



**CONNECTING THE DOTS:  
Orcas, Salmon and Toxic  
Chemicals in the Salish Sea**



## DEFENDERS OF WILDLIFE

Defenders of Wildlife is a national, nonprofit membership organization dedicated to the protection of all native wild animals and plants in their natural communities.

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Cover photo: Breaching transient orca in the Salish Sea © Alethea Leddy

## Connecting the Dots: Orcas, Salmon and Toxic Chemicals in the Salish Sea

### Puget Sound's Toxic Orcas

Southern resident orcas are one of the most critically endangered marine mammal populations in U.S. waters (Reynolds et al., 2009) and one of eight marine species at risk of extinction in the near future (National Oceanic and Atmospheric Administration [NOAA], 2015). Icons of the Salish Sea, which includes the marine waters of Puget Sound, the Strait of Georgia and the Strait of Juan de Fuca, orcas, also known as killer whales, are a culturally important species to dozens of First Nations and cherished by citizens throughout British Columbia, Washington and Oregon. People from all over the world travel to the Pacific Northwest in hopes of seeing these amazing whales.

After decades of studying southern resident orcas, we now know much about their behavior, culture—the learned behaviors unique to this population—and what they need to survive. We also have answers to some of the most pressing questions about the population's decline, including the impact of toxic chemicals found in the orcas' food supply.

This report focuses on that impact and what we can do about it. It analyzes the latest research on the effects of toxic chemicals on both southern resident orcas and their main prey, chinook salmon. Most important, it offers easy solutions that everyone living in the ecosystem can take to reduce toxic chemicals in the Salish Sea. Using toxic chemicals or opting for alternatives is a personal decision, and small changes can make a big difference for wildlife. From lawn maintenance and car care to personal healthcare products, our individual choices matter for southern resident orcas, salmon, our own health and the greater health of the Salish Sea ecosystem.

### An Invisible Threat in the Salish Sea

Many toxic chemicals end up in our waters. Some can easily be traced to a specific source such as industrial and municipal wastewater.

Some are harder to pinpoint. Stormwater runoff, for example, is considered nonpoint source pollution because it gathers a mix of chemicals as it flows off roofs, lawns, parking lots and roads. This cocktail of polluted water travels downstream to rivers and creeks on its way to the Salish Sea, where it becomes the largest source of contaminants impacting



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this important wildlife habitat (Herrera Environmental Consultants, 2011; Ecology and King County, 2011; Pearson et al., 2011).

Unlike other types of habitat degradation, we often cannot see chemicals leaching into the water or accumulating in the environment, making them easier to ignore. Once in the environment, these chemicals can cause a host of problems for fish and other aquatic wildlife, including southern resident orcas.

## The Worst of the Worse

Most human-made chemicals adversely impact the surrounding environment, but certain chemicals are worse than others. Persistent chemicals—those that do not degrade quickly—linger longer in the environment and often travel farther, making it more likely that organisms will ingest them (Grant and Ross, 2002).

The worst of these chemicals are fat-soluble persistent organic pollutants or POPs. POPs stay intact in the water and accumulate in the body fat of organisms that ingest them. Many marine mammals accumulate extremely high levels of these toxics in their blubber, the thick layer of fat that keeps them warm in the ocean.

Southern resident orcas rely on energy stored in their blubber when they cannot find enough fish to eat—an all-too-common occurrence for these endangered whales. The more fat reserves they metabolize in their blubber during lean times, the more chemicals are released throughout their bodies, with dire consequences to their health (Alava et al., 2012; Grant and Ross, 2002; Lundin et al., 2016; Mongillo et al., 2016; National Marine Fisheries Service [NMFS], 2008).

## The Problem of Bioaccumulation

Bioaccumulation is what happens when toxic chemicals concentrate in an organism. Those chemicals concentrate up the food chain in a process called biomagnification. When predators eat their prey, they also absorb the bioaccumulated toxics. The more prey consumed, the more toxic chemicals consumed, resulting in a buildup of toxics, particularly in animals with long lifespans like orcas.

At the top of the Salish Sea's food chain, southern resident orcas accumulate incredibly high levels of pollutants because their main prey, chinook salmon—the largest and generally fattest Pacific Northwest salmon—carry high concentrations of pollutants and POPs in their own bodies from eating smaller contaminated fish and aquatic invertebrates. Contamination levels vary among chinook salmon, but in the Salish Sea ecosystem, several populations are among the most contaminated on the West Coast (Mongillo et al., 2016; O'Neill and West, 2009).

