SEMI-ANNUAL PERFORMANCE REPORT

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Amount of Grant: $344,843

Project Title: Acoustic Monitoring of Beluga Whales and Noise in Cook Inlet

Grantee: Alaska Department of Fish & Game

Cooperators: NMFS, University of Alaska Fairbanks, Alaska SeaLife Center, Department of Defense, & Hawaii Institute of Marine Biology

Award Period: From 1 October 2007 through 30 September 2010

Period Covered by this Report: 1 October 2009 through 31 March 2010

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Summary of Progress and Expenditures to Date

Fieldwork Accomplishments

During this reporting period fieldwork continued with the recovery and redeployment of the acoustic 4 moorings in the lower and mid inlet (MacArthur River, Kenai River, Kachemak Bay, & Tuxedni Bay) for the overwinter period. Combined with the 4 moorings deployed in the upper inlet during the previous reporting period (Cairn Point, Fire Island, Eagle Bay-South, and Beluga River), 8 moorings each with an EAR and C-POD were deployed throughout the inlet for the overwinter period. Attempts to recovery these moorings will take place in spring 2010; see Figure 1.

Data Analyses and Results

Substantial progress was made on the analysis of the recordings obtained from the EARS and the detections from the C-PODs for the summer-fall deployment period.

C-PODs

1. Logged periods

At the lower inlet deployment locations numerous 'noisy' events, most probably related to ship noise, were detected. The C-Pods suffered a firmware problem that made them stop sampling when these noisy events occurred. As a result, the total number of days during the 160 day deployment period for which data was logged was very low (3-11 days) except for Kenai River (132 days), as shown in Table 1.

