Specific Oil Detection by Oil Detection Canines

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Abstract

Oil Detection Canines (ODC) are proven to detect spilled oil within various environments. The canines can detect hydrocarbon targets sequestered within the environment, including along shorelines. A limitation within the capability is that an ODC detects and responds to all types of hydrocarbons on a shoreline, including any from historical spills or naturally occurring oils, such as washed-up tarballs from off-shore seeps. In locations that historically are known to have stranded tarballs, the value of a K9 SCAT survey is limited when large numbers of tarballs are present as the canine detects and responds to all of these. This can slow down the Shoreline Cleanup Assessment Technique (SCAT) surveys, reduce efficiency through the requirement to investigate each response, and fatigue the canines due to the number of alerts. A project supported by the Texas General Land Office (TGLO) was designed to investigate the ability of a trained ODC to discriminate hydrocarbons on a beach that represent a newly spilled oil while ignoring other potential "background" oils. In 2021 Texas Tech University's Canine Olfaction Lab conducted a laboratory-based research trial to investigate the ability of canines to respond to different weathered oil samples. This research study demonstrated that trained canines could effectively discriminate between weathered oils in a laboratory environment. This knowledge was used to design a field program to conduct monthly surveys with two teams: one involved two canines trained on a sample representative of spilled oils handled by citizen scientist volunteers, and the other with an ODC trained on a range of oil ages. The field survey results prove that a Specific Oil Detection Canine (SODC) can discriminate between the age of representative spilled oils and other oil deposits in the same location.

1 Introduction

Oil Detection Canines (ODCs) are a proven capability that has successfully supported research and field deployments (API, 2016a, 2016b, 2020; Owens et al., 2017, 2018). Research has provided robust and extensive data related to the capability of ODCs in detecting hydrocarbon products. Field deployments have demonstrated that ODCs can perform in real-world settings and have exposed the canine teams to situations that are impossible to simulate in a research facility. A canine's ability to detect oil on shorelines is one example of this experience, with thousands of confirmed alerts to oil. The Shoreline Cleanup Assessment Technique (SCAT) is a proven methodology for responding to an oil spill incident. With ODCs being integrated into the SCAT capability, the term K9-SCAT is used to identify the ODC enhancement to the SCAT protocols.

In May 2017, an ODC was deployed in Prince William Sound, Alaska, to determine if a trained canine could detect sequestered oils from the Valdez spill of March 1989. Despite the oil being weathered in an exposed shoreline environment for 28 years, the canine detected oil at multiple sites under the sediment of the shorelines (Owens et al., 2018).

In February 2020, an American Petroleum Institute (API) research trial demonstrated the ability of ODCs to detect heavily weathered oils in the research laboratory and targets of those oils buried underground to a depth of 5 m (15 feet) (API, 2020).

Marine tar residues result from natural and anthropogenic oil releases, which, when exposed to weathering and other processes, form tarballs, patties, and mats (Warnock et al., 2015). The marine tar residues wash up along beaches worldwide, including the Texas shoreline, often in large numbers, ranging in size from fractions of a centimeter up to several meters in length (USCG, 2022).

Chiron K9 trains ODCs on the Texas coast, providing an opportunity to locate tarballs in a real-world environment and offering natural and double-blind detection of buried oil. The canines are not trained to locate the tarballs before going to the shoreline. Instead, a generalization process occurs during training because the canines learn to detect any example of a hydrocarbon sample by exposing them to various oil types. Generalization refers to the ability of canines to be trained to detect a target odor and respond to similar odors (DeGreeff et al., 2020); for an ODC, this involves exposure to and imprinting on a range of oil types rather than a single crude oil or refined product. Generalization is often an advantage as it means canines trained on stored samples at a training facility can deploy anywhere in the world and respond to any oil type during a spill response. ODCs have successfully detected differing sources of spilled oil in Nova Scotia (Owens et al., 2017) and Saskatchewan, Canada, and the USA in Alaska, Wyoming, California, Florida, and Texas, despite only being trained in Texas.

In locations with existing oiled sediments from one or more historical sources or in areas susceptible to tarball deposition, the value of a K9-SCAT survey is limited if the canine detects and responds to all of these "background" oils, as this slows down the SCAT surveys, reduces efficiency through the requirement to investigate each response, and fatigues the canines due to the number of alerts. Therefore, an advantage to the traditional K9-SCAT capability would be the ability to differentiate between background or naturally occurring oils on a shoreline and oil released during a specific spill incident.

