Salish Sea Hydrophone Network
2007-2008 progress report

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Feburary 15, 2009

Summary

This document summarizes the progress made on the Salish Sea hydrophone project from September 1, 2007 through August 31, 2008. Our goals were to maintain and expand both the network and associated educational outreach. NOAA provided distinct funds for research and education, so these activities are reported separately after a brief synopsis of the network traffic. Expenses and budget status are tracked for funding sources in a Google spreadsheet (private).

Our main accomplishments in the last year were building out an acoustics exhibit in the Whale Museum and adding a node to the network in Neah Bay. An additional achievement was proving that southern resident killer whales could be detected by the Port Townsend Marine Science Center hydrophones, even when the animals were vocalizing on the far side of Admiralty Inlet, near the Whidbey Island shoreline (~4-6 km range). We have generally succeeded in maintaining a working network, though we have suffered outages (either in live streaming or data logging) at each node that typically lasted a few hours to a few weeks. Overall, utilization of the network (for research, education, and other uses) has expanded.

Synopsis of network traffic

A relatively novel aspect of the hydrophone network is that hydrophone signals are streamed live from each node in the network, in addition to the on-site data logging and analysis that is typical of a scientific hydrophone deployment. This live streaming facilitates research by allowing human listeners to monitor and analyze the sound in real-time. It also enlivens education and enhances management activities by enabling students and stewards to assess orca presence/absence, as well as environmental conditions in their habitat.

The live hydrophone signals are streamed by a company called Spacial Networks and can be heard through free software like iTunes and WinAmp. The streams are accessed through a web site (http://orcasound.net) where traffic is monitored using Google analytics. We can gain two measures of network utilization by analyzing both the access log for the web site and the spacialnet.com log files.

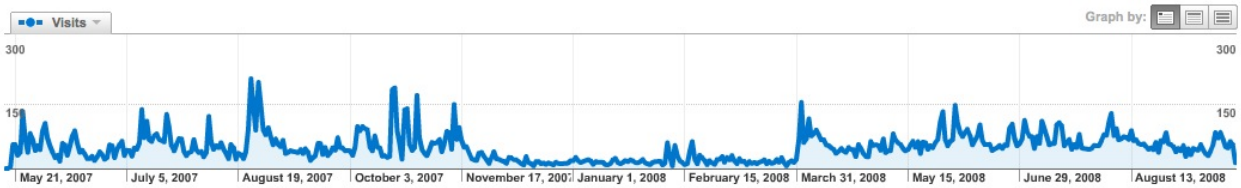
Web site access log analysis

Tracking of the web site access statistics began in mid-May, 2007. Since then about 24 thousand visits have occurred from about 9,100 unique visitors. In terms of unique visitors, the typical day sees about 50-100 (172 max) during summer days and about 10 during winter days. This is higher than expected from the listening logs (see below), possibly because not all web site visitors are listening to the live streams. Alternatively, they may be listening to archived sounds (a few hundred are available at this point), examining the "sound tutor" page, or visiting other links.

Examining the complete time series of visits (below) reveals that there is substantial

seasonality in the last year's data. This is primarily due to the extra attention that the Lime Kiln and Orcasound hydrophones get during the summer months (April 01 through November 15 or so) when the orcas frequent the core of their summer range. Beam Reach students and staff monitoring the hydrophones during the fall of 2007 and spring of 2008 may have extended the site traffic into the shoulder seasons. In comparison, the traffic associated with the Port Townsend and Seattle Aquarium nodes show no seasonality.

Dashboard May 17, 2007 - Sep 24, 2008



Site Usage

24,465 Visits	**32.77%** Bounce Rate
63,767 Pageviews	**00:02:31** Avg. Time on Site
2.61 Pages/Visit	**37.24%** % New Visits

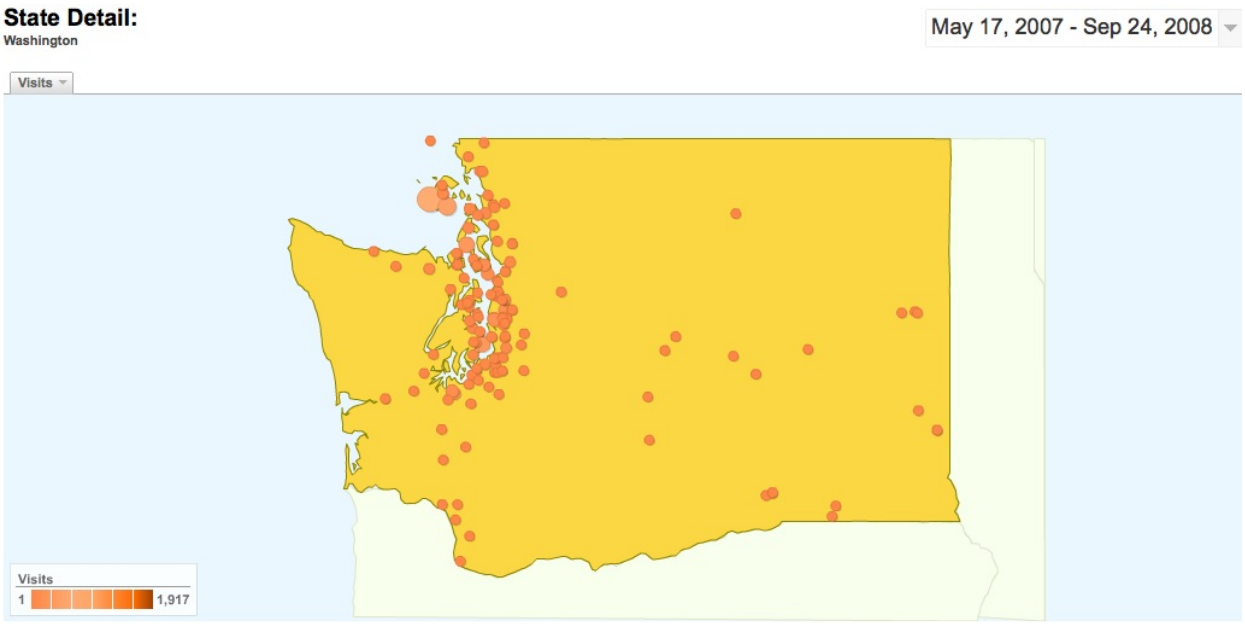
The typical visitor spends about two minutes on the site and visits 2-3 pages (the main page and one or two of the node-specific pages). Comparing 2008 (through 9/23) with 2007 data shows that about 60% of visitors in 2008 are returning listeners, while 40% are new to the experience. Another measure of visitor loyalty (below) is that about 40% of the listeners visited the site 9 or more times; a similar percentage visited only once.