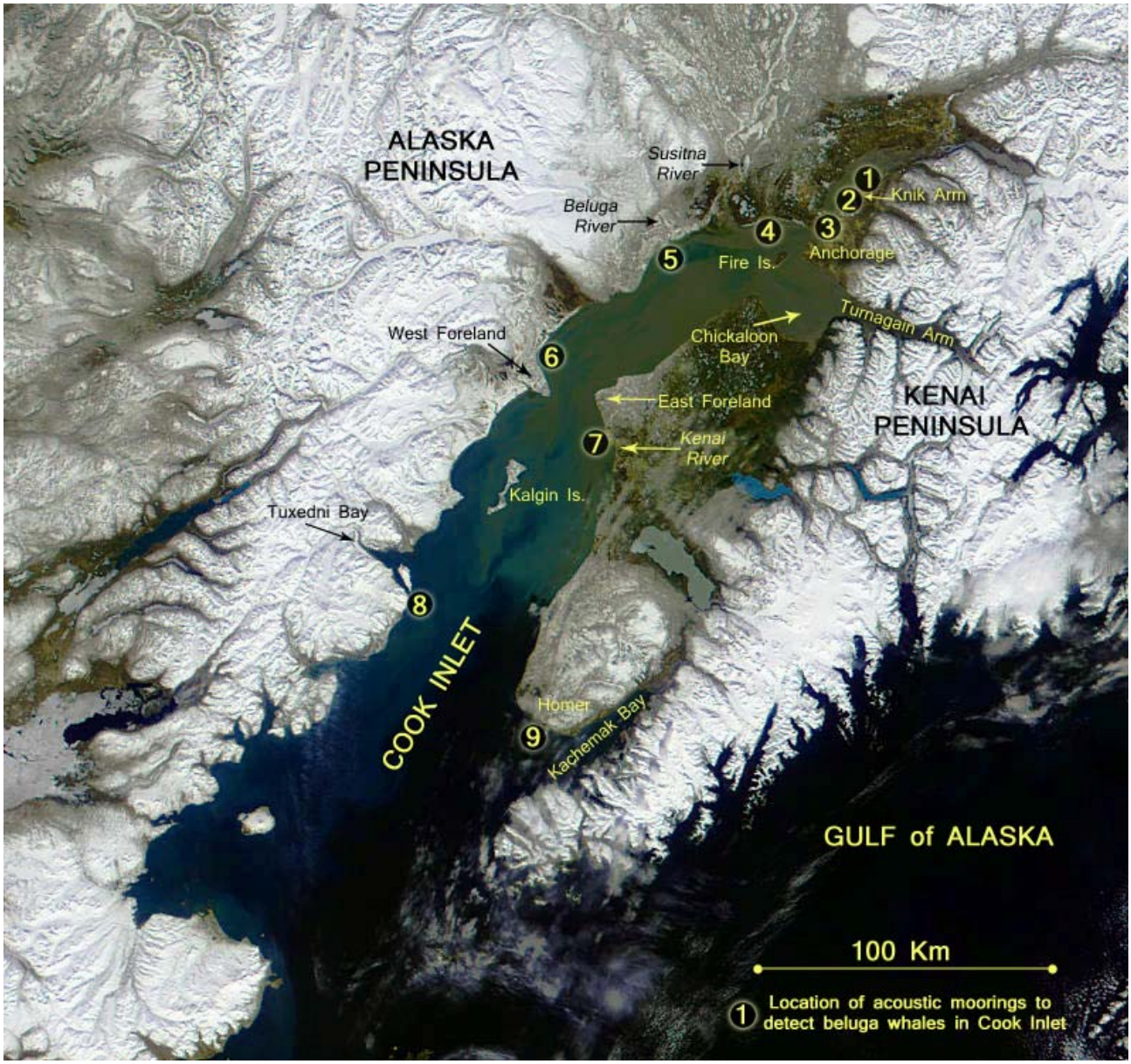


Figure 1. The location of passive acoustic moorings deployed in Cook Inlet, Alaska, to monitor beluga whales during the 2009-2010 overwinter period. Location #1, in Knik Arm, represents the mooring at the mouth of Eagle River; this mooring was not deployed for the over-winter period. Location #2 represents the mooring in southern Eagle Bay, which was deployed for the overwinter period.

Table 1.

Location	Homer	Kenai River	Tuxedni	Trading bay		
Log begins	7/1/2009 19:33	6/30/2009 19:26	7/1/2009 14:23	6/30/2009 22:24		
Log ends	7/3/2009 16:23	11/8/2009 9:44	7/11/2009 12:16	7/3/2009 12:53		
Total logged days	3	132	11	4		
Deployment	Jul 1 to Dec 8	Jun 30 to Dec 10	Jul 2 to Dec 6	Jun 30 to Dec 8		
Deployed days	162	162	160	161		Avge %
% days logged	2	81	7	2		23

For three upper inlet deployment locations (Fire Island, Eagle River, and Cairn Point) there were also numerous 'noisy' events that were relatively high compared to the lower inlet locations, likely due to sediment noise generated by the current flow and resonances due to line strumming. Fire Island was by far the noisiest location, yet Eagle River and Cairn Point showed a level of noise higher than lower inlet locations but still much lower than Fire Island. Table 2 shows the number of pulsive events (raw data, before being classified) logged per day on average for the three locations.

Table 2.

Location	Avg. events logged/ day
Fire Island	28,592,385
Eagle River	1,353,705
Cairn point	826,224

The same firmware problem caused shorter logging periods than expected for the upper inlet locations; see Table 3. The firmware problem has been addressed by the manufacturer and hopefully will not occur again with the new C-PODs that will be deployed in the spring, replacing the problematic instruments currently deployed.

Table 3.

Location	Fire Island	Cairn pt.	Beluga river	Eagle river mouth		
Log begins	9-Jun-09	6/6/2009 6:04	7/6/2009 16:14	7/7/2009 12:28		
Log ends	24-Jun-09	7/24/2009 12:43	6/24/2009 16:20	9/16/2009 14:16		
Total logged days	13	48d 6h 40m	80	71d 1h 48m		
Deployment	Jun 4 to Jul 7	Jun 6 to Aug 24 2009	June 6 - Aug 24	Jul 7 to Sep 28		
Deployed days	34	80	80	83		
% days logged	47	61	100	86		
Log begins	7/9/2009 10:09					
Log ends	7/24/2009 16:52					
Total logged days	15d 2h 40m					
Deployment	Jul 7 to Aug 24					
Deployed days	48					
% days logged	31					
Log begins	8/26/2009 10:48	26-Aug	6/24/2009 16:33			
Log ends	8/27/2009 6:03	LOST	9/28/2009 14:30			
Total logged days	1d 19h 16m		34d 19h 09m			
Deployment	Aug 26 to Sep 28		Aug 26 - Sep 28			
Deployed days	35		35			
% days logged	6		100			
Logged total	33	49	85	71		
Deployment total	118	80	85	83		Avge %
% days logged total	28	61	100	86		69

2. Beluga whale detections

No beluga whales were detected in the lower inlet between June and August 2009. In the upper inlet, few beluga whales were detected at Fire Island, however this was a very noisy location and masking within the echolocation bandwidth could have dramatically reduced the detection probability. Cairn point detections were also low but masking must also be considered in this location. Beluga River and Eagle River mouth showed a clear seasonal pattern in beluga detections.