## Pollution Sources and Impacts

Bioaccumulated contaminants affect salmon and southern resident orcas in similar ways. High toxic loads impact developmental processes in growing animals, interrupt brain and nervous systems, disrupt endocrine systems, compromise



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immune systems, harm reproductive organs and functions and cause cancer (NMFS, 2008).

Flame retardants, personal care products and pharmaceuticals are emerging toxics of concern. Researchers are just starting to understand the full impact these understudied chemicals have on ecosystems. Preliminary research links some to endocrine disruption and liver and thyroid impairment in marine organisms (Mongillo et al., 2016; NMFS, 2008). Other chemicals, like synthetic estrogen, are of increasing concern.

Dioxins and furans—byproducts of paper production—were once a major source of pollution in Puget Sound (Ecology and King County, 2011). Now industries make efforts to capture hazardous chemicals before they enter our waterways. But they remain prevalent in our environment. Today, sources of these chemicals include wood treatment, residential wood-burning and municipal incinerators (NMFS, 2008). Toxic at minute concentrations, dioxins and furans cause thymus and liver damage, birth defects, reproductive impairment, endocrine disruption, immune dysfunction and cancer.

DDT and PCBs are still found throughout the Salish Sea. The United States and other countries banned them decades ago, but they are still present in watersheds, throughout

oceans and in fish and many wildlife species. PCBs can cause skeletal abnormalities, reproductive impairment, hormone disruption and immune dysfunction. DDT, a pesticide used until the 1970s, is responsible for reproductive impairment, suppressed immune function and adrenal and thyroid defects (Grant and Ross, 2002).

The largest source of pollution in Puget Sound is nonpoint source pollutants from fertilizers and runoff from yards, roads and parking lots (Ecology and King County, 2011). Nonpoint source pollution also comes from marinas and recreational boats—often under-recognized sources. Boat paint, oil leaks and abandoned vessels contribute to the problem.

### An Unexpected Source of Contaminants: Derelict and Abandoned Vessels

Thousands of recreational and commercial vessels operate throughout the range of southern resident orcas and chinook salmon. At the end of a vessel's operational life, it is sometimes abandoned in the water, either purposefully or accidentally. Derelict vessels often contain harmful quantities of oil, lubricant and other toxic substances in the materials used to construct the vessel or in the cargo onboard. These chemicals can injure or kill marine mammals, waterfowl and other aquatic life. They also contaminate aquatic lands, nearby shorelines and water quality. Vessels that settle on the bottom of the Salish Sea can disrupt the aquatic environment, scouring or crushing sensitive habitats like eelgrass and kelp beds. Older large vessels, like military vessels, sometimes lack a shipyard where they can be taken apart responsibly. As a result, military vessels sit along the West Coast slowly decaying. PCBs were once used in paint on military ships and as they age, this paint flakes off into the water. More common are old fishing vessels and recreational boats that are abandoned when the owner doesn't have the

means to take them to the dump. Washington state has made progress implementing its derelict vessel removal program. While this program has been effective, there is a significant amount of work remaining to completely mitigate this source of toxic pollution. Prevention efforts keep toxics out of the environment and cost significantly less than removing a sunken vessel.

The type of pollutants stored on abandoned vessels and the amount of hazardous materials removed is not currently tracked by Washington state. The small state program currently does not have the capacity to inventory the removal of POPs and other hazardous materials from derelict or abandoned vessels. However, between 2013 and 2015, this program removed 116 vessels. With an influx of money from the state legislature, the program removed several larger vessels that were a major source of pollution. Today there is a renewed need for additional funding to address the backlog of over 100 known derelict vessels and to locate and remove others that likely lie on the bottom of Puget Sound.

