



## Cost-effective recreational-grade single beam echosounder with side scan sonar system in imaging bubbly coastal submarine groundwater discharge

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Submarine groundwater discharge (SGD) is any direct flow of fluid across the seafloor, which forms bubbly or leaky springs and seeps from the intertidal zone to the deep sea. SGDs can significantly alter physico-chemical conditions of seepage zones. Identifying and mapping SGD is crucial to further recognize its influence in both marine and terrestrial ecosystems. However, mapping this phenomenon has been a continuing challenge, mainly due to the difficulty in its detection and quantification. This study explores the capability and applicability of an inexpensive, commercially available, recreational-grade combination of depth meter and side scan sonar system to image different types and identify point sources of coastal SGDs. Standard and systematic methodologies for efficient imaging and processing were established. The utility of the recreational-grade system was assessed and validated using a research-grade side scan sonar. SCUBA diving and CTD casting were conducted for ground-truthing and further characterization. Lower frequency sonars (83/200 kHz) showed more distinct acoustic signatures of discrete and dispersed bubbly SGDs, than the higher frequency system (455 kHz and 780 kHz research-grade unit). Sonar images showed that SGD plumes can be indicated by near seafloor to midwater cloud-like features. Spring-type SGDs tend to form cloud features with a funnel-shaped morphology. In sites where SGDs are dispersed, the acoustic signature is a curtain-like cloud, with higher bubble density in the upper water column. This is consistent with diver-based observation of increasing bubble sizes (<1 mm to ~30 mm) from point source to water surface. CTD casts indicate that the SGDs have recirculated seawater, with increasing temperature and salinity with depth. In the assessment of system and data processing requirements, and costing, a recreational-grade unit provides a good alternative for coastal SGD works.