Visitor Loyalty May 17, 2007 - Sep 24, 2008

Most people visited: 1 times

Number of Visits	Visits	Percentage of all visitors
1 times	9,114	37.25%
2 times	2,249	9.19%
3 times	1,233	5.04%
4 times	850	3.47%
5 times	627	2.56%
6 times	499	2.04%
7 times	422	1.72%
8 times	360	1.47%
9-14 times	1,581	6.46%
15-25 times	1,658	6.78%
26-50 times	1,820	7.44%
51-100 times	1,502	6.14%
101-200 times	1,172	4.79%
201+ times	1,378	5.63%

Finally, about 75% of the visitors came from the U.S., primarily from Washington, California, and Oregon -- although every State was represented. Within Washington (see below), visitors originated from 142 cities though most came from Friday Harbor or Seattle.

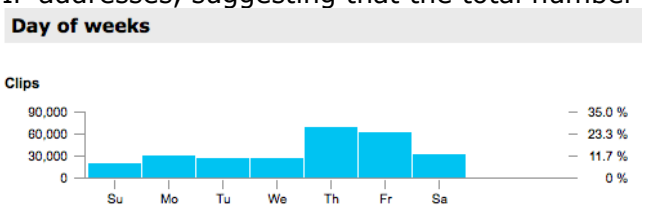


This state sent 11,155 visits via 142 cities

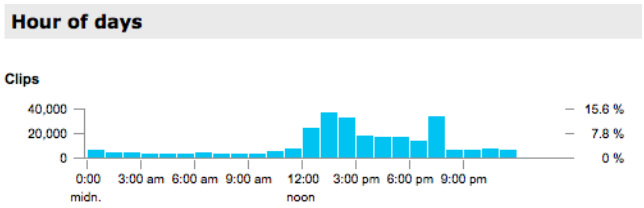
Similarly, most of the referrals to the web site came from within Washington. While 42% of the traffic was direct and 16% was organic (Google searches), 12% came from referrals related to Orca Network's website or emails and another 12% came from the link below the OrcaCam of the Center for Whale Research.

Listening log analysis

For the period covered by the spacialnet.com log files -- 09 Oct 2006 - 18 Sep 2008, (711 days) -- the network has had 5,832 visitors listen to a total of almost 7 years of underwater sound (daily mean of 3 days, 14 minutes) or 1311 Gb of data (mean of 1.84 Gb/day) transferred via an average bandwidth of 38.9kbps. Geographically, 88% of the unique visitors listened from the U.S., 6% from the U.K., and 4% from Canada; at least five individuals listened from these other places: Germany, the Netherlands, Poland, Japan, Australia, New Zealand, France, India, Puerto Rico, and Mexico. About half of the sessions were conducted by only 10 listeners; the other half were associated with 100 other unique IP addresses, suggesting that the total number of unique listeners is about 110.



It appears that listening happens pretty consistently throughout the week, with a minimum on Sunday and maxima on Thurdsays and Fridays. (One possible explanation for the maxima may be Scott's influence as those are days when he is more consistently able to listen to the streams...)



Most listening is happening in the local afternoon and evening. Over the last year and a half, however, listening has occurred during all hours of the local day. This may be due to having international listeners in a range of time zones and/or people leaving the stream running while sleeping (we know both are occurring).

Research progress

The research goals of the network are to monitor the acoustic environment of southern residents and detect southern residents in different parts of their range, ideally in real-time. We have certainly accomplished the former (with minor data gaps). We have also succeeded in supplementing the traditional methods of locating the orcas. In many cases, the human listening network has produced the first location of a day or obtained presence/absence information (and recordings) during nighttime or low visibility periods when the sighting network is inoperable.

While we have not fully automated the detection and notification system, many of the requisite technologies have been tested or are being utilized by the human-powered detection and notification system. The crux of the automated system is reliably detecting killer whale sounds (and other sounds of interest) without too many false triggers on ship-generated sounds. We continue to work on the problem, study how others have addressed it, and have enlisted the help of other experts in signal processing, detection, and classification.

The issue is challenging enough to warrant a workshop, but we believe it can be resolved through on-going NOAA funding of the network for the specific case of southern resident calls within the ship noise that is common in Washington waters. Estimates of detection rates could be acquired by collaborating with The Whale Museum researchers and interns at the Lime Kiln lighthouse. In a single summer of tracking behavioral states and acoustic activity as the whales pass the lighthouse during daylight hours, we could quantify the detection efficiency.

The development and tuning of automated detection algorithms has been most intense at Orcasound, primarily because Val resides there and can monitor the detection efficiency in real time (without logging in via myPC). The 2008 detection threshold settings have resulted in automated recordings of SRKW calls for every time when southern residents are known (based on sightings) to have been vocalizing as they passed the Orcasound node. Unfortunately, the relatively low detection thresholds also result in many ship sounds being archived. These false triggers constitute the greatest challenge to automated, real-time detection. Consequently, our available efforts have been focused on classification schemes that could sort out the ship sounds that sound similar to SRKWs and automatically report only the real SRKW detections.

While this problem is tackled, the detection thresholds have been set much higher at the other nodes (Port Townsend, Lime Kiln, and Seattle Aquarium) to preserve disk space. The WhoListener software hasn't been installed at Neah Bay because we have not yet resolved the source of intermittent electrical interference (low frequency hum and occasional radio reception).