To evaluate this potential, a research project (*Development of Oil-Specific Detection Canine Capability to Differentiate Between Background and Newly Deposited Oils on the Texas Coast)* was awarded to the Corpus Christi campus of Texas A&M University (TAMUCC) by the Texas General Land Office (TGLO). The objective of the study was to investigate the ability of a trained ODC to discriminate specific hydrocarbon samples that represent a "recently spilled oil" while ignoring other potentially present ("background") oils. This new capability is termed the Specific Oil Detection Canine (SODC) to differentiate this ability from the traditional oil-detecting canine.

In the first phase of this project in 2021, the Texas Tech University's (TTU) Canine Olfaction Laboratory conducted a research trial to investigate the ability of canines to differentiate between several weathered oil samples. This research demonstrated that trained canines could effectively discriminate between different oils within a laboratory environment (DeChant et al., in prep).

Once TTU established this ability, the subsequent applied phases of the study were designed to evaluate the capability of two SODCs trained in a laboratory to survey a section of Texas shoreline and ignore tarballs and any other existing background oils while responding (alerting) only to oil on which they had been specifically trained (imprinted).

2 Method: Laboratory Training

Two canines were selected for the SODC study,

- Bin, a male German Shorthaired Pointer. Date of Birth: July 24, 2016. Bin was trained at TTU's Canine Olfaction Lab for the SODC lab-based trials. He was imprinted on a Bunker C fuel oil at TTU and subsequently imprinted by Chiron K9 with a West Texas Intermediate (WTI) crude oil during the odor carousel stage described below and trained to ignore other oils.
- Luna, a female German Shorthaired Pointer. Date of Birth: October 02, 2018. Luna was trained at the Chiron K9 facility and was imprinted on the WTI crude and the Bunker C fuel oil.

Initial laboratory training for both canines was conducted utilizing an Olfactometer. Carbon-filtered air from a commercial air pump was controlled by rotameter flow meters and directed via automated solenoid valves to pick up the desired odor in saturation vials. This odor panel consists of three sample ports to which different odors are delivered by flowing air through individual vials containing targets, distracters, or nothing (no odor). Only one odor is presented to each sample port at a time. Clean dilution air and odor are mixed in a Teflon (polytetrafluoroethylene [PTFE]) manifold and delivered to the sample port—a computer controls which airstream is delivered to the individual ports and collects the canine response data. Therefore, once the canine is trained to use the device, the trials are fully automatic and are considered "double-blind" tests. An audible cue by the computer signals the canine's correct or incorrect response. A correct response is when a canine holds its nose within the target port for 4 seconds. An incorrect response is either a canine holding its nose within a port not containing a target odor for 4 seconds or not responding to a port that does contain a target odor. The canine is reinforced with a reward, such as a treat or a toy, for correct responses and not reinforced for incorrect responses (Aviles-Rosa et al., 2021). Bin completed his olfactometer training at TTU's Canine Olfaction Lab (DeChant et al., in prep), whereas Luna completed her olfactometer training at the Chiron K9 facility (Fig. 1).

Olfactometer training consisted of imprinting; that is, the association of a target odor (WTI or Bunker C) with a reinforcement reward. Once this association was established, then discrimination of the target from other presented odors was added. Initially, the odors from which the canine was required to discriminate WTI were sand, feathers (collected from a beach), and candy. Weathered oils, including tarballs, were added as the training progressed. After the training was completed, an assessment program was conducted to evaluate whether Luna could discriminate WTI crude from other oils. The assessment consisted of four sets of ten trials conducted in one day. Eighteen vials were prepared, six per olfactometer port. The hydrocarbon samples were mixed into Quikrete Play sand, with the same sand used as an unoiled control in one of the vials (Table 1).

Table 1 Contents of olfactometer vials

Vial Number	*Content*	*Weight*	*Comments*	*Source*
1	WTI crude	0.5gm	Mixed into 4.5gm sand	Texas crude, Midland, Texas
2	Juniper	0.5gm	Mixed into 4.5gm sand	Macondo *
3	CTC	0.5gm	Mixed into 4.5gm sand	Macondo **
4	Mustang Island tarball	0.5gm	Mixed into 4.5gm sand	Collected by the author (PB) from the shoreline
5	Sand	5gm		Quikrete Company, Atlanta, GA
6	Blank			

***Juniper**: A Macondo crude oil collected on July 19, 2010, by the skimmer vessel USCG Juniper as part of the spill response to the Deepwater Horizon incident on April 20, 2010 (Forth et al., 2015)

****CTC**: A Macondo crude oil collected on July 29, 2010, by barge number CTC02404 from various skimmer vessels during the spill response of the Deepwater Horizon incident on April 20, 2010 (Forth et al., 2015)

Luna detected all 40 presentations of the WTI target odor and provided no false positive responses to any other odors.

