AMMPA Standardized Information:
Killer Whale

FINAL–Last updated 10/19/15

Scientific Classification

Order: Cetacea

- The word "cetacean" is derived from the Greek word for whale, *ketos*.
- Cetacea is one of only two scientific orders of large aquatic mammals that live their entire lives in water (Sirenia is the other). The order Cetacea include all whales, dolphins and porpoises.
- Living cetaceans are divided into two suborders: Odontoceti (toothed whales) and Mysticeti (baleen whales).

Suborder: Odontoceti

- The scientific suborder, Odontoceti, is comprised of toothed whales. These whales also have only one blowhole opening. The word "Odontoceti" comes from the Greek word for tooth, *odontos*.

Family: Delphinidae

- Dolphins are part of the scientific family Delphinidae. There are at least 36 species of delphinids, including bottlenose dolphins, pilot whales and killer whales (Berta *et al*., 2006).

Genus and Species: *Orcinus orca*

- The Latin name *Orcinus* translates as "belonging to Orcus" (Heyning and Dahlheim, 1999). Orcus was a Roman god of the netherworld and this genus name is likely a reference to the hunting prowess of the killer whale.
- In Latin, *orca* translates to "large-bellied pot or jar" (Ellis, 1989), but also refers to "a kind of whale" (Heyning and Dahlheim, 1999).
- Despite the widespread distribution and many geographically isolated populations of killer whales, most scientists consider them all the same species. However, factors such as morphological and genetic distinctions indicate that a taxomonic update may be needed (Ford, 2009; Morin *et al*., 2010).

Common Names

- Killer whales gained their common name because they kill other whales. They were once called "whale killers" by sailors who witnessed their attacks on larger cetaceans (Carwardine, 1992). Over time, the name was gradually switched to "killer whales" (Heyning and Dahlheim, 1999).
- Another common name for killer whales in Spanish is *ballena asesina*, which translates to "assassin whale." The German common name is *schwertwal*, or "sword whale"–a reference to their large dorsal fin (Ellis, 1989). Native Americans call them by names including *klasqo'kapix* (Makah, Olympic Peninsula), *ka-kow-wud* (Quillayute, Olympic Peninsula), *max'inux* (Kwakiutl, northern Vancouver Island), *qaqawun* (Nootka, western Vancouver Island), and *ska-ana* (Haida, Queen Charlotte Islands) (Hoyt, 1990; Ford *et al*., 2000).

Killer Whale Ecotypes (Forms)

- Scientists currently recognize at least 10 distinct ecotypes (or forms) of killer whales. These ecotypes differ at the molecular level and display distinct differences including variations in size, habitat, color pattern, dorsal fin shape, vocalizations, prey type and hunting strategies.
- In the Northern Hemisphere, there are five recognized ecotypes (Ford, 2009; Dahlheim *et al*., 2008; Foote *et al*., 2009).
  1. Type 1 and type 2 killer whales inhabit the eastern North Atlantic (Pitman, 2011).
  2. In the eastern North Pacific Ocean, observers have recognized that various groups of killer

whales show physical and behavioral differences. They categorize pods of eastern North Pacific killer whales into three ecotypes: "transient," "resident" and "offshore" (Pitman, 2011).

3. Researchers analyzed samples collected from 73 whales in the eastern North Pacific and found significant genetic differences among transient whales (also referred to as "Bigg's killer whales" in honor of early killer whale researcher Michael Biggs) and two separate groups of resident whales (Pitman, 2011; Hoelzel *et al*., 1998).
4. The offshore ecotype has been identified but not as well studied as the resident and transient ecotypes. It appears to be more closely related to the resident ecotype than to the transient ecotype (NOAA SAR offshore, 2003, citing Black *et al*., 1997).
5. A fourth potential killer whale ecotype in the Pacific inhabits the Eastern Tropical Pacific (ETP) (Schulman-Janiger *et al*., 2011; Olson and Gerrodette, 2008).

- There are five recognized ecotypes in the Southern Hemisphere (Pitman and Ensor, 2003; Pitman *et al*., 2007; Pitman and Durban, 2010; Pitman and Durban, 2011; Pitman *et al*., 2011).
  1. Antarctic type A killer whales (Pitman, 2011).
  2. Small type B–this ecotype may also be called "Gerlache killer whales" because they are regularly found around the Gerlache Strait off the western Antarctic Peninsula (Pitman, 2011).
  3. Large type B–this ecotype is sometimes referred to as "pack ice killer whales" (Pitman, 2011).
  4. Type C–also referred to as "Ross Sea killer whales" (Pitman, 2011).
  5. Type D–this ecotype may also be called "Subantarctic killer whales" (Pitman, 2011).

