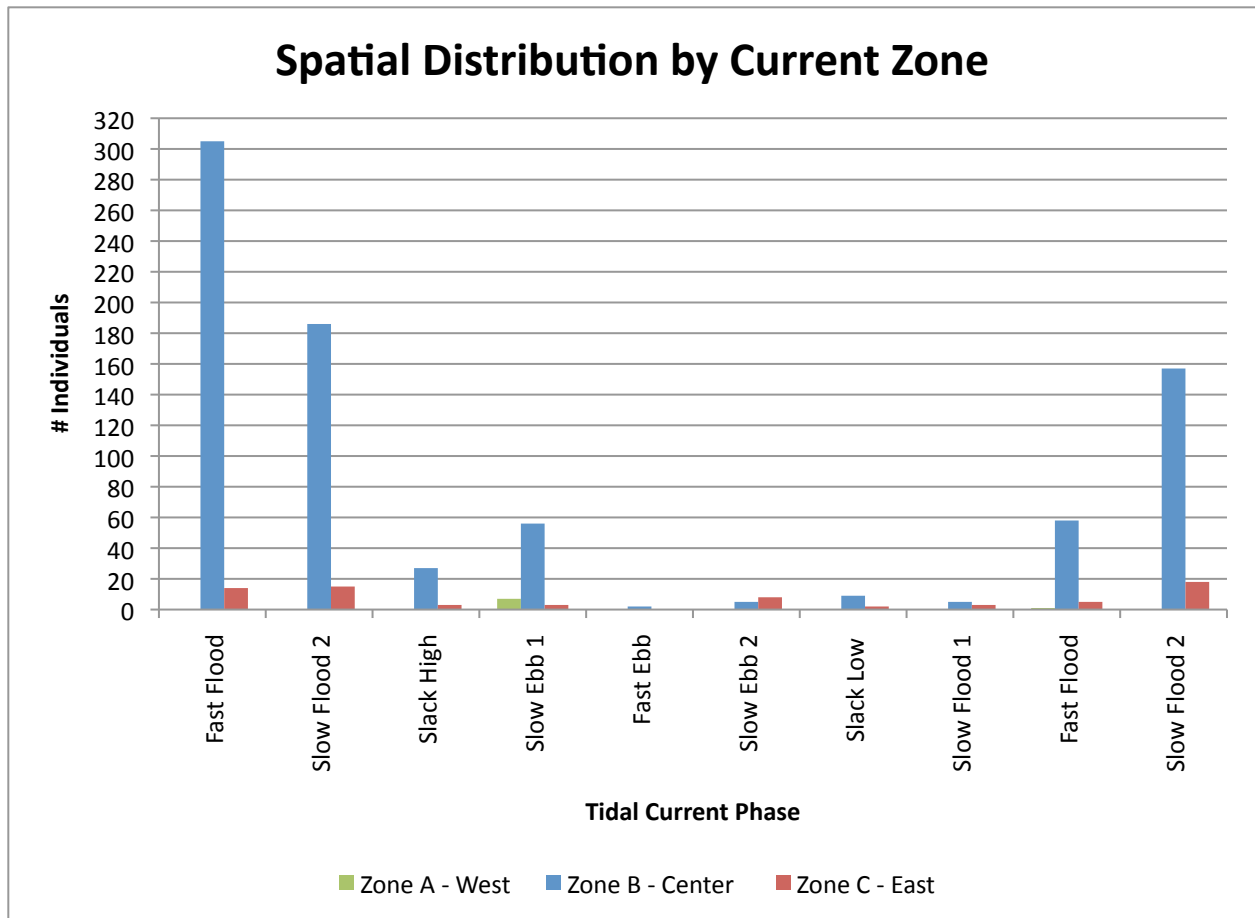


Figure 6b. Spatial distribution of Rhinoceros Auklets in Cattle Pass by current zones. Zones correspond with the east, center, and west areas of the channel. Surveys taken on 20-Aug. 2011

A	B	C	
	42		1
	77	14	2
	38		3
	58		4
	58		5
	32		6
			7
			8
			9

7a. Fast Flood (7:00 AM)

A	B	C	
	66		1
	30		2
	9		3
	33		4
	5		5
		15	6
	41		7
	2		8
			9

7b. Slow Flood 2 (8:50 AM)

A	B	C	
	5		1
	3		2
		1	3
		2	4
			5
			6
	19		7
			8
			9

7c. Slack High (10:45 AM)

A	B	C	
5	22	3	1
	23		2
			3
	1		4
2	1		5
			6
	8		7
			8
			9

7d. Slow Ebb 1 (12:00 PM)

A	B	C	
			1
			2
			3
			4
	2		5
			6
			7
			8
			9

7e. Fast Ebb (1:20 PM)

A	B	C	
			1
	1		2
		4	3
			4
	4		5
		4	6
			7
			8
			9

7f. Slow Ebb 2 (3:00 PM)

A	B	C	
	2		1
			2
	2		3
		2	4
	5		5
			6
			7
			8
			9

7g. Slack Low (4:20 PM)

A	B	C	
			1
	2		2
	2	2	3
			4
		1	5
			6
	4		7
			8
			9

7h. Slow Flood 1 (5:40 PM)

A	B	C	
		1	1
	3		2
	1		3
	1	2	4
	2	2	5
			6
	51		7
1			8
			9

7i. Fast Flood (7:00 PM)

A	B	C	
	83		1
	1		2
			3
		13	4
	1		5
		5	6
	72		7
			8
			9

7j. Slow Flood 2 (8:15 PM)

Figure 7a-j. Abundance and Distribution of Rhinoceros Auklet in Cattle Pass by sector and current zone. Surveys taken on 20-Aug. 2011.