Effects of Duration of Oil Exposure on Feather Waterproofing Ability

Group member: Ella Wang, Junlin Sun

Abstract:

Oil exports have constantly played a significant role in contributing to economies all over the world, Australia being no exception, with approximately 16.3 megalitres of crude oil exported in the financial year of 2023 (Statista, 2023). This has consequently led to a substantial number of oil spills occurring over the past decades, resulting in irreversible damage on marine life. During the Exxon Valdez oil spill in 1989, over 35,000 seabird carcasses were recovered in the northern Gulf of Alaska (Saadoun, 2015). Numerous general experiments have been conducted on the effect of spills on the ocean, however, not many have been orchestrated with a specific focus on seabirds and the effect of the duration of exposure. By imitating the exposure of birds to crude oil through the use of pelican feathers and vegetable oil, the experiment revealed that the duration of contact between the two, plays a significant role in the level of damage to the waterproofing abilities of feathers. These discoveries, with specific times measured, could further enhance rescue and clean procedures of birds impacted by spills. This can allow a greater number of seabirds to return to their environments and continue a normal life cycle with minimal possible impact.

1.0 Introduction and Background Research

1.1 *Oil Spills*

Oil spills are defined by the release of liquid petroleum hydrocarbon, such as crude oil or other fossil fuels, into either the marine or terrestrial ecosystem. Classified as a hazardous waste, this cause of pollution is largely due to industrialisation and greatly endangers ecosystems by physically damaging habitats. Oil spills are the most frequent form of organic pollutant to a marine system, and thousands of both major and minor oil spills occur each year; the spilling of fuel whilst refuelling a ship, barge accidents, the leaking of pipelines, sinking of oil tanker ships, or the unexpected failing of drilling operations. Major oil spills can be extremely toxic to the environment, having a long-lasting impact on both the ecosystem and the country's economy.

1.2 *Effect on Marine life*

Oil spills pose a significant threat to the environment, an example of which is the event Deepwater Horizon in the Gulf of Mexico during 2010, where 4.9 million barrels of oil were released into the ocean, equivalent to approximately 700,000 tonnes (Ritchie et al., 2022). Marine lives are immensely harmed by these spills, in particular, otters and seabirds, as they are found on the sea surface where oils float due to a lower density. A variety of short and long-term effects take place after birds are exposed to oil, such as damage to plumage – a feathery covering on birds, poor health, reduced buoyancy, delayed migration and death. The plumage of birds offers insulation and regulates body temperature. Oil bonds onto feathers, causing a structural modification that then mats and separates the feather barbules, damaging the waterproofing ability of feathers. This may expose a bird's skin to harsh temperatures, and the outcome is most likely death due to hypothermia.

1.3 *Feathers and its relation to crude oil*

Birds preen as a method of maintaining their feathers' waterproofing abilities by gathering a small amount of oil from their preen glands. This enables a natural coating that repels water when they use their beaks to rub this oil onto feathers, forming an arrangement of interlocking barbules that prevent water from leaking through. Long periods of a feather's exposure to crude oil will damage the feather's waterproofing ability. Crude oil is a fossil fuel with a complex mixture, consisting of organic compounds, mainly hydrocarbon molecules, as well as heavy metals and other substances such as sulphur and nitrogen. Due to these complex chemical structures, oils form a very strong bond with feathers, damaging its structural form and making it very difficult to remove.

1.4 *Experimental development*

As crude oil was deemed unsuitable and unsafe for use in a school setting by students, it was decided that vegetable oil was the most readily available and closest substitute that could be attained due to the conditions the practical was conducted under. Both vegetable oil and crude oil are hydrocarbons, meaning they are primarily composed of hydrogen and carbon atoms.

Pelican feathers were the most suitable type of feather for this specific experiment, as they could be obtained relatively quickly. Furthermore, this species of bird experienced a 30% mortality rate during the Deepwater Horizon oil spill, the second highest rate with the first being seagulls, making them extremely applicable in the topic and experiment that is being conducted. (Douglass et al., 2019).

Due to the water phobic nature of oil, the feathers were wiped down and rinsed with water, as opposed to being placed immediately on top of the beaker in order to overcome the oil's water-resistant properties.

As opposed to dropping a specific volume of water on top of the feather, it was dropped for a controlled period of time. If a specific amount of water were utilised and the maximum volume that could possibly leak through the feather did so, no discernible discrepancies would be apparent because the feather's potential for water leakage is confined. It was also considered that a large quantity of water could potentially roll off the feather if the waterproofing was not damaged to a great extent, not allowing the water a chance to seep through. Therefore, the process of releasing water onto the feather, was conducted over a 10-minute period, with the data then being recorded. This decision was made to increase the reliability of the experiment. In addition to this, the method used made for a more realistic experiment as pelicans their feathers covered by water while diving into the ocean.