Fossil Record

- Early whales evolved some 50 million years ago from terrestrial mammals that returned to the sea (Barnes, 1990).
- While the fossil record is poor in regard to modern cetaceans, most modern forms of both odontocetes and mysticetes appear in the fossil record five to seven million years ago. Molecular and fossil analysis sustain the theory that cetaceans are distant cousins of even-toed ungulates (artiodactyls) and that hippopatamids are the closest living relative to cetaceans (Geisler and Theodor, 2009).
- The remains of one such ancient hippopatamid discovered in Kashmir, India–*Indohyus*–is placed in the extinct family Raoellidae. It's theorized that *Indohyus* took to the water as a means of escaping predators, as opposed to finding new food sources, some 48 million years ago. The middle ear space of *Indohyus* features a thick bone covering called an involucrum–previously, the only other animals known to have an involucrum have been cetaceans (Thewissen *et al*., 2007).
- In Italy, experts have uncovered Pliocene (two to five million years old) fossils that seem to be related to modern killer whales. The fossil skull of a whale that has been named *Orcinus citoniensis* had smaller teeth–and more of them–than modern killer whales. Scientists have identified large, fossil delphinid teeth, mostly from the Pliocene, as those of an *Orcinus* species (Ridgway and Harrison, 1999).

Distribution

- Killer whales are found throughout the world's ocean. Next to humans, and perhaps the brown rat (*Rattus norvegicus*), killer whales are the most widely distributed mammal (Ford, 2009).
- Killer whales are most abundant in the Pacific Northwest, along northern Norway's coast in the Atlantic and in the higher latitudes of the Southern Ocean (Ford, 2009).
- Resident and transient killer whale ecotypes range within the northeastern Pacific from the Aleutian Islands to southern California (Ford, 2009).
- In the Antarctic, type A killer whales are circumpolar and live offshore in ice-free water; type B killer whales inhabit inshore waters of Antarctica and the Antarctic Peninsula, near the pack ice; type C killer whales inhabit inshore waters and pack ice and are most common in the eastern Antarctic; and

the few sightings of type D killer whales have been in deep, subantarctic waters (Pitman and Ensor, 2003; Pitman *et al*., 2007; Pitman and Durban, 2010; Pitman and Durban, 2011; Pitman *et al*., 2011.)

- In the North Atlantic, type 1 killer whales are found in the waters of the northeast Atlantic and Great Briton, while type 2 killer whales are mainly spotted off the west coast of Ireland and Scotland (Foote *et al*., 2009).

Migration

- In the North Pacific, resident pods tend to travel within specific, localized ranges while transient groups' ranges are wider and less predictable. Both resident and transient killer whale ecotypes in the north Pacific do not undertake "migration" in the formal sense of the word (Barrett-Lennard and Heise, 2006).
- Resident pods are observed to remain within a range of about 800 km (500 mi.) of the coastline (Marine Mammal Commission Annual Report, 2002). Residents travel direct routes, moving generally from headland to headland along the coast. Their movements coincide with the migration of their primary prey, salmon (Ford *et al*., 2000).
- Transients may spend twice as much time traveling as their movements tend to be circuitous, often following the contours of the shoreline. Transient whales have been sighted within a 1,450 km (900 mi.) range (Hammers, 2003).
- Type A killer whales appear to be migratory, entering Antarctic waters during the austral summer (Kasamatsu and Joyce, 1995).
- Similar travel patterns to resident/transients are echoed in type B and type C, with type B killer whales traveling more widely (Andrews *et al*., 2008).
- Type B undertake rapid migrations from the Antarctic to subtropical waters off Uruguay and Brazil. These rapid travels may be over 5,800 miles (9,400 km) round trip. This migration may be for the purpose of maintenance, with the animals regenerating skin in warmer waters without the high cost of heat loss (Durban *et al*., 2011).
- A tagging study has shown that killer whales in the eastern Canadian Arctic region also undertake long-distance movements, likely to avoid heavy ice formation in the winter months (Matthews *et al*., 2011).

Population

Killer whales are difficult to accurately census given their worldwide distribution. However, it's estimated that their global population is at least 50,000 (Taylor *et al*. 2013).