Chemical	Vessel Sources	Risks to Orca
Polychlorinated Biphenyls (PCBs)	Electrical transformers, capacitor fluid, wiring, former military vessels	Reproductive impairment, skeletal abnormalities, immune system disruption, endocrine disruption
Polybrominated diphenyl ethers (PBDEs)	Flame retardants: on all boats for fire protection. Quantity dependent upon vessel size	Endocrine disruption, impairs liver and thyroid function
Dibutyltin (DBT)	Antifoulant pesticide in vessel paint	Immune system disruption
Polychlorinated naphthalenes (PCNs)	Vessel insulation, wiring, capacitors, engine oil additive	Endocrine disruption
Polychlorinated paraffins (PCPs)	Flame retardants, paints, sealants, additive in lubricating oils	Endocrine disruption

## Toxic Chemicals and Chinook Salmon

The Pacific Northwest is called “Salmon Nation” for good reason. While many of us associate the Columbia River with large salmon runs, researchers estimate Puget Sound tributaries historically had a greater number of spawning salmon than Columbia basin tributaries (Gresh et al., 2000). The bountiful summer and fall chinook salmon runs in the Fraser River and throughout Puget Sound attracted orcas to the Salish Sea every summer. Today habitat loss from floodplain development and dams has reduced salmon populations throughout the region, but researchers have also found that chemical contamination is a major issue for chinook and coho salmon in Puget Sound.

A recent study by the National Marine Fisheries Service and the University of Washington found cocaine, hormones and prescription medication in juvenile chinook salmon and other fish collected in Puget Sound (Meador et al., 2016). Mixed with other chemicals, the impact of these substances on salmon is unknown but concerning. In Canada, researchers have found male fish producing eggs and female proteins. The feminization of male fish is likely the result of hormones, like synthetic estrogen, taken by humans and flushed down sewer pipes. This has caused some fish populations to crash (Kidd et al., 2007), and researchers are starting to see similar issues among chinook salmon in Puget Sound (Peck et al., 2011). The technology needed to remove many of these emerging toxics and hormones does not exist, and treatment plants are unable to remove these contaminants from our wastewater (Meador et al., 2016).



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## Stormwater: A Mysterious Toxic Cocktail

Stormwater is rainfall and snowmelt that flow over the landscape, gathering chemicals along the way. Researchers have yet to successfully duplicate stormwater in the lab and do not fully understand the effect this chemical mixture that often ends up in our waterways has on organisms, but it is clearly lethal to salmon. Salmon placed in collected stormwater experience 100 percent mortality within hours (Spromberg et al., 2011). The good news is that biofiltration systems—like raingardens, which trap rainwater runoff from roofs, parking areas and other surfaces—can completely reverse this trend (McIntyre et al., 2016a; McIntyre et al., 2016b; Spromberg et al., 2015).

For salmon that spend the majority of their lives in the Salish Sea, the impact of toxics is even greater. Native chinook salmon often do not swim to the open ocean. Instead, they live their whole lives in Puget Sound and the Salish Sea. This increases their exposure to several POPs and other toxics so much so that these salmon contain up to three to five times as many contaminants as salmon that spend years in the ocean (Mongillo et al., 2016; NMFS, 2007; O’Neill et al., 2009).

Pollutants and heavy metals impact the health of individual chinook salmon, but mounting evidence points to broader, population-wide impacts as well. Researchers found that the survival rate of juvenile chinook salmon in polluted estuaries is 45 percent lower than those in clean estuaries (Meador, 2014). Additional studies by the Northwest Fisheries Science Center show that juvenile chinook salmon in the sound are exposed to POPs and PAHs (polycyclic aromatic hydrocarbons) at concentrations known to cause immune dysfunction and impair growth (Johnson et al., 2007b; Meador et al., 2010; Olson et al., 2008; Sloan et al., 2010; Stehr et al., 2000).

Roughly one-third of Puget Sound salmon sampled by the Washington Department of Fish and Wildlife showed contamination at levels known to cause health and developmental problems. Because juvenile chinook salmon in Puget Sound are at a particularly high risk from pollution, researchers believe that toxic contamination may be a leading determining factor in the mortality of these salmon (O’Neill et al., 2015).



CREOSOTE PILING REMOVAL, WA-DNR

Additional research on other salmon species found similar problems. Juvenile coho salmon exposed to copper, a common pollutant from road runoff, lost their sense of smell and the ability to detect nearby predators (McIntyre et al., 2012).

Researchers have also documented die-offs of coho salmon, females full of unfertilized eggs, in toxic streams. Referred to as “pre-spawn mortality,” this phenomenon of fish dying before they make it upstream to reproduce causes the loss of future generations. Annual rates of coho salmon pre-spawn mortality observed over multiple years across several contaminated drainages have ranged from approximately 20 percent to 90 percent of the total fall run within a given watershed. Rates from clean streams are less than 1 percent (Scholz et al., 2011). At the low and high ends of this range of mortality rates, researchers predict that the average time it will take for these populations to go locally extinct is between 115 and eight years, respectively (Spromberg and Scholz, 2011).