Figure 1 Luna during a Chiron K9 olfactometer test

After completing the olfactometer phase, both canines, Bin and Luna, continued the same training plan to prepare them for field deployment. This next step involved an odor carousel (Fig. 2), a 12-arm stainless steel wheel with a pot at the end of each arm. Both canines were imprinted to Bunker C and WTI oils at this stage. Mason jars containing different odor samples are placed inside the pots. For each run, one jar contained a sample of the WTI or Bunker C oils. The remaining eleven jars contained either tarballs or distractor odors such as beach sand, seawater in the sand, seaweed, and shells, which had been collected from Texas beaches. The canines had to search the carousel pots and respond to the WTI or Bunker C target oil while ignoring the tarballs and distractor odors. Once each canine had completed three successful trials with zero false positives and responded to the target odor, the experiment transitioned to the field phase.

Figure 2 Bin during an odor carousel test at the Chiron K9 lab

3 Method: Field Surveys

The field activities were conducted by a professional trainer experienced in canines' care and ethical use. These observational trials were not considered outside the normal biological functions of working dog training. However, as part of the study protocol, the project was reviewed and approved by an Institutional Animal Care and Use Committee (IACUC) (NRC, 2011; NIH, 2019) of TAMUCC. The training methods for these SODCs are described by Bunker (2021) and in the certification standards developed by the International Canine Spill & Leak Detection Association (ICSALDA, 2019).

Permits were issued to TAMUCC by Texas Parks and Wildlife for the canine field training on beaches within Mustang Island State Park with a restriction that no training targets (oil) could be placed on the beach. This restriction was addressed using Training Aid Delivery Devices (TADDs) (Fig. 3) to contain the target oils. TADDs were developed by the US Army specifically to contain training materials safely while allowing the volatile molecules to escape and be detected by a canine. The TADD is a glass or plastic jar with a lid that contains a hydrophobic and oleophobic chemical-resistant membrane (Maughan, 2020). The membrane allows the odor to escape but prevents the contents from making contact with the environment. This allowed

WTI crude and Bunker C training targets to be deployed on the shoreline without releasing the oil to the environment (Fig. 4). The headspace escaping from a TADD has a similar profile to the target oils. Therefore, the TADD accurately represents the target headspace of a simulated spilled oil (Bunker et al., 2022).

All training aids (TADDs) were stored, transported, and handled utilizing industry-standard cross-contamination prevention protocols. Disposable gloves were used at all times when handling the TADDs. The TADDs were stored in mylar bags and separated from each other within transportation containers. The holes in the sand into which the TADDs were placed were dug with a stainless steel trowel, cleaned, and decontaminated after every use.

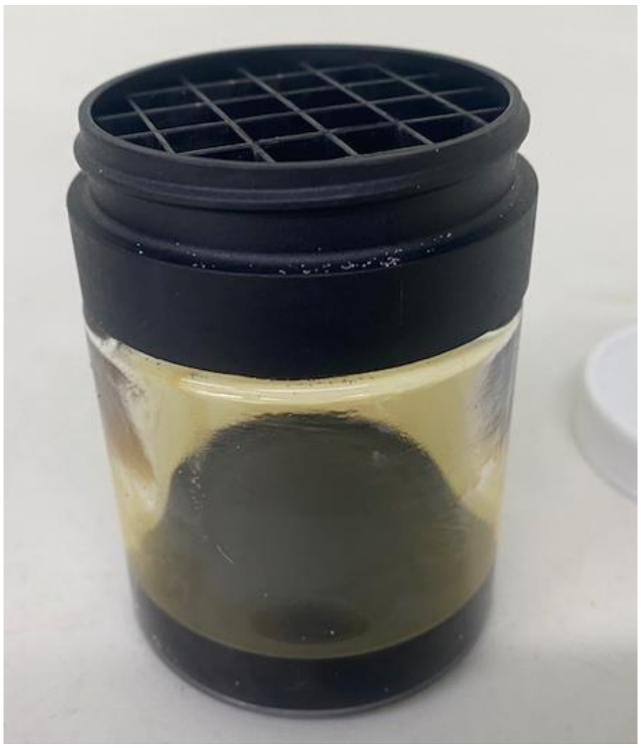

Figure 3 A Training Aid Delivery Device (TADD)

Figure 4 Bin alerts to a TADD containing a target oil placed in the beach sediments

4 Field Evaluation Phase

The canines were introduced to the TADDs containing target oil samples (Bunker C and WTI) utilizing the odor carousel as in the previous training sessions. This time TADDs with target oils were used, as well as tarballs inside TADDs and blank (empty) TADDs. The canines were required to search the carousel pots containing TADDs and respond to the WTI or Bunker C target oil while ignoring the tarballs in TADDs and blank TADDs. Once each canine had completed three successful trials with zero false positives and responded to the target odor, the training transitioned to TADDs in the field phase.