The human listening network is becoming better organized. In addition to the population of listeners and web site visitors, a core of researchers, stewards, and educators have been helping test key elements of the real-time notification system. When a listener detects a killer whale sound, they can email detection@orcasound.net or send a text message via twitter.com and have a moderator process their information. Since it's creation in early summer, 2008, detection@orcasound.net has received about 10 notifications.

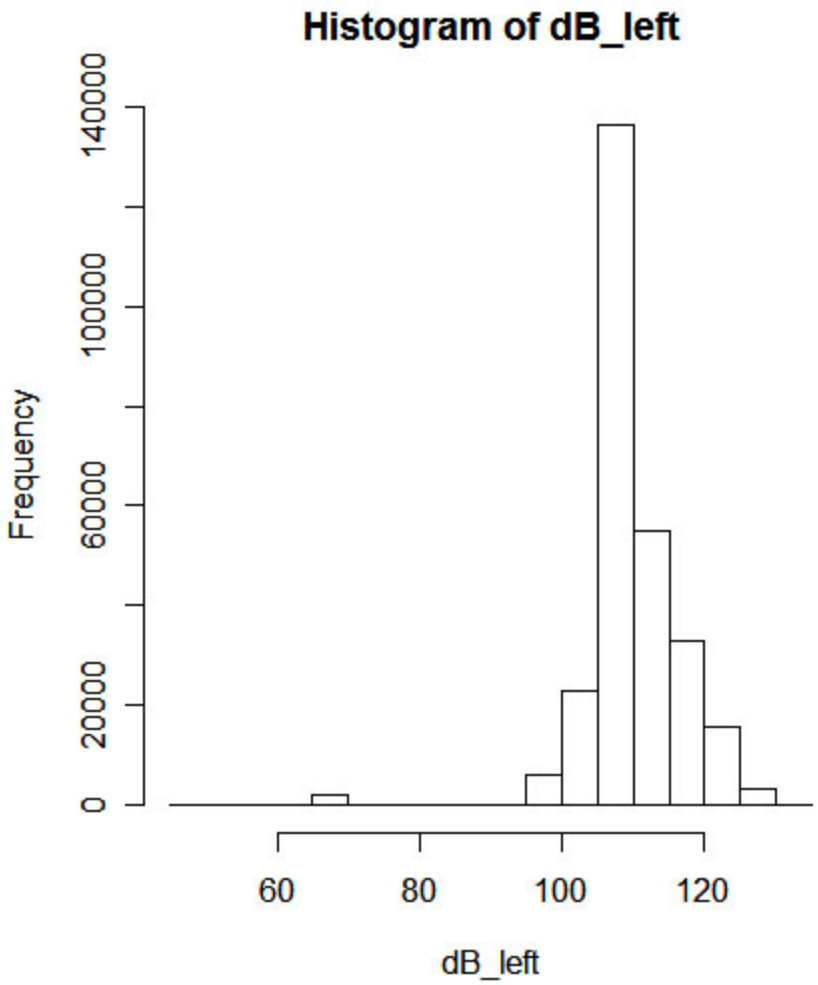
The moderator can then relay the detection via two channels: the locate@orcasphere.net listserv or the killerwhales Twitter feed. The locate@ listserve now has about 22 members who receive locations in real-time emails or daily summaries. As of February, 2009, the twitter.com/killerwhales feed (currently private) has 18 members and has provided 82 updates since its inception on 5/27/07.

The Whale Museum

A new computer was added in July, 2008, to experiment with buffering streams. During a test period, Val was able to archive all five streams on this computer. With some additional software development, we believe that it would be strategic to have a ~1-week buffer archived in short, ~10-minute sound files. This would allow retrospective analysis in those cases when killer whale sightings are reported belatedly and it would be helpful to verify that the computer and human detectors did not fail.

Orcasound

Over the past year, Orcasound has recorded average ambient underwater sound levels about three times each minute. From the period June 1, 2007 to Sept. 26, 2008, 275,229 observations were recorded. (This interval is 483 days and the system averaged 23.7 observations per hour.)
Here is a histogram of this 15 months of observations.

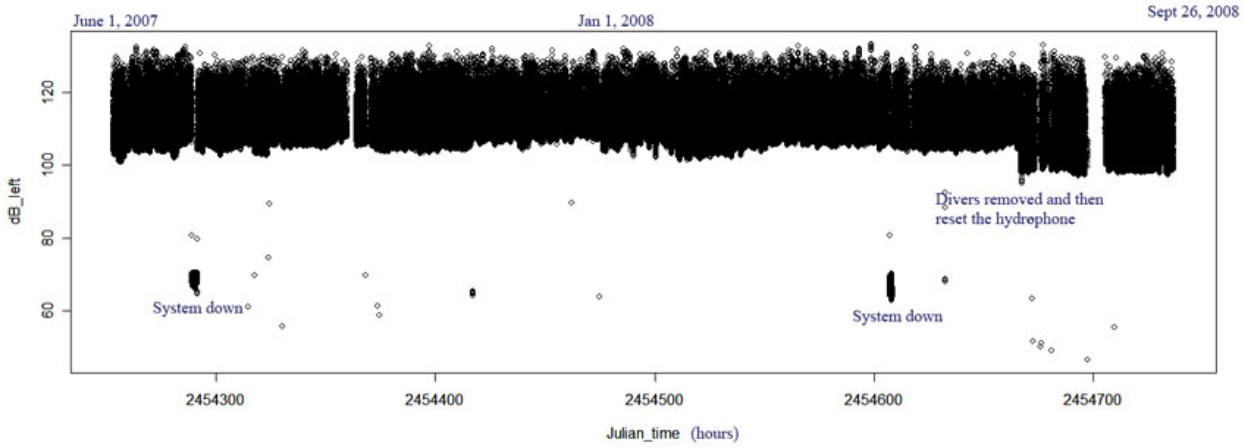


This data, dB_left, is one of the two channels recorded at OrcaSound. The summary statistics for these data are:

Minimum:	46 dB
1st Quantile:	107 dB
Median:	109 dB
Mean:	110 dB
3rd Quantile:	113 dB
Maximum:	133 dB

The minimum occurred when the system had gone down.