3. Detections of other marine mammals

Harbor porpoise echolocation was also detected in CPOD data. Harbor porpoise presence was especially prevalent in the lower inlet even with the short sampling periods. However, this species was also briefly detected in the upper inlet at Cairn point and Beluga River. Some echolocation detections showed acoustic features clearly different than beluga whales or harbor porpoises. Detections (44 consecutive click trains including 705 clicks) in Beluga river on September 12th between 6:10 and 6:21 a.m. showed lower peak frequencies than beluga or porpoise clicks at 49.3

kHz on average and longer than normal pulse durations. Both features have been described as distinctive of killer whale clicks (Au et al., 2004; Simon et al. 2007)[1].

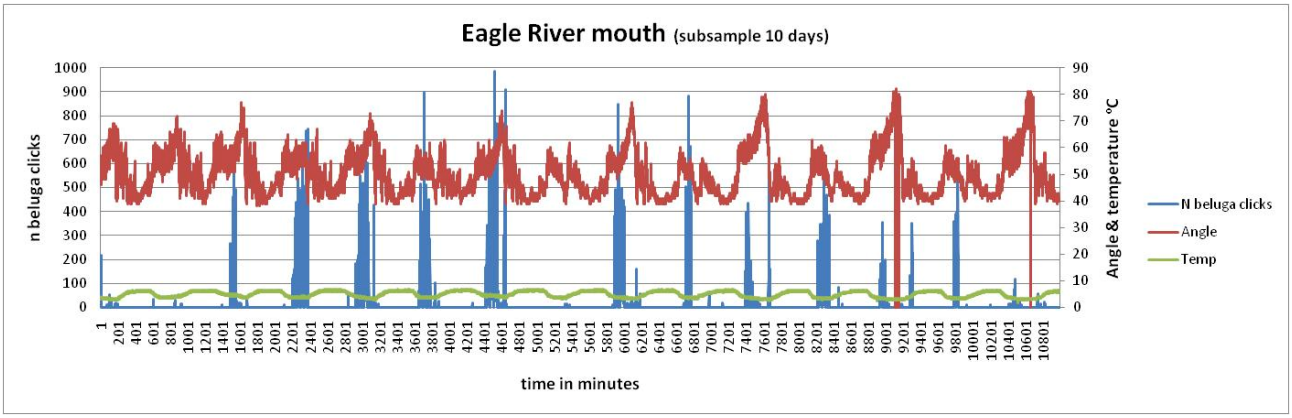
Another event attributed to killer whale echolocation was detected at the Kenai River location on 11 August 2009. EAR data shows vocalizations between 7:21-7:26 a.m. that are potentially attributed to killer whales. The C-POD data shows one single click train at 7:17 a.m. with acoustic characteristics that can be attributed to killer whales but not to beluga or harbor porpoise. These are a long train duration of 5.2 seconds, an average frequency range of 66 kHz and a long average click interval of 0.39 seconds.

4. Diel patterns

Patterns of beluga whale presence were calculated only for the Beluga River and Eagle River locations because these are the only datasets large enough to show potential trends.

The correlation detected in Eagle River mouth indicates that beluga whales are detected when current is stronger (C-POD angle is higher), that is, when the tide is low and therefore the river current is more evident in the deployment location (Figure 2). This interpretation is supported by the correlation with water temperature; i.e., colder water being fresh water coming out from the river at low tides.

Figure 2.



However, beluga whale diel presence in Beluga River showed a different trend with peaks at 11:00 and 14:00.