### Creosote Pilings in the Salish Sea

A small program at the Washington Department of Natural Resources is working to remove creosote pilings from the Salish Sea. The coal tar creosote in these pilings contains up to 10,000 chemicals. The most concerning are polycyclic aromatic hydrocarbons (PAHs), phenols, and creosols. PAHs do not migrate far from the point of contamination and accumulate in the sediment. In fish, PAHs have been shown to be cardiotoxic, deforming developing hearts and inhibiting proper heart contractions in fully formed hearts (Brette et al., 2017; Incardona et al., 2015). Exposure of salmon eggs to low levels of PAHs from an oil spill causes health problems, including deformities, in developing salmon, meaning fewer adults return to spawn. Juvenile salmon migrating through urban estuaries are exposed to PAHs and other chemicals, resulting in reduced disease resistance and changes in growth and metabolism (Johnson et al., 2007a). Fortunately, as of 2017, roughly half of the existing inventory of chemical-laden old wood pilings has been removed from Puget Sound.

## Toxic Chemicals and Southern Resident Orcas

Southern resident orcas spend up to half the year in their summer range, feeding on Fraser River and Puget Sound tributary salmon. These salmon swim through urban rivers and spend time in the Salish Sea next to several major metropolitan cities with higher concentrations of pollutants. Once the large summer runs of Fraser River salmon end, the orcas rely on Puget Sound chinook salmon—and to a lesser extent coho salmon—that spawn early in the fall (NMFS, 2008; Hanson et al. 2010) before they head to their winter range. During the winter, they feed on gathering salmon runs at the mouths of major rivers along the outer coast of Washington, Oregon and California, including the Columbia, Klamath, and Sacramento-San Joaquin (San Francisco Bay) salmon runs.

As the most urban orcas in the world, southern resident orcas retain unique chemical signatures throughout their range. For example, DDT is found in higher concentrations in southern residents that spend more time foraging off the California coast (Krahn et al., 2004; Krahn et al., 2007; Krahn et al., 2009; Lundin et al., 2015; NMFS, 2008; Mongillo et al., 2016). In fact, scientists learned that the southern residents feed on chinook salmon from the Sacramento River in the Central Valley of California by comparing DDT and PCB patterns in the fish and whales (NMFS, 2009), a useful but unfortunate method of identifying the origins of salmon in the whales' diet. Southern residents consume an estimated 6.6 times as many POPs as their northern resident counterparts in the more remote waters of Alaska (Cullon et al., 2009).

In marine mammals, POPs can impair immune and hormonal systems (Krahn et al., 2007; Krahn et al., 2009; Lundin et al., 2015), potentially affecting the reproductive success of females (Wasser et al., 2017). Endocrine disruption in marine mammals is poorly understood and the effects on reproduction and fetal development are currently unknown (Hood, 2005).

All southern resident orcas have dangerously high levels of toxics in their bodies, but the impacts of these chemicals vary within the population. Researchers now know that male orcas never shed their stored toxic load (Ross et al., 2000; Krahn et al. 2009), which has consequences for sperm health and fertility. Females that give birth have an opportunity to shed their toxic load through milk production. Unfortunately, this makes orca calves especially vulnerable to toxic chemicals.



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Milk is produced from a mother's fat reserves, which is usually filled with toxics. This contaminated milk further concentrates these chemicals and passes them directly to calves. Milk becomes even more contaminated when food is scarce (Ross et al., 2000).

A recent study showed that the chemical load in a first-time mother orca is extremely high and decreases with each subsequent birth. By the time the whale has a low contamination level, the female may have experienced several births and calf deaths. The study revealed that this may effectively shorten the reproductive ability of each female orca by five or more years. In a slow-to-reproduce and already depleted population, this significantly effects the future of southern resident orcas (Lundin et al., 2016).