A mixture of saltwater and oil was implemented, raising the level of liquid to prevent the feather from adhering to the bottom of the bowl when submerged. This mixture of water and oil also better imitates oil spills as opposed to using purely oil. The water provided buoyancy for the feather and since oils are hydrophobic, the two liquids did not mix, allowing the feather to be fully exposed to the oil while also floating at the surface.

2.0 Investigation

2.1 *Aim*

The experiment aims to investigate the effect of different durations of oil exposure (1/4hr, 1hr, 3hrs, 47hrs, 92hrs) on the waterproofing of pelican feathers measured by the leakage of water (ml) through the feather in the span of 10 minutes.

2.1 *Hypothesis*

It was hypothesised that as the duration of oil exposure increased, the water leakage through the feather would also increase. The feathers will become increasingly impaired, with the level of damage apparent through the increasing leakage of water through the feather. This is due to the separation of barbules within the structure of the feather that, due to prolonged periods of oil exposure, should lead to a corresponding increase in the extent of damage to the feather. Oil will adhere to the feather and cause it to undergo structural changes and alterations, making water more likely to pass through.

2.2 *Variables*

Independent variable	Duration of exposure to oil
Dependent variable	Water leakage (ml) through feather

Controlled variable	Possible effect on results	Control technique
Number of feathers used for each trial	If different numbers of feathers were used per trial, the accuracy of each average would vary, making for inaccurate results.	Add in 3 feathers to each bowl and take the average leakage of the 3.
Saltwater to oil ratio	Differences in oil to saltwater concentration varies the coverage of the feather by the oil and affects results.	Measure ratio carefully and pour water and oil directly into bowl.
Type of feather (pelican)	Different types of bird feather may have different results due to different structures, affecting the reliability of the experiment.	Use only pelican feathers throughout the experiment.
Equipment	Substances remaining from previous trials may affect the structure of feather or disrupt the water: oil ratio.	Clean and rinse equipment before experiment.
Method of measuring	Different measuring methods of water leaked through can produce a slightly varied result.	Use the same sized test tube and measuring cylinder. Follow the method step by step.

Uncontrolled variable	Possible effect on results	Viable method to control
Exact size and weight of feathers	Water droplets may roll of the feather based on different shapes and some feathers may be less structurally integral.	Feathers were weighed to account for any possible flaws in results and similar sized feathers were selected.
Degree to which each feather is rinsed after submerging in oil	Some feathers that are not rinsed as carefully may have residues of oil left on the surface, skewing results.	Feel the surface of the feather after rinsing and wiping, if there is any residue left on, continue rinsing.
Measurement from test tube to measuring cylinder (missed droplets that hang in the test tube)	As there may be some droplets that remain in the test tube during the transfer to measuring cylinder, the volume that the cylinder measure may not always be accurate.	Tilt the test tube upside down and hold until virtually all drops have transferred into the measuring cylinder.

2.3 *Materials*

- 18 pelican feathers (around 0.1g on average)
- 6 plastic containers 20cmx20cmx20cm
- 3L of saltwater (salt and distilled water mixture)
- 500ml vegetable oil
- 500ml beaker x2
- 250ml beaker x1
- 10ml measuring cylinder
- Paper towel x10
- 3 pipettes
- 3 test tubes

2.4 *Risk Management*

Equipment	Potential hazard	Standard handling procedure
Glass beaker	Glass can shatter and cut hands.	Inspect for chipped or slightly broken beakers. Sweep broken glass with brush and dustpan; do not use fingers.
Vegetable oil	Ingredients may cause allergy. When heated, it may cause burns or catch fire. Do not drink.	Be aware of the temperature, consumption may cause sickness.
Plastic bulb pipette	Organic substances cause the pipette to swell, causing leaks	Avoid cleaning and use with organic solvents.