Here is a time series for this 15 month interval:



All hydrophones were removed in summer, 2008. A cleaned and refurbished hydrophone was deployed in late August. As of February, 2009, additional refurbished hydrophones are slated for re-deployment, time and budget allowing. Afterwards, the new array will be surveyed in and re-calibrated.

Lime Kiln

While the system weathered the winter of 2007-8, it failed during the extreme low tides of the spring. Splicing was accomplished, but the repairs didn't last. A temporary hydrophone was deployed in July, 2008. The two hydrophones are scheduled to be replaced in the fall of 2009.

Port Townsend

A second hydrophone was added, testing a long-term deployment of a CRT hydrophone sensitive to higher frequencies.

Seattle Aquarium

Calibration was checked. At the request of Aquarium staff, the hydrophone was re-located near the end of the pier in September, 2008.

Neah Bay

A pier-based hydrophone system was brought on-line in July, 2008, with support from the Makah Tribe and Jonathan Scordino.

Educational outreach progress

During 2007-2008, the hydrophone network expanded to reach educational audiences, primarily at The Whale Museum and the Port Townsend Marine Science Center. We also made substantial headway in the development of a listening station at the Seattle Aquarium.

These efforts were coordinated in part through a social networking site: http://orcasound.ning.com/ This group has 17 members and utilizes ning.com tools for photo-sharing, discussion forums, reference/resource organization, and more.

The real-world audiences for our outreach activities are the visitors to the partner nodes (extant and potential). The following table presents recent estimates of the number of visitors to each node:

Location	visitors per year	school children per year
The Whale Museum	30,000	9,000
Lime Kiln State Park	170,000	>3,000
Port Townsend Marine Science Center	20,000	6,000
Seattle Aquarium	735,000	155,000 (youth, see breakdown below)
Deception Pass State Park (West Beach)	~3,000,000	Not known
Total	~3,955,000	>174,000

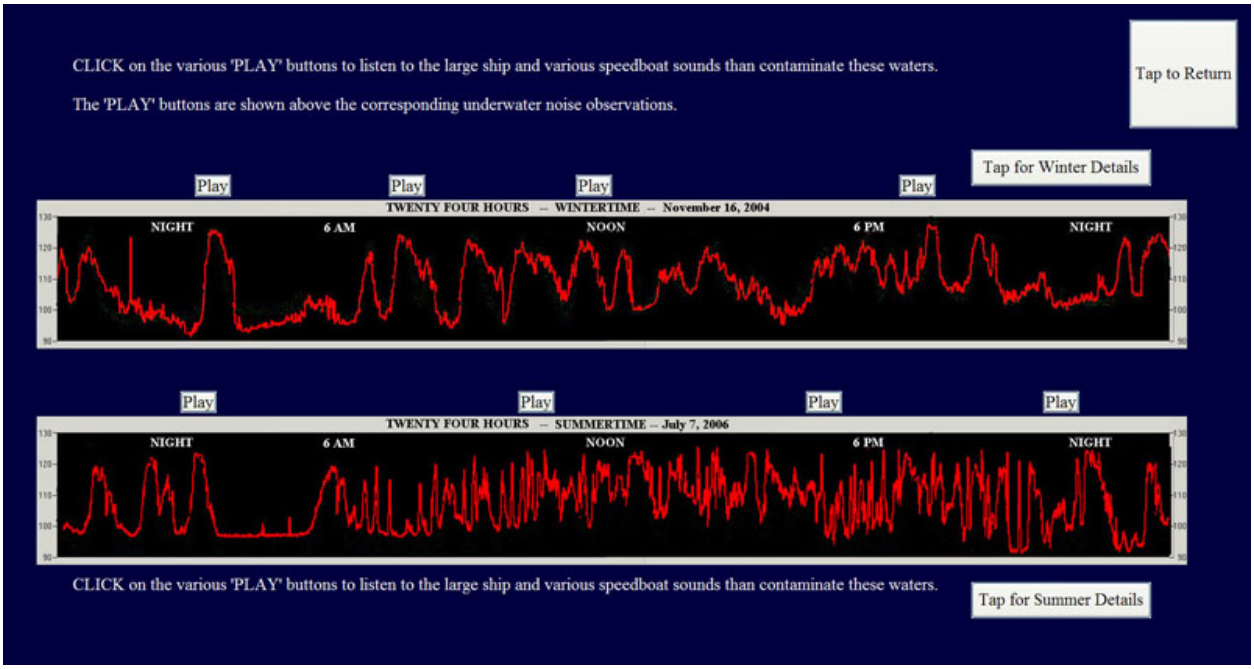
The Whale Museum

In February 2008, The Whale Museum opened its refurbished exhibit halls to the public. Upstairs, at the entrance to the main hall there is new computer-based acoustics exhibit designed to introduce visitors to the underwater sounds of the Salish Sea. The visitor interacts with the computer using a large illuminated trackball and a large illuminated 'mouse' button.

At the beginning the visitor is presented with a moving message to 'Tap the Big Blue Button'.