## Hungry Southern Resident Orcas, Vanishing Chinook Salmon and Toxic Chemicals

Southern resident orcas are one of most contaminated marine mammals in the world. When prey is scarce, they are forced to rely on their toxic-laden fat layer for energy (Alava et al., 2012; NMFS, 2008; Lundin et al., 2016). Marine mammals utilize blubber during lean times, but when that blubber contains high concentrations of POPs their reserves become dangerous and even deadly. Ken Balcomb, senior scientist at the Center for Whale Research in Washington, has likened toxic blubber to bad meat in the freezer: It's one thing to store it. It's a whole other thing to eat it.

With chinook salmon runs declining or already vanished



across the southern residents' range, orcas have had to rely on fewer and fewer fish. In the Salish Sea, the Fraser River, which runs through Vancouver, B.C., is one of the orca's largest remaining food sources in summer, but these salmon runs are also heavily contaminated and in decline. Historically, the Fraser River system supported nearly 1 million spawning chinook salmon (Northcote and Atagi, 1997), but B.C. salmon stocks in general are estimated at 36 percent of their historical (1800s) run size. Puget Sound stocks are even more depleted, at only an estimated 8 percent (Lackey et al., 2006).

Dismal chinook salmon runs in 2016 resulted in few summer sightings of southern resident orcas in the Salish Sea. When orcas did breach researchers reported seeing outlined ribs indicating emaciation. They also reported orcas with

'peanuthead,' a condition of starvation. When orcas deplete their blubber reserves, their skull becomes visible, giving their head a peanut shape.

In contrast, transient, or Biggs, killer whales, the mammal-eating orcas that also spend time in the Salish Sea, have comparatively higher toxic loads than the southern residents, but their population is increasing and they appear healthy despite their toxic burden. This is likely due to an ample prey base of seals and other marine mammals (NFMS, 2008). This implies that when an abundant and reliable prey source exists, orcas are better equipped to deal with the impacts of concentrated pollutants in their bodies. With only 29 reproductive females in the entire population in 2016, the death of even one southern resident orca is a horrible loss.



## Defenders of Wildlife, You and the Work Ahead

Defenders of Wildlife’s southern resident orca program works to resolve issues in the orcas’ summer and winter ranges. To sustain the population, we need to increase prey availability and reduce chemical contamination.

Defenders, along with our partners and Washington’s congressional delegation, supported the Water Resources Development Act reauthorization, aimed at addressing the pollution crisis in the Salish Sea. The act passed in 2016, making up to \$300 million available for regional clean-up efforts and supporting U.S.

Environmental Protection Agency and NOAA programs that work to reduce pollution throughout the Puget Sound region.

At the state level, we continue to advocate for financial support for state programs that reduce toxics in Puget Sound, such as the Creosote Piling Removal Program and the Derelict Vessel Removal Program, both housed at the Department of Natural Resources. Defenders is also pressing for state and federal funding to address toxic pollution from stormwater runoff, a key program in the Washington Department of Ecology.

At the local level, we are working to identify the resources needed by counties for derelict vessel prevention efforts and stormwater mitigation. This includes building new relationships with local governments, schools and nonprofits to better manage stormwater runoff and expand raingardens throughout the region. Governments, nonprofits, and individuals can reduce the amount of pollution entering Puget Sound, which can restore habitat for chinook salmon and improve the health of our orcas.

Solving this problem also relies on individuals. Reducing toxics in the Salish Sea involves everyone. The products we choose to purchase all have an impact on southern resident orcas and chinook salmon. By being conscientious consumers and making small lifestyle changes, individuals can play a big and important role in keeping the Salish Sea clean and healthy.