2.5 *Method*

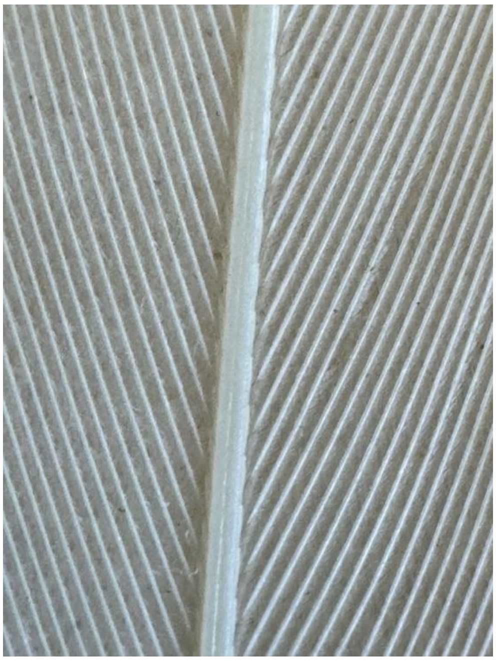
1. Weigh all 18 feathers.
2. Get 6 bowls with enough capacity to fit 3 full-sized feathers.
3. Label each of the bowls with the following: Controlled, 1/4hr, 1hr, 3 hrs, 47hrs, 92hrs.
4. Prepare 1 bowl with 500ml of saltwater at a 35:1000 ratio of salinity to distilled water (to imitate seawater)
5. Prepare the 5 other bowls with the same ratio and quantity of salt-water, add in 100ml of vegetable oil to each of the 5 bowls.
6. Add in 3 pelican feathers to each bowl and start the timer.
7. Take out feathers from '15 mins bowl' after 15 minutes.
8. Wipe oil off feathers and rinse with water.
9. Pat feathers dry.
10. Position feather directly on top of test tube so that the entire opening of the beaker is covered.
11. Drip water using a pipette, one drop at a time, directly onto the section of the feather on top of the opening of the test tube.

12. Start timer for ten minutes and continue dropping water onto feather.
13. After ten minutes, pour the water in the test tube that leaked through the feather into a measuring cylinder. Record the volume of water that leaked through the feather into results table.
14. Repeat steps 10-13 with the two other feathers.
15. Average the volume of the three results and record in table.
16. Repeat steps 7-15 with different times accordingly (e.g. Take out from ‘1hr’ after 1hr, ‘3hr’ after 3hr)

3.0 Data and Graph

3.1 *Qualitative data*

Figure 1. Images of control feather with no oil exposure (left), and feather with 47hr oil exposure(right). Taken on iPhone with x7.5 zoom, positioned approx. 10cm away from feather.



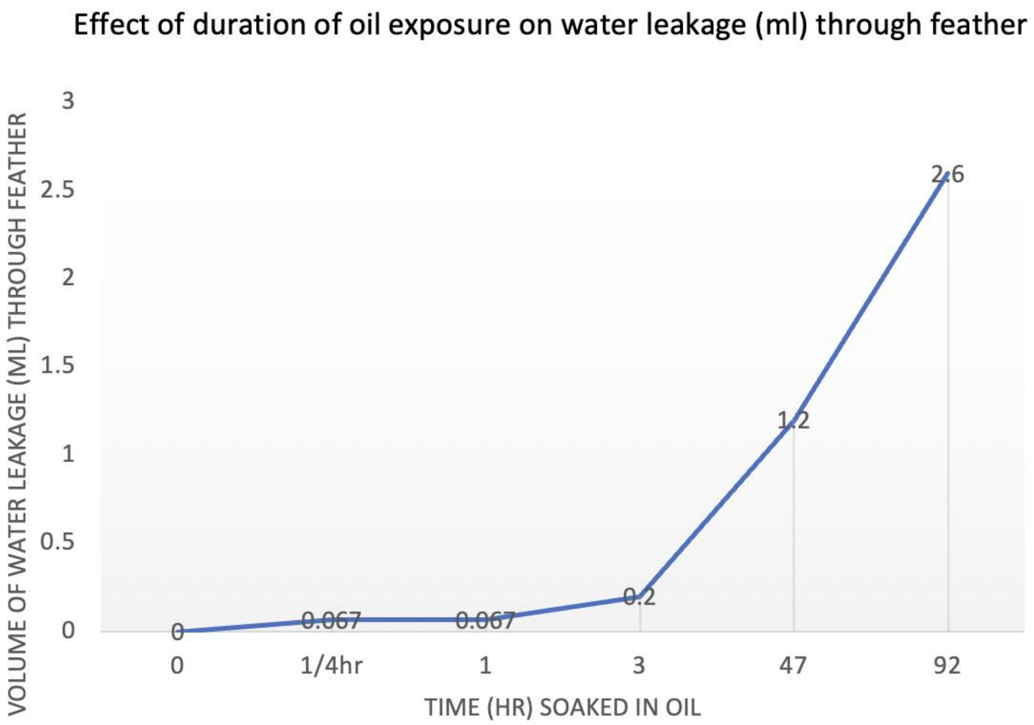
3.2 *Quantitative data*

Figure 2. Effect of duration of oil exposure (0hr, 1/4hr, 1hr, 3hr, 47hr, 92hr) on the water leakage (ml) through feathers.