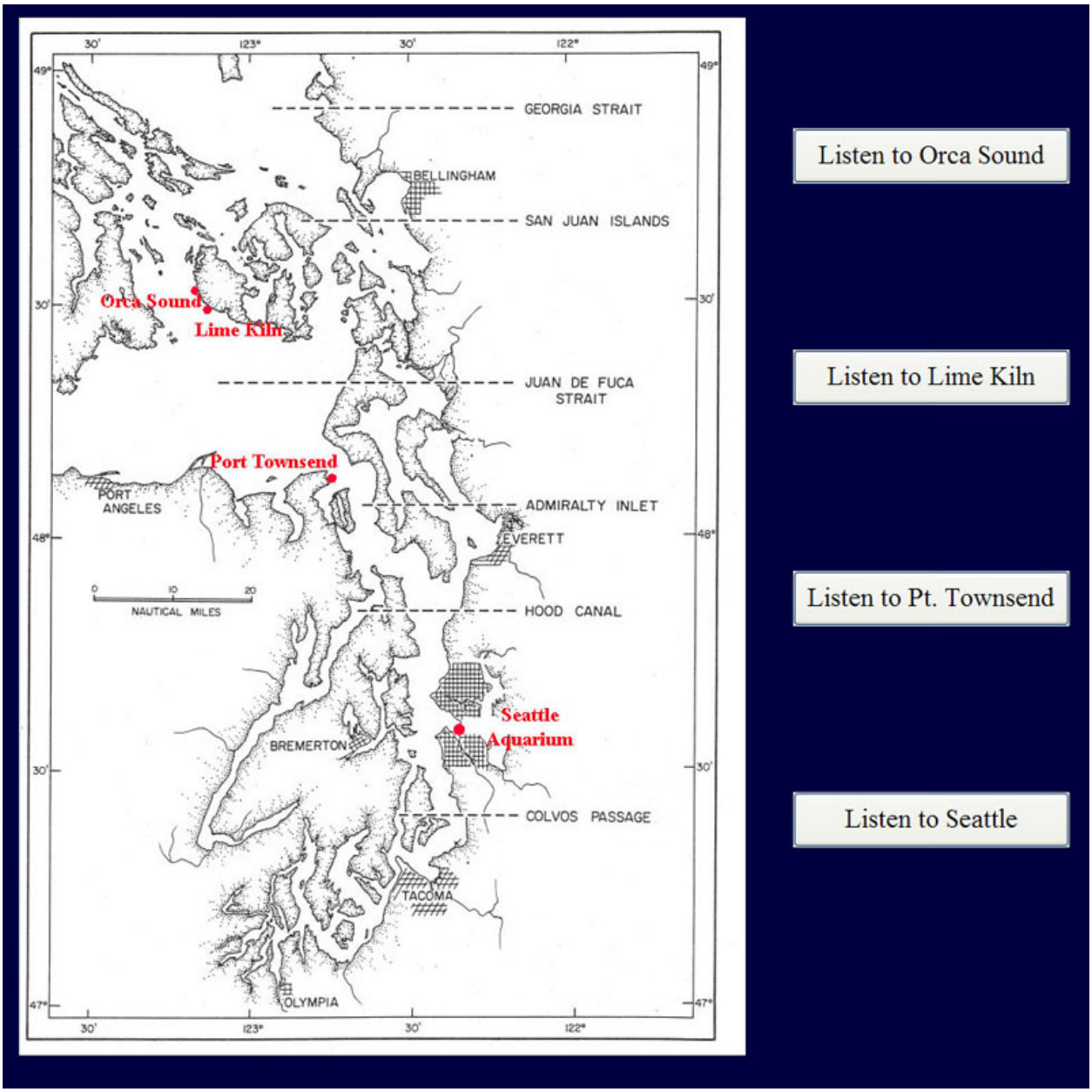
And when this is done three choices are presented.

The first choice, above, leads to a sequence of screens that document the sounds of large ships and speeding motor boats and shows typical 24-hour periods in the winter and in the summer. When the user clicks on one of the play buttons, the sound of a vessel is played through a speaker over the visitor's head in a hemispheric reflector. And, at the same time a photograph of the vessel is put up on the screen.



The second choice on the introductory screen takes the visitor to a Flash animation created by a Beam Reach student, Brett Becker. In this animation, the visitor moves the mouse over the red regions and hears the sounds that Brett recorded at that place during his Beam Reach course.

The third selection takes the visitor to a page where a click of the mouse plays the current sounds that are streaming from the hydrophones that we have been placing around the Salish Sea. In February, 4 nodes were active.