Habitat

- Killer whales are much more abundant in the Arctic, the Antarctic and areas of cold-water upwelling. Killer whales are found in the open ocean, but they seem to be most abundant in coastal waters (Ridgway and Harrison, 1999).
- Populations have been documented foraging for long periods of time in shallow coastal and inter-tidal flats in just a few meters of water (Scheffer and Slipp, 1948; Tomilin, 1957).
- In addition to being found in colder water, killer whales also have been seen in warm water areas such as Florida, Hawaii, Australia, the Galapagos Islands, the Bahamas and the Gulf of Mexico (Heyning and Dahlheim, 1999). Such sightings are infrequent, but they do demonstrate the killer whales' ability to venture into tropical waters.
- Rarely, killer whales have been seen in fresh water rivers around the world such as the Rhine, the Thames and the Elbe. One even traveled some 177 km (110 mi.) up the Columbia River apparently in pursuit of fish (Scheffer and Slipp, 1948).

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Diet

- Killer whales are active, top-level ocean predators (Wiles, 2004). They have been observed preying on more than 140 species of animals, including 50 different species of marine mammals (Ford, 2009).
- Killer whales are the largest predator of warm-blooded animals alive today (Nowak, 1999). Some killer whales eat marine mammals such as seals, sea lions, baleen whales, other toothed whales, walruses and occasionally sea otters. Killer whales have been reported to eat many other types of animals including leatherback sea turtles, dugongs (Jefferson *et al*., 1991) polar bears and even a moose (Heyning and Dahlheim, 1999).
- Some killer whales eat penguins and other seabirds (Nowak and Paradiso, 1999).
- Each killer whale ecotype specializes in different prey types and hunting strategies.
- In many parts of the world, killer whales feed mainly on either fish or marine mammals, but not both (Barrett-Lennard and Heise, 2006).

Regional Differences in Diet

- Observations in New Zealand suggest that some killer whales specialize in hunting elasmobranchs such as thresher sharks (*Alopias vulpinus*), smooth-hammerhead sharks (*Sphyrna zygaena*), manta rays (*Manta birostris*), eagle rays (*Myliobatis tenuicaudatus*), stingrays (*Dasyatis* spp.) and others (Visser, 1999; Visser, 2005).
- The five forms of Antarctic killer whales differ in their diet (Pitman and Ensor, 2003):
  1. Type A whales eat mostly Antarctic minke whales.
  2. Large type B whales eat mainly seals, especially Weddell seals (Pitman and Durban, 2011). Small type B killer whales predominately hunt penguins (Pitman and Durban, 2010).
  3. Type C killer whales eat mostly Antarctic toothfish (*Dissostichus mawsoni*).
  4. Little is known about the diet of type D killer whales. When observed, this ecotype was seen preying on Patagonian toothfish (*Dissostichus eleginoides*) caught on longlines (Pitman *et al*., 2011).
- In the North Atlantic, the type 1 killer whales consume a varied diet that includes seals plus small, schooling fishes such as herring and mackerel (Foote *et al*., 2009). Type 2 killer whales specialize in cetacean prey including dolphins, porpoises and baleen whales such as minke whales (Foote *et al*., 2009).
- The diet of offshore killer whales in the northeastern Pacific include fishes such as salmon (*Oncorhynchus* spp.), sculpin (*Cottus* spp.), Pacific halibut (*Hippoglossus stenolepis*) and Pacific sleeper sharks (*Somniosus pacificus*) (Dahlheim *et al*., 2008; Ford *et al*., 2011).
- The feeding habits of resident and transient whales of the eastern North Pacific Ocean differ.
  1. Resident killer whales in the northeast Pacific are known to eat one species of squid (*Gonatopsis borealis*) and 22 species of fish including rockfish (*Sebastes* spp.), Pacific halibut (*Hippoglossus stenolepis*) and Pacific herring (*Clupea pallasi*) (Baird, 2000; Ford *et al*., 1998, 2000; Saulitis *et al*., 2000). Salmon, especially Chinook salmon (*Oncorhynchus tshawytscha*), is apparently the preferred food source for this particular group of killer whales (Ford *et al*., 1998).
  2. Resident whales spend about 60% to 65% of daylight hours foraging (Ford and Ellis, 1999). They eat a variety of fishes, although salmon is a main food source for these whales (Ford *et al*., 1998). There is no evidence of resident killer whales eating marine mammals (Ford, 2009).
  3. Transient whales spend about 90% of daylight hours foraging (Ford and Ellis, 1999). They eat primarily marine mammals such as seals, sea lions, baleen whales and other toothed whales while only occasionally eating fish (Ford, 2009).
  4. Researchers theorize that the divergent, specialized feeding habits of resident and transient killer whales helps prevent these two groups of whales from competing with each other for food (Ford, 2009).