The last training step before the field evaluation surveys was teaching the canines an off-leash survey technique termed Wide Area Search (WAS). The system requires the canines to zig-zag off leash in front of the trainer, under direction, searching the shoreline as directed within the survey transect using a positive reinforcement training methodology, such as a treat or toy reward, when the target is successfully located. Before the shoreline trials, the canines were required to follow the WAS system under the trainer's control within the 6-acre outside training area at the canine facility. Once the canines could complete a WAS under the trainer's control, target odors contained in TADDs were placed within the training areas. Each canine completed three trials under the trainer's control and indicated on-target oils within the search area, demonstrating they were ready to transition to the field evaluation survey phase.

After completing the training phases at the Chiron K9 facility, Bin, and Luna were teamed with citizen scientist volunteers from the Corpus Christi area. The field training of the volunteers was conducted on Gulf Coast beaches on Mustang Island, near Corpus Christi, that were known to contain naturally-occurring tarballs (Fig. 5) routinely. The handlers completed an initial training period to ensure they were proficient in handling the canines on the shoreline and conducting the WAS surveys.

Figure 5 Bin and handler survey a beach using the Wide Area Search technique.

As available, the volunteer handlers were required to search a predefined shoreline transect area of approximately 6,400 m^2 along a 160-m length of sand shoreline on one day each month. This survey program began in May 2022 and is currently ongoing. For each monthly field survey, TADD training samples were placed within the beach; the test evaluated whether the SODC would ignore all naturally occurring "background" oils and only respond to the TADDs that contained the imprinted oil samples. TADDs were also placed within the survey areas, which contained tarballs collected from the local beaches and blank TADDs. The canines SOCD and ODC did not demonstrate any change in behavior or response on the TADDs not containing target oils. Following the SODC survey, a control ODC (Poppy) was handled by the author (PB) to survey the same area. Poppy is a generalist ODC trained to respond to any hydrocarbons (Fig. 6).

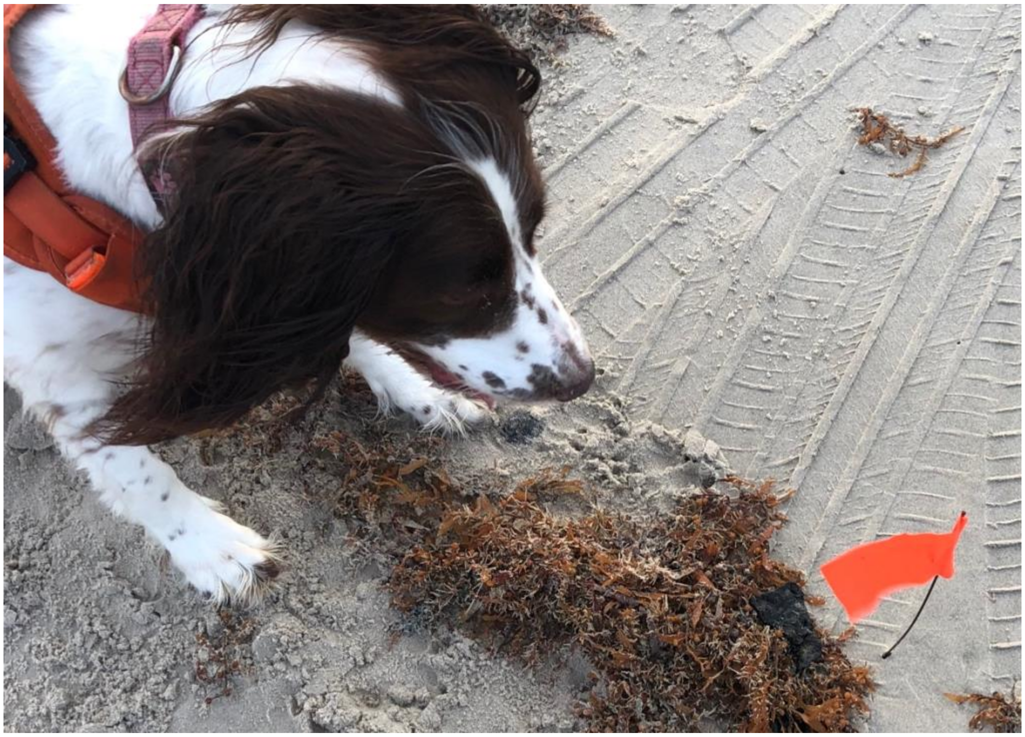

Figure 6 Poppy alerting to tarball within seaweed

Table 2 provides a selected data set of confirmed alerts made by Poppy.