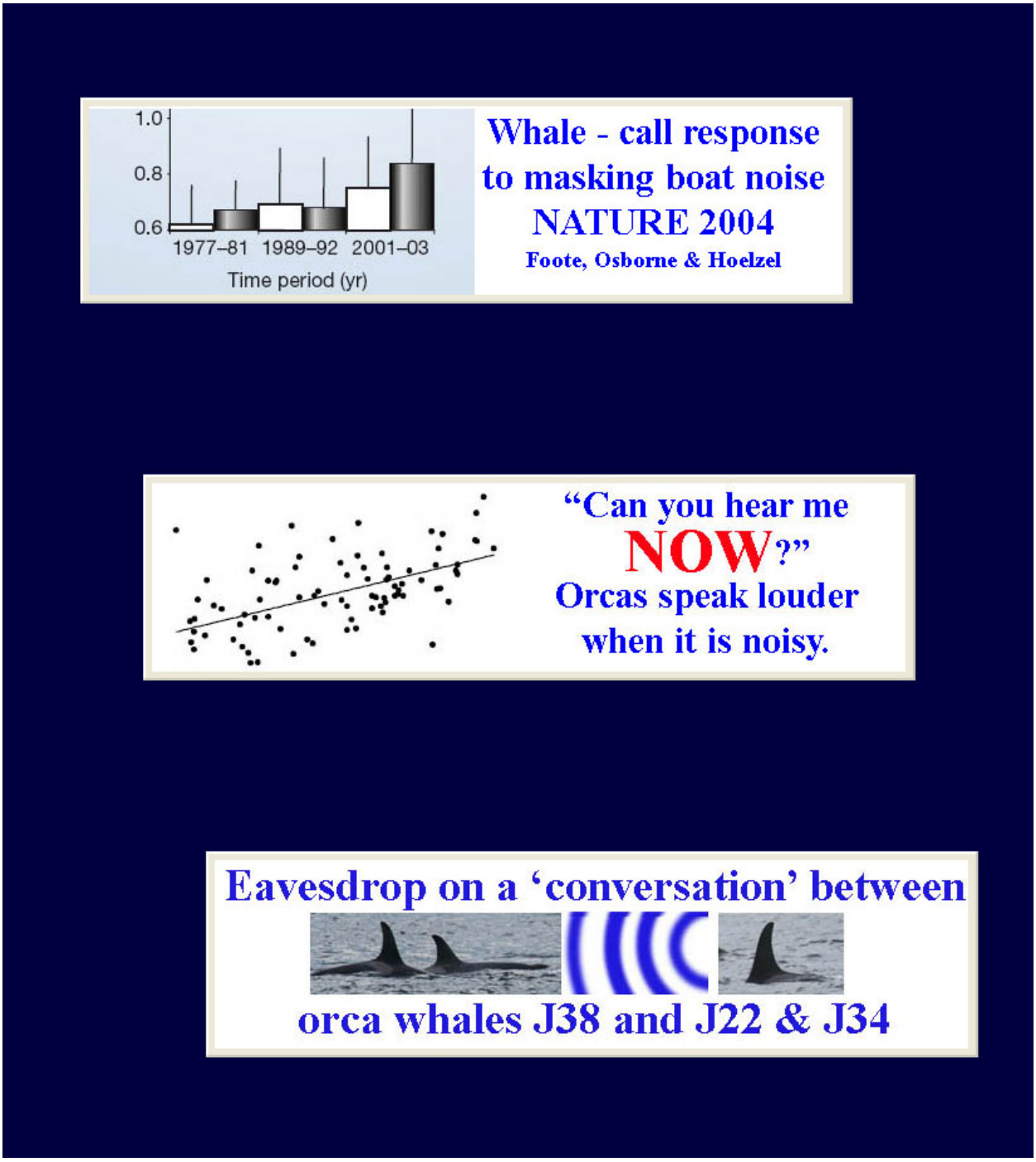
After the visitor leaves this first acoustics exhibit, they enter the main exhibit hall. There we have installed another hemispheric acoustic dome which allows a visitor standing in front of a large screen TV to watch and listen to recordings of land-based whale watching at Lime Kiln lighthouse. A future enhancement is to use this area to offer the visitor a real-time alternative to the recorded video and audio. At the push of a button live video from the lighthouse and an audio stream from the hydrophones will be presented using the existing monitor and overhead speaker.


WHALE
WATCH
PARK
WHALE
WATCHING
SITE
Lime Kiln Point
State Park
WATCHING
FROM SHORE

Just to the right of the scene above, we have constructed a tiny version of the Lime Kiln lighthouse and inside this small space we have a similar display with three acoustics presentations that showcase recent research of the vocalizations of the Southern Resident orcas.


depth sounder freighter outboard propeller
boat putt-putt small diesel whining propeller
airgun ATOC pile drivers sonar torpedo explosions
machines ocean acoustic tomography rain lightning
sea surface cracking sea ice undersea earthquakes
from undersea volcanoes light rain waves on a beach
wind quiet ambient snowfall whooshing sand kelp
fish birds diving crustaceans whale calls songs
click pulse bursts fishfarts moo whistles moans whup
lob flipper slaps pulses breach gurgles bubbles
wheeze
pops
nds
Salish Sea

Here are the three choices.



The first choice presents the results that Andy Foote, Rich Osborne, and Russ Hoelzel published in Nature. This section includes a simulation in which the listener hears calls that are shorter in time (characteristic of the 80's) and longer in time (characteristic of the current period). The listener usually finds it difficult to distinguish the differences that Foote et. al. found.

The second choice leads to a screen where the visitor can click on a variety of combinations of orca source levels and various background noise levels. The data show the Lombard Effect for the source levels of the Southern Residents. The visitor can hear how difficult it is to hear if the source level does not change as the background noise increases. The display is shown below.