5. Such divergent feeding habits, not known to occur in any other sympatric mammal species, has also resulted in significant differences in vocalizations, use of echolocation, group size and behavior between the two groups (Ford, 2009).

Anatomy and Physiology

Average Adult Length in the Wild

- Adult male killer whales are larger than adult females.
- Data from Icelandic killer whales indicate that an average-size male is about 5.8 to 6.7 m (19-22 ft.) long (Christensen, 1984).
- Data from Icelandic killer whales indicate that an average-size female killer whale is 4.9 to 5.8 m (16-19 ft.) long (Christensen, 1984).
- Average length of adult killer whales varies dramatically between the different ecotypes. Male type A killer whales can reach lengths of 9.2 m (30 ft.), making them the largest killer whales (Pitman *et al*., 2007). The smallest are the type C killer whales in which the adult females average 5.2 m (17 ft.) and the adult males average 5.6 m (18 ft.) in length and can reach a maximum of 6.1 m (20 ft.) (Pitman *et al*., 2007).

Maximum Length and Weight Reported in the Wild

- The largest recorded male was 9.8 m (32 ft.) in length and weighed 10,000 kg (22,000 lb.) (Jefferson *et al*., 1993).
- The largest recorded female was 8.5 m (28 ft.) and weighed 7,500 kg (16,500 lb.) (Jefferson *et al*., 1993).

Average Adult Size in AMMPA Facilities

- At SeaWorld, average size for adult males is 6.6 m (21.7 ft.). Two adult male killer whales at SeaWorld weigh 4,340 kg (9,570 lb.) and 5,380 kg (11,860 lb.). (S. Clark, personal communication. May, 2014).
- At SeaWorld, average size for females is 5.5 m (18 ft.) and 2,442 kg. (5,384 lb.). SeaWorld's adult female whales range in weight from 2,313 kg (5,100 lb.) to 3,719 kg (8,200 lb.). (S. Clark, personal communication. May, 2014).

Skin

- A killer whale's skin is smooth. The outer layer continually and rapidly renews itself, and the old skin sloughs off (Heyning and Dahlheim, 1988).
- Increased skin cell turnover increases swimming efficiency by creating a smooth body surface which reduces drag (Hicks *et al*., 1985).
- A killer whale's blubber (hypodermis) lies beneath the dermis. This blubber, measuring from 7.6 to 10 cm (3-4 in.) thick, is a layer of fat reinforced by collagen and elastic fibers (Pabst *et al*., 1999; Parry, 1949). In general, blubber plays a number of important functions:
  1. Reducing heat loss, which is important for thermoregulation (Reynolds & Rommel, 1999).
  2. Storing fat, which provides energy when food is in short supply (Reynolds & Rommel, 1999).
  3. Contributing to a killer whale's streamlined shape, which helps increase swimming efficiency (Reynolds & Rommel, 1999).

Coloration

- Killer whales are solid black and white, with a gray patch called a "saddle" or a "cape" on the back, just behind the dorsal fin. The large areas of black and white are distinctly separate.
- The entire dorsal (top) surface and pectoral flippers are black except for the gray saddle.
- The ventral (bottom) surface, lower jaw and undersides of the tail flukes are mostly white. The undersides

of the tail flukes are fringed with black.
- An oval, white "eyespot" is just above and slightly behind each eye.
- Killer whales are countershaded: the dorsal (top) surface is darker than the ventral (underneath) surface. When lighting is from above, a countershaded animal appears inconspicuous.
- The distinctive coloration of killer whales is a type of disruptive coloration, a pattern that obscures the outline of an animal by contradicting the animal's body shape. In the flickering, filtered sunlight of the sea, other animals may not recognize a killer whale as a potential predator.
- The size and shape of a killer whale's white areas and gray saddle vary among ecotypes.
- Conspicuous eye and saddle patches may help killer whales in groups coordinate social interactions, hunting and swimming in formation (Pitman and Durban, 2011).
- Albinism in killer whales is rare, but has been documented (Ellis, 1989).
- In British Columbia, a white-colored animal was diagnosed with Chédiak-Higashi Syndrome, an inherited fatal disorder characterized by loss of pigmentation and reduced life span (Taylor and Farrell, 1973). Others appear to be full-grown adults and the cause of their white coloration is unknown (Renner and Bell, 2008).