		Water leakage (ml)			
		Trial no. /average			
Time period (hr)		1	2	3	average
	0 (controlled)	0	0	0	0
	1/4	0.1	0.1	0	0.067
	1	0	0.2	0	0.067
	3	0.2	0.3	0.1	0.2
	47	1	0.8	1.8	1.2
	92	2.7	2.1	3.0	2.6

3.3 *Graph*

Figure 3. Effect of duration of oil exposure (0hr, 1/4hr, 1hr, 3hr, 47hr, 92hr) on the water leakage (ml) through feathers.



4.0 Discussion

4.1 *Data discussion*

As the duration of oil exposure increased, the oil caused increasing damage to the feather barbules and its structure, decreasing its waterproofing ability. This is shown through the corresponding increase in water leakage through the feather as the time of oil exposure increased. 3 feathers were soaked in plain saltwater for 15 minutes to act as a control. The results were as expected, the control group experience no leakage. The following results were mostly consistent, presenting a correlation between the increase in water leakage, the dependent variable, and the duration of exposure to oil, the independent variable – with one exception. The ¼hr and 1hr trial produced similar results and both had an average of 0.067ml across the three trials. Suggesting that prominent damage to the waterproofing of the feather has not yet taken place after such short periods of time. Once past 1hr, the results saw a drastic increase as it escalated exponentially (see *figure 3*). The 3hr group had 0.2ml of leakage, the 47hr group had 1.2ml, and the 92hr group had 2.6ml (see *figure 2).*

The pictures taken (see *figure 1)* demonstrate slight changes to the structure of the feather, with the spaces in between the barbs of the 47hr feather appearing thinner and less structurally sound than that of the one without exposure to oil. However, these images may not be an accurate measure, as the capabilities of a phone cannot compare to that of a microscope. As well as that, the data may be unreliable as the distance the phone is held from the feather may vary due to human error.

The recorded results were predominantly reliable as most trials in each group stayed within a 0.5ml range of each other with a minimum difference of 0.1ml. However, small variations along the experiment procedure may have impacted the results, as for the 47hr and 92hr group as the maximum difference between each feather in those specific trials was 1ml (range of: 1ml for 47hrs, 0.9ml for 92hrs). This may have been caused due to the difference in weight and size for each feather (see *figure 4)*, therefore affecting its ability to facilitate the water droplets, and causing droplets to potentially roll off the edges instead of staying atop of the feather.

Figure 4. Weight of feathers (g)

	1	2	3	Average
Controlled	0.182	0.039	0.073	0.098
1/4hr	0.202	0.083	0.089	0.125
1hr	0.090	0.080	0.110	0.093
4hr	0.100	0.050	0.110	0.087
47hr	0.217	0.082	0.074	0.124
92hr	0.177	0.072	0.087	0.112

Note that feather number 1,2 and 3 do not correspond with feather 1,2,3 in figure 1.
All weights have been modified to 3 significant figures.

4.2 *Strengths*

The results were recorded in quantitative measures. The water that seeped through each feather and into the test tube was then measured with a 10ml measuring cylinder. This allowed precise calculations for each dependent variable, along with providing numerical understandings of the effect of oil on feathers that can be interpreted into a graph. 3 trials were conducted for each time period in order to obtain an average and largely eliminate any uncontrolled variables that may have affected one feather's measurement. The structure of the feather before and after exposure to oil was recorded qualitatively through a camera.

4.3 *Weaknesses*

A trial was conducted before the experiment to identify flaws and make required adjustments. In the trial, the oil was not wiped off the feather properly, but instead was simply placed on a paper towel without any human interference for 5 minutes. However, it became clear that this was making for a biased experiment, as the water phobic properties of oil did not allow any water to penetrate through the feather, with water droplets constantly rolling off the edge. As the experiment aims to identify the damage caused to the structural aspect of the feather, the outer coating should not influence the result. Thus, the method mentions to rinse and pat dry the feather prior to the conduction of the experiment.

Another flaw was that the measurements were performed by two different people, hindering the precision and accuracy of the experiment as each person may have slightly varied methods of executing the same task. To minimise this error, the experiment was conducted under the management of both students with timely communications and directions when steps varied.

Originally, tape was used as a form of securing feather onto the test tube. However, this was very unpractical as there was great difficulty in avoidance of accidentally covering the opening of the beaker with tape. The feathers were also very light and fragile, and the tape bent it so that the feather barbs were separated, likely to cause inaccuracy as the water droplets may seep between these gaps. This was modified and decided that the feather should be balanced atop the test tube and held still when swaying or wavering. This ensured that the process of water leakage was accurately executed.