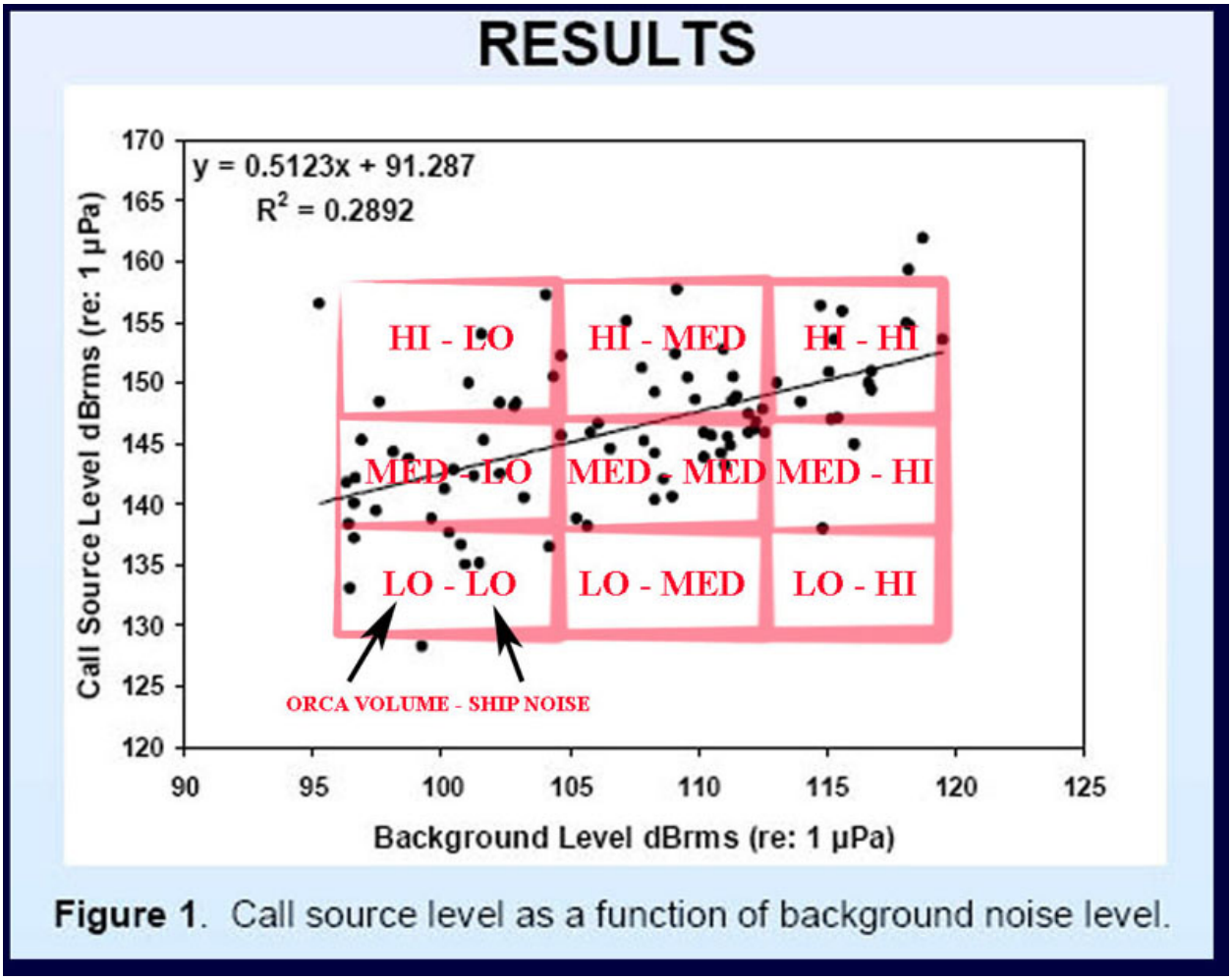
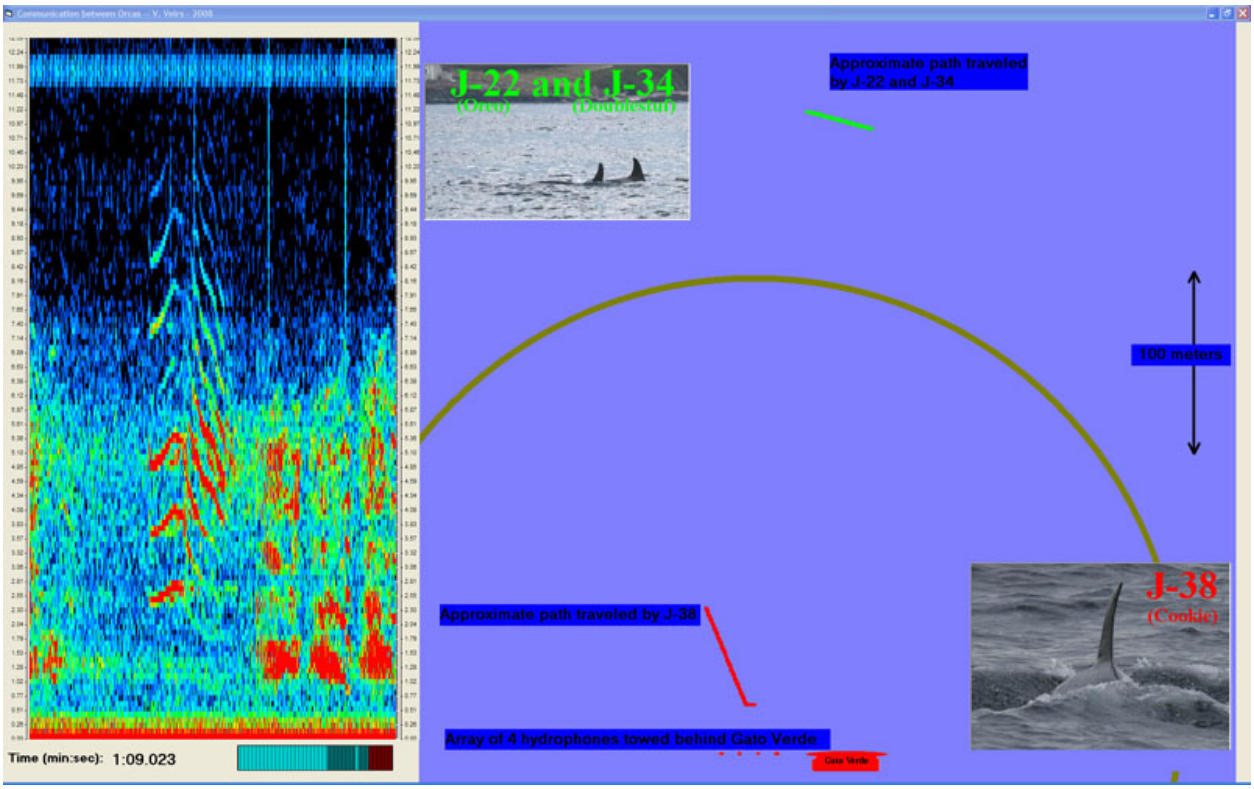


Figure 1. Call source level as a function of background noise level.

The third choice takes the visitor to a 'conversation' between family members of orcas. The data underlying this exhibit were taken during the Beam Reach program last fall (2007) and were reported at the joint USA and European Acoustical Society meeting in Paris (2008). The computer plays the sound files that were recorded and the localized calls are denoted by circular waves emanating from the location of each successive vocalization.



Since the new acoustics exhibits opened, many visitors have viewed the exhibit halls. Some tarry for extended periods over the six acoustics exhibits and some just pass by seeming 'afraid' to interact with the Big Blue Ball and the Big Blue Button. One visitor happened to be a writer for the New York Times who is writing about underwater noises. We have been in continuing communication with her about underwater sounds in this region.

Lime Kiln

At the Lighthouse at Lime Kiln State Park, The Whale Museum has maintained the hydrophones and the low-power FM radio transmitter that allows park visitors to hear the underwater sounds of Haro Strait. Docents at the Lighthouse put a solar powered FM receiver out each day and visitors can turn the radio on via a timer. They can listen to the sounds. After a period (up to 20 minutes) the timer turns the radio off so that it isn't always blasting the often obnoxious sounds of speedboats and large ships.