Table 2 Confirmed Tarballs and Tar Patties Detected by an Oil Detection Canine

	2 May 2022	**4 May 2022**	**26 July 2022**	**30 August 2022**	**28 February 2023**
Total # Tarballs (TB: <10 cm)	52	138	297	Over 1000	8
Total # Tar Patties (TOP: >10 cm)	0	0	18	61	1

5 Results and Discussion

As part of a TGLO-funded project, monthly surveys along a section of Mustang Island, TX, have been conducted by an ODC and volunteer SODC teams.

As an example of the results, on 28 February 2023, a routine survey was conducted by one SODC, Bin, and one ODC, Poppy. Before the SODC canine team arrived, two TADDs containing imprinted oil samples, one of WTI and one of Bunker C, were buried within the survey area (Figs. 7 & 8). The SODC conducted the first survey and only responded to the two TADDs. After Bin had completed a survey, Poppy, the generalist ODC, repeated the same survey. Poppy responded to eight naturally occurring tarballs (Fig. 10), one tar pattie (Fig. 11), and two TADDs (Table 3). Bin completed the survey in 8 minutes and 29 seconds. Poppy completed the survey in 13 minutes and 28 seconds. The total area surveyed was 6400 m^2 (1.58 acres).

This result demonstrates that the beach contained naturally occurring background oiling on the day of the survey and that the SODC successfully ignored that background. This survey's results are consistent with the previous seven (7) surveys. The survey program was still ongoing at the time of writing (March 2023). The complete data set will be evaluated in the context of beach profile topographic surveys conducted simultaneously as part of the study program.

Figure 7 TADD containing WTI crude (28 February 2023)

Figure 8 TADD containing Bunker C (28 February 2023)

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Figure 9 **Waypoints of alerts by the ODC Poppy on 28 February 2023**

Table 3 Description of targets alerted by the ODC Poppy on 28 February 2023

Waypoint	Item	Size	Comments	ODC Alert	SODC Alert
32	Tarball	1cm x 1cm	Very weathered hard texture	X	
33	Tarball	0.5cm x 2cm	Soft, thin, and pliable	X	
34	Tarball	2cm x 2cm	Soft, thin, and pliable (Fig. 10)	X	
35	Tarball	1cm x 1cm	Very weathered and hard texture	X	
36	Tarball	2cm x 2cm	A cluster of six similar tarballs in the same location	X	
37	Tarball	3cm x 2cm	Soft, thin, and pliable	X	
38	Tarball	4cm x 3cm	Soft, thin, and pliable	X	
39	**TADD**	**10ml**	**WTI Crude**	**X**	**X**
40	Tarball	2cm x 3 cm	Soft, thin, and pliable	X	
41	Tar pattie	90cm x 60cm	Weathered and being washed ashore during the survey. Very hard and brittle with a honeycomb appearance. (Fig. 11)	X	
42	**TADD**	**10ml**	**Bunker C**	**X**	**X**

Figure 10 ODC Poppy alerts on a tarball during survey assessment (28 February 2023)

Figure 11 ODC Poppy alerts on a tar pattie being washed ashore (28 February 2023)

The ODC can discriminate based on odor profile and ignore similar-looking items. An advantage of the ODC is that the canine can discriminate tarballs from the natural and manmade existence of items that look similar to weathered oil (Fig. 12). This is an advantage during tarball surveys or to glean baseline data of an areas existing presence of oil. During the ODC survey, small pieces of burnt wood, charcoal, and trash were encountered. The human surveys would pick the items up to investigate whether they are tarballs. The ODC, therefore, significantly reduces the time taken to detect weathered oil on a beach with confusing background items. As the SODC is trained to ignore tarballs, it would not be utilized within a tarball survey.

Figure 12 Example of items contaminating a beach – none were tarballs

Figure 12 ODC responding on a tarball within a line of charcoal and beach trash

6 Conclusions and Future Work

The SODC teams are a proven capability that would integrate into K9-SCAT and minimize the alerts to naturally occurring hydrocarbons. SODCs can discriminate the difference between one specific oil type versus background oils. This allows responders to conduct K9-SCAT surveys on shorelines containing oil, such as tarballs, without the canine responding. The capability enhances a SCAT response and provides a fast, efficient, effective, and reliable clearance tool explicitly focused on a specific spilled oil. The next step would be uncontrolled trials to demonstrate the capability to transfer the detection capability of the canine from training to field deployments.

7 Acknowledgments

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