In this case, there is a moderate relationship with the tide, since beluga whales were detected more often when the C-POD angle was higher. However the relationship between the C-POD angle and the tide cycle is not yet clear for this location: river current might be stronger at low tides as seems

[1] Au, W.L.; Ford, J.K.B.; Home, J.K. & K.A. Newman Allman. 2004. Echolocation signals of free-ranging killer whales (*Orcinus orca*) and modeling of foraging for Chinook salmon (*Oncrhynchus tshawytscha*). Journal of the Acoustical Society of America 115(2):901-909.
Simon, M.; Wahlberg, M. & L.A. Miller. 2007. Echolocation clicks from killer whales (*Orcinus orca*) feeding on herring. Journal of the Acoustical Society of America 121(2):749-752.

to be occurring at Eagle River however the deployment location is further away from the river mouth. Therefore the increase in current might be better explained by the flushing cycle of the Inlet.

For harbor porpoises detected in Beluga River, two clear peaks are identified at 06:00 and 18:00. This bimodal peak could be related to the tide cycle, however tide correlations have not yet been analyzed for this location.

5. Noise related problems

Noise in the frequency range of C-PODs (20 kHz – 160 kHz) was very closely correlated to the current cycles in all three noisiest locations (Fire island, Cairn point and Eagle river), indicating that most probably the noise sources are generated by current flow, being sediment noise and probably resonances due to line strumming. Spectral distribution of Fire Island noise shows a bimodal pattern, with peaks at 21 kHz and 40 kHz; see Figure 3. The stronger peak at 21 kHz could be attributed to the strumming related resonances since these types of noises typically affect lower frequencies. It would be very interesting to analyze the noise spectra and structure from EAR recordings made in Fire Island concurrently with these logs to better understand the source of the noise and look for ways to avoid it in future deployments. The spectral distribution for Cairn Point is shown in Figure 4.

Little work has been done regarding the acoustic noise generated by the bed-load transport of sediments. However Thorne (1990)[2] indicates that the peak in the broadband bed-load noise is to first order inversely dependent on particle size. Therefore particles around 0.5-1.0 cm in diameter would generate sound in the 20 kHz band, and 0.3-0.06 cm in diameter for peaks in the 50-70 kHz band. It would be extremely interesting to obtain information regarding sediment size in Fire Island and Cairn point locations in order to confirm that sediment dynamics is the source of this ultrasonic noise.

[2] Thorne, P.D. 1990. Seabed generation of ambient noise. Journal of the Acoustical Society of America 87(1):149-153.