Port Townsend

In March, 2008, we installed a stereo speaker system on the outside wall of the Port Townsend Marine Science Center. These two speakers face the water and visitors can turn on a timer and listen to the real-time sounds while they look for the source of the sounds: ships or speed boats or ferries. Docents or PTMSC staff can adjust the volume by opening the side of the box with a key.

A version of the orca vocalization research computer program described above has been provided for use by the docents at the Port Townsend Marine Science Center. Also in March, 2008, Scott oriented the docents to the research computer and the streaming web site (http://orcasound.net). A similar training with an emphasis on conducting citizen science through the hydrophone network is planned for late January, 2008.

Chrissy McLean has leveraged the hydrophone node into an admirable educational outreach effort. She has planned free winter, 2009, programming which will focuson Underwater Sound and Orca Communication. These programs are targeted at underserved schools on the Olympic Peninsula. Versions of these classes will be included in PTMSC school programs this spring, two marine biology summer camps, and two camps that we run in conjunction with Centrum Arts ("Waterworld" focusing on the integration of art and science, and a new "Whale Camp" which will study whales through art, science, native culture and legend).

Seattle Aquarium

Staff of the Seattle Aquarium have toured the Whale Museum's new acoustic exhibits. After some delays due to the acquisition and testing of the Voices in the Seas kiosks by the Aquarium, Brooke and Scott proposed to introduce some elements of the Whale Museum exhibits within the Aquarium's Orca Family Center in early 2009. The proposed "listening station" will replace the current writing station in mid-2009 and will be designed for adult visitors and children older than about 8 years. Through a collaboration with Pacific Studios, the listening station will be embedded in a 3-dimensional characterization of a mother and calf. The 22" display will present the live audio feeds and select recordings from each hydrophone node, along with conservation messaging. The user interface will be the same as at The Whale Museum (trackball and back-lit button), but listeners will don headphones to "act like scientists" and to ensure they can hear the audio without interference from other nearby sound sources (Voices in the Sea and the video/theater).

We look forward to raising awareness about underwater noise levels and killer whale's use of sound in the Aquarium visitor population. Based on survey data gathered between January 1 through November 18, 2008, the listening station could reach a large audience of about 800,000 people/year. About 55% of the population originates in the greater Seattle metropolitan area (King, Snohomish, Pierce, and Kitsap Counties), 11% come from elsewhere in Washington State, 29% come from other U.S. States, and 5% come from other countries. The following table presents the age distribution for the survey period:

Age	Total
Adult	495,473
Child	81,787
Child < 3yrs	1,120
Youth	156,976
Total	735,356

Neah Bay

We have had another preliminary conversation with Janine Bowchamp. She expressed interest in using the hydrophone sounds in some of their classroom activities. In support of such activities, we have created an archive of Neah Bay sounds at http://orcasound.net/nb

Previous reports

2006 report

Accolades and anecdotal experiences

These are excerpts from Orca Network emails unless otherwise noted:

August 1, 2008
Yay! J's are being chatty again on OrcaSound. Clicks, whistles and calls - everything! I tuned it at 6.15 pm but around 6.25pm the boat noise overpowered - too bad. This always makes me smile. - Ly

August 26, 2008
What wonderful calls were heard today on OrcaSound, about 3:15 p.m. my time. (so 12:15 P.M. your time - Pacific).
Vikki White, Pennsylvania

September 29, 2008
Southern Residents reported east of Race Rocks at 4pm today heading East towards the islands! Listen to the hydrophones tonight!
John Boyd (JB), Western Prince

December 4, 2008
While waiting for a meeting of SSAMN (Salish Sea Association of Marine Naturalists) at the library, I had the chance to use their wi-fi. I knew that whales had been around Seattle yesterday, so I was scanning between Lime Kiln, Smuggler's Cove, Port Townsend, and Neah Bay hydrophones. The library was nice and quiet, and with headphones on, I was really getting into the clarity of sound. While listening in at Lime Kiln, I heard an interesting clanging sound reminiscent of a bell. And then a slight squeek. I turned up the volume and listened more intently, and heard a vocalization that sounded kind of like a cross between a humpback and an orca. Then it got louder, and I realized it was vocalizations from RESIDENTS that were very far away, and I was picking up echoes, which gave it a longer duration. Soon I was clearly picking up J calls, K calls, and a few L's. So I called to Jeanne, who happened to be out on the west side, and she confirmed that residents were several miles off shore, heading from San Juan Island towards Discovery. Those guys sure did some swimming, as they were also spotted at Turn Point lighthouse at 9:00 AM. So they must have gone from Seattle yesterday, probably up Rosario (and maybe to the Fraser River?), and then back down Boundary and out towards Discovery Island. I was very excited to hear the whales, and was so glad to have one more chance to experience them this year!
John Boyd (JB), Marine Naturalist

November 29, 2008
I woke up this morning listening to J-pod on the Salish Sea Hydrophone Network. I believe the whales, at this point, were Southbound in Andrew's Bay near Ken's place. My tour left the harbour at 1:30 this afternoon and approx. 30 minutes later we arrived on scene 2nm Southeast of Clover Point (Victoria Waterfront) with a very spread out J-pod which were heading Southwest towards Race Rocks. We had great vocals this afternoon and were treated to a very close spy hop with J27 (Blackberry). Talking to Capt. Jim and Radar, all J-pod whales were accounted for except J-1 (Ruffles) and J-2 (Granny), however, I'm sure they were out there somewhere. The conditions today were not ideal, foggy and rainy, with the whales spread over many miles North/South. Positive I.D.'s were J8, all the J14's, J27, 31, 39, J17, 28, 35, and the J16's. On my way home from Race Rocks at 4:15 (sunset) we passed by the animals which were now 2 nm Southeast of Albert Hd. still heading out.
Jeff Lamarche, Seafun Safaris