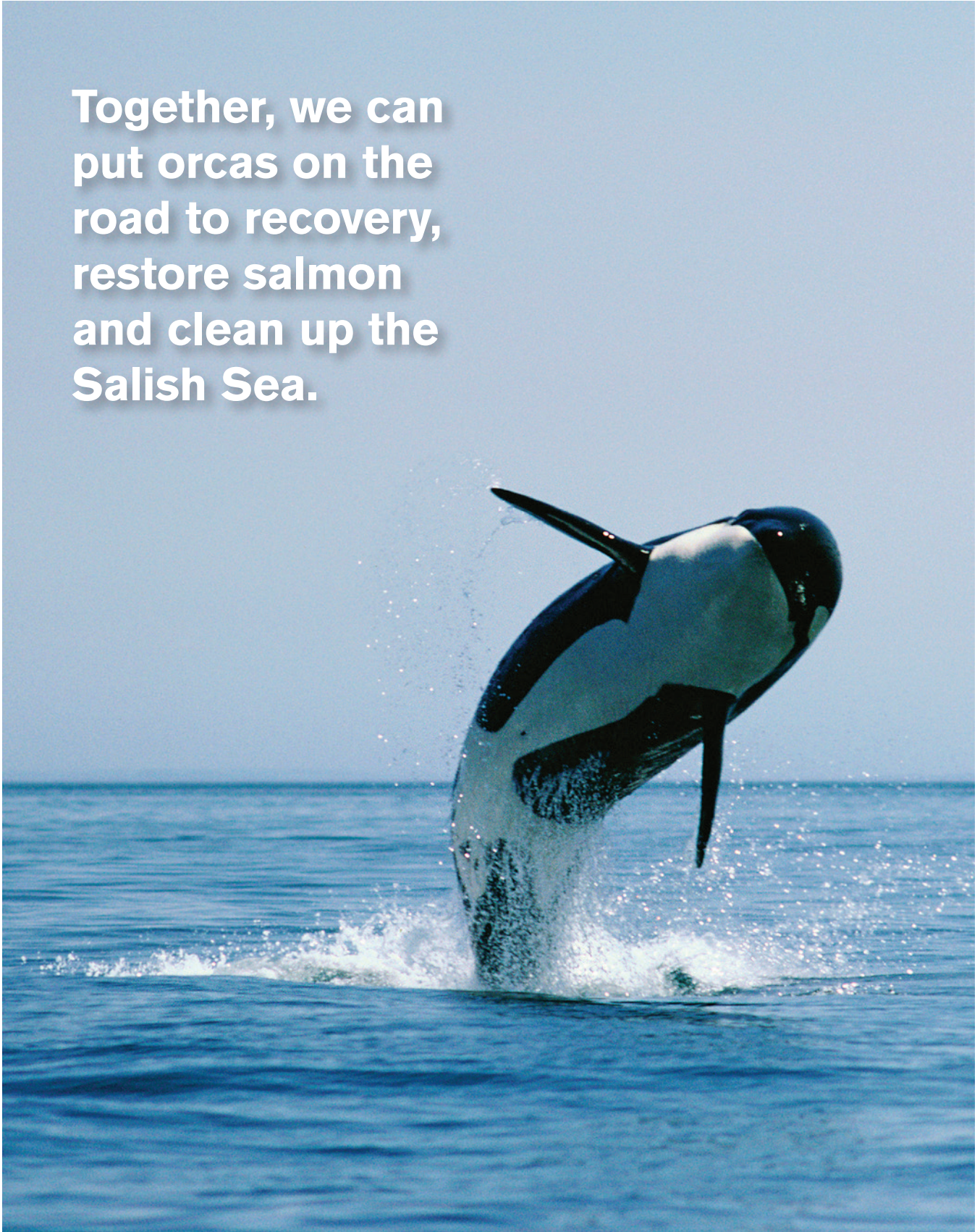
Together, we can put orcas on the road to recovery, restore salmon and clean up the Salish Sea.



### How You Can Help Keep Toxics Out of Orcas

1. **Look for natural, biodegradable personal care products** like shampoos and detergents.
2. **Be conscientious about garden and lawn-care products.** Fertilizers often contain arsenic, lead and mercury. Visit [www.naturallyardcare.org](http://www.naturallyardcare.org) to learn how to take care of your yard without harming the Salish Sea.
3. **Make sure your car is well maintained and free of oil leaks.** Over 8 million gallons of oil leak into the Salish Sea every year. Visit [fixcarleaks.org](http://fixcarleaks.org) to learn more.
4. **Clean up after your pets.** Dog waste is a major source of fecal contamination in the Salish Sea. Scoop up dog waste and dispose of it properly.
5. **Install a raingarden,** which filters toxic stormwater coming off your roof, lawn, and driveway, provides habitat for pollinators, and can increase the value of your home. Learn about the incentive programs you may qualify for at [www.12000raingardens.org/](http://www.12000raingardens.org/)
6. **Use a commercial car wash** or wash your car on your lawn, which keeps soap, oil, copper, and other metals from washing off your driveway directly into gutters that drain into the Salish Sea.

**Together, we can  
put orcas on the  
road to recovery,  
restore salmon  
and clean up the  
Salish Sea.**



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