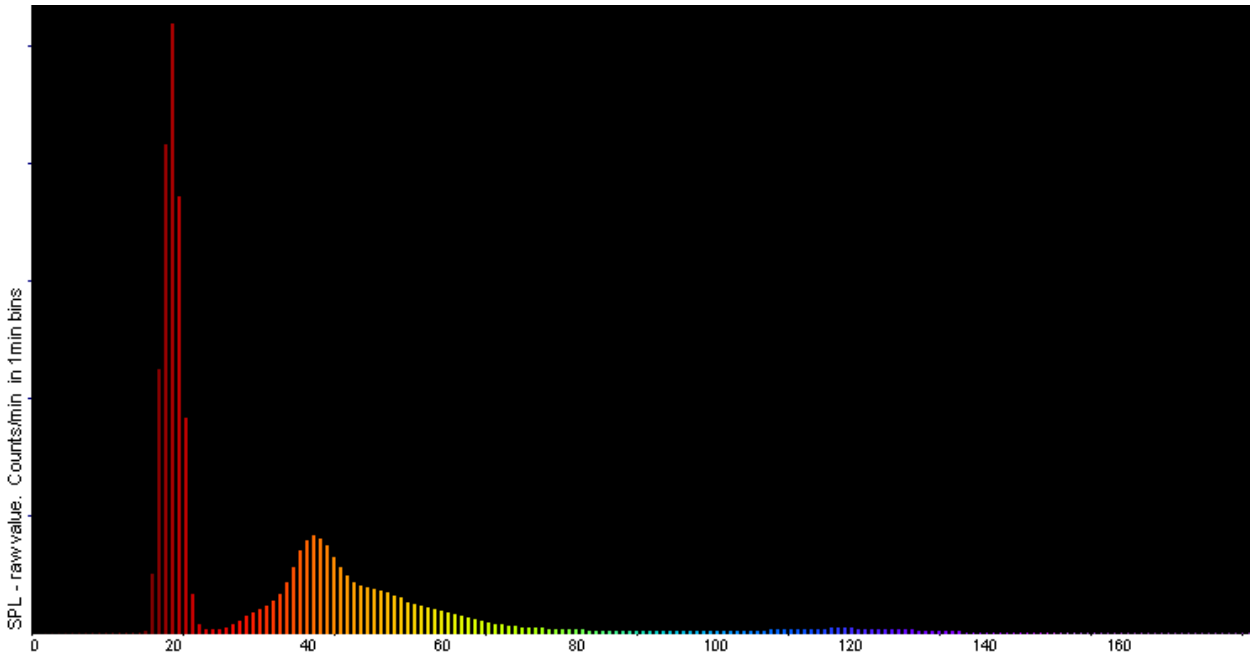


Figure 3. Spectral distribution of noise logged in Fire Island. Horizontal axis corresponds to frequency in kHz and vertical axis to relative sound pressure level. The higher frequency peak might be a harmonic of the source, and the source is current speed related. The 21 kHz may be an artifact of the high pass input filter on the C-POD, therefore the actual peak could be lower.

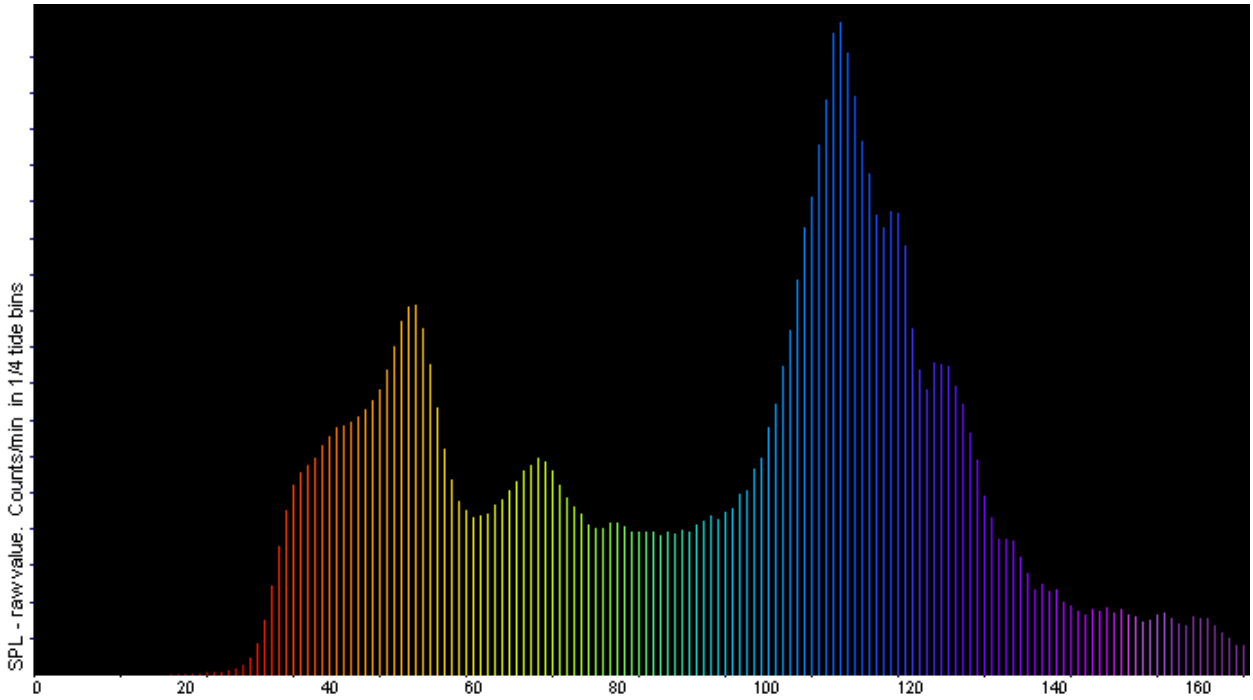


Figure 4. Spectral distribution of noise logged in Cairn point. Horizontal axis corresponds to frequency in kHz and vertical axis to relative sound pressure level. The peak at 110 kHz corresponds to harbor porpoise echolocation activity, while the 50 and 70 kHz peaks are related to the current speed related noise.