4.4 ***Future improvements***

The experiment could be improved by looking at a wider range of variable, such as considering longer periods of time, such as 1 or 2 weeks. The experiment could also be performed with different types of oils, and using a more accurate substitute, or simply using crude oil. Although vegetable and crude oil have certain similarities, there are still some differences between the two; crude oil consists hydrocarbons of a larger variety including sulphur, nitrogen, and heavy metal such as iron and nickel, whereas there is a higher distribution of unsaturated fats in vegetable oil. The experiment would produce more accurate results if additional trials were executed. Different types of feathers could also have been used, to provide more well-rounded results. However, due to the time constraints and limited range of materials available, these improvements were not realistic to implement into this current experiment. In future, a microscope should be used in order to obtain qualitative data with greater accuracy and information than that of a phone, with multiple images being taken to observe trends in the structural differences of the feathers.

5.0 Conclusion

This experiment explored the effect of oil exposure (time in hrs) on the waterproofing of feathers (measured by water leakage through feather) and discovered that as the duration of oil exposure increased, the waterproofing ability of the feather decreased. Therefore, the results supported the hypothesis and verified that the longer the feather is exposed to oil, the greater the damage inflicted upon the feather. This experiment resembles the effect of oil spills on birds such as pelicans that are in danger of this form of pollution. Crude oil, which in this experiment is replaced with vegetable oil, can cause great harm as toxins adhere on to the outer layer of feathers and destroy its natural waterproofing ability. Birds respond differently and many health issues may arise such as hypothermia, hyperthermia, ingestion of oil during preening, damage to internal organs, severe weight loss, anaemia, and loss of buoyancy. It may take up to weeks for rescuers to clean and properly wash a bird before it is ready to be released into the wild. This experiment reveals that rescuers should strive to remove birds from oil within the first 3 days of exposure, as the damage increases rapidly from then on.

6.0 References

Chemistry matters (n.d.) *Petroleum Hydrocarbons (PHCs)*, Chemistry Matters, accessed 17 February 2024. https://chemistry-matters.com/chemicals/petroleum-hydrocarbons-phcs/#:~:text=Petroleum%20Hydrocarbons%20(PHCs)%20is%20the,or%20size%20of%20the%20molecules

Frith A (2019) *The affects of crude oil on bird feathers* [PDF], The School for Excellence, accessed 15 February 2024. https://www.tsfx.edu.au/resources/46606.pdf

International Birds Rescue (n.d.) *Oil can be lethally harmful to waterbirds*, Birds Rescue, accessed 16 February 2024. https://www.birdrescue.org/our-work/research-and-innovation/how-oil-affects-birds/

Maung-Douglass E, Graham L, Hale C, Sempier S, Skelton T, Swann L & Wilson M (n.d.) *BIRDS OF A FEATHER — COPING WITH OIL* [PDF], Oil Spill Science, accessed 15 February 2024. https://masgc.org/oilscience/birds-and-oil.pdf

National Oceanic and Atmospheric Administration U.S. Department of Commerce (1 August 2020) *Oil spills*, NOAA, accessed 15 February 2024. https://www.noaa.gov/education/resource-collections/ocean-coasts/oil-spills

NOAA (5 February 2019) *How Do Spills Happen?*, Office of Response and Restoration, accessed 17 February 2024. https://response.restoration.noaa.gov/training-and-education/education-students-and-teachers/how-do-spills-happen.html#:~:text=Oil%20spills%20into%20rivers%2C%20bays,drilling%20rigs%2C%20and%20storage%20facilities.&text=Spills%20can%20be%20caused%20by,making%20mistakes%20or%20being%20careless

Saadoun I.M.K. (2 September 2015) *Impact of Oil Spills on Marine Life*, Intech Open, accessed 23 February 2024. https://www.intechopen.com/chapters/48738

Whitmer E.R, Elias B.A, Harvey D.J & Ziccardi M.H (1 April 2018) *AN EXPERIMENTAL STUDY OF THE EFFECTS OF CHEMICALLY DISPERSED OIL ON FEATHER STRUCTURE AND WATERPROOFING IN COMMON MURRES (URIA AALGE)*, BioOne, accessed 16 February 2024. https://bioone.org/journals/journal-of-wildlife-diseases/volume-54/issue-2/2017-01-016/AN-EXPERIMENTAL-STUDY-OF-THE-EFFECTS-OF-CHEMICALLY-DISPERSED-OIL/10.7589/2017-01-016.full