EARS

Beluga whale acoustic signals (Figure 5) were detected at the following mooring locations during the summer-fall deployment period: Eagle River, Beluga River, Fire Island and Trading Bay. No belugas were heard at Eagle Bay, Cairn Point, Tuxidni Bay, Kenai River, and Homer Spit. All confirmed beluga detections occurred in upper Cook Inlet. Belugas were not heard at any lower inlet locations south of Trading Bay, but signals produced by killer whales (Orcinus orca) were recorded on October 6, 9 and 15 at Homer Spit and on November 11 at Kenai River. These killer whale calls were tentatively identified as belonging to resident killer whales of the AB clan (Craig Matkin, personal communication).

Beluga detections were highest during two multi-day episodes at Beluga River and Eagle River. Specifically, at Beluga River signals were recorded nearly continuously between July 7, when the EAR was deployed, and July 13. These sounds were highly variable and included many forms of whistles, calls, buzzes and echolocation pulse trains. At Eagle River a similar episode of nearly continuous detections occurred between August 16, when the EAR was first deployed, and August 22, when the EAR stopped recording due to a hardware malfunction. Of the EARs that recorded throughout their deployment, belugas were detected most consistently at Fire Island, where signals were recorded on 31 of the 118 (26.2%) deployment days. Of note, however, is that the Eagle River EAR detected belugas on all 6 days that it recorded.

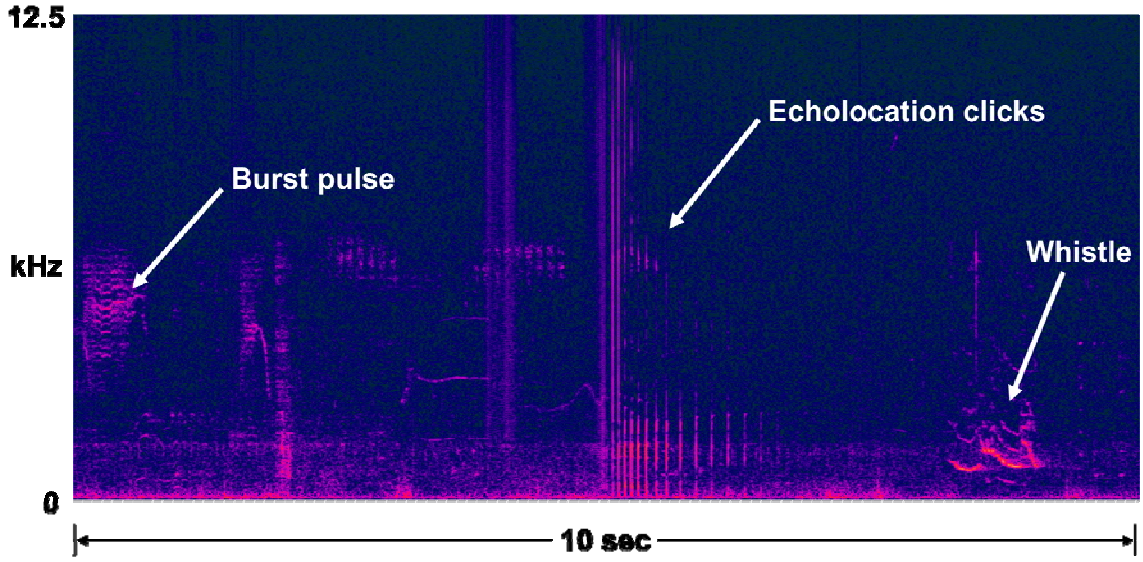


Figure 5. Sonogram of beluga signals recorded on the EAR at the Beluga River mooring site.

Future Plans

The moorings will remain deployed throughout the upcoming over-winter period and recovered in spring 2010. Because the attempts to recover two moorings (Eagle River North and Cairn Point) were unsuccessful, likely due to an accumulation of vegetative debris, alternative mooring designs have been developed and will be field tested in Kink Arm/Eagle Bay during spring-summer 2010.

Data analysis of all data received to date will be pursued through the next reporting period, along with data obtained from instruments recovered from the over-winter period.

Coordination and Collaboration

Several other acoustic studies in Cook Inlet, most involving belugas, are being conducted and we continue to coordinate and collaborate with these projects. In particular, once we have completed additional data analysis we will begin to compare acoustic and visual detections of beluga whales at the same sites.

Project Costs

The large majority of project funds have been expended, primarily on equipment for the moorings and the contract to have the data analyzed by the University of Hawaii.