Dorsal Fin
- In adult males, the dorsal fin is tall and triangular. Reaching a height of up to 1.8 m (6 ft.) in a large adult male, it is the tallest dorsal fin of all cetaceans (Heyning and Dahlheim, 1988). In most females, the dorsal fin is slightly falcate (backward-curving) and smaller–about 0.9 to 1.2 m (3-4 ft.) tall (Heyning and Dahlheim, 1988).
- Like the flukes, the dorsal fin is made of dense, fibrous connective tissue, without bones or cartilage–the dorsal fin of adult males can grow to be taller than most humans without any hard bones to support it.
- Dorsal fin size and shapes varies between ecotypes.
- Researchers photograph the dorsal fin when the whale rises out of the water to breathe. This action exposes the most markings on the back and dorsal fin. Researchers have learned to recognize some individual killer whales from photographs, especially images of the dorsal fin and saddle patch but they may also note subtle differences in whales' body appearance, dorsal fin shape and relative size, pigmentation patterns, scars, deformities, detail of tail fluke edges, encrustations, blemishes and bite marks. Photo-identification is an important research tool for studying various aspects of cetacean biology and helps to detail the movements, reproduction, daily behaviors and population dynamics of individual whales and the groups they travel in (Olesiuk *et al*., 2005).
- Some killer whales (both male and female) have irregular-shaped dorsal fins: they may be curved, wavy, twisted, scarred or bent. Of the 30 adult male killer whales that have been photo-identified in New Zealand waters, seven (23%) had collapsing or bent dorsal fins (Visser, 1998).
- It is not fully understood why wild killer whale populations develop abnormal dorsal fins or why the observed killer whale males around New Zealand had such a high rate of dorsal fin abnormalities compared to other studied populations. Researcher theories include that these observed abnormalities may be attributed to age, stress, and/or attacks from other killer whales (Visser, 1998). However, as killer whales at SeaWorld tend to spend more time at the surface working with their trainers, and many of the adult males have slumped or bent dorsal fins, it seems probable that time spent at the surface may be a contributing factor.

Teeth
- Toothed whales have only one set of teeth; they are not replaced if lost (Graham and Dow, 1990).
- The number of teeth for killer whales varies among individuals, but there are usually 10 to 14 teeth on each side of each jaw for a total ranging from 40-56 teeth (Heyning and Dahlheim, 1999).

- The length of a killer whale's tooth is up to 10 to 13 cm (4-5 in.) long (Ford, 2009; Nishiwaki, 1972) and about 2.5 cm (1 in.) in diameter. Teeth are interlocking, conical in shape and designed not for chewing but rather for grasping and tearing prey (Graham and Dow, 1990).
- The teeth of killer whales begin to erupt from several to 11 weeks of age, which corresponds with the time that calves are seen taking solid food from their mothers (Haenel, 1986; Asper *et al*., 1988; Heyning, 1988).
- Extensive wear has been noted on the teeth of older individuals (Heyning and Dahlheim, 1999). Killer whales have been seen with abscesses and males, females and juveniles have been observed with teeth worn down to the dentin with pulp exposed (Graham and Dow, 1990).
- Most adult North Atlantic type 1 killer whales have severely, worn-down teeth, which is consistent with a diet of suctioning up small fishes (Foote *et al*., 2009). Adult offshore killer whales also tend to have teeth worn down to the gumline presumptively due to their diet that includes sharks with abrasive skin (Dahlheim *et al*., 2008; Ford *et al*., 2011).

Sensory Systems

Hearing

- Killer whales have a well-developed, acute sense of hearing. A killer whale's brain and nervous system appear physiologically able to process sounds at much higher speeds than humans, most likely because of their echolocation abilities (Ridgway, 1990; Wartzok and Ketten, 1999).
- Ears, located just behind the eyes, are pinhole sized openings, with no external ear flaps. A toothed whale's small external ear openings don't seem to be important in conducting sound. They lead to reduced ear canals that are not connected to the middle ears (Au *et al*., 2000). Soft tissue and bone conduct sound to a toothed whale's middle and inner ears. In particular, fat lobes in a toothed whale's lower jaw appear to be an adaptation for conveying sound to the ears (Au *et al*., 2000).
- In killer whales, the ear bone complex (ootic capsule) isn't attached to the skull. Ligaments hold each ear bone complex in a foam-filled cavity outside the skull. This separation of the ear bone complex allows a killer whale to localize sound (directional capacity), which is important for echolocation (Au *et al*., 2000; Wartzok and Ketten, 1999).

Range of Hearing

Early studies published in 1972 suggested that the hearing range of killer whales was about 0.5 to 31 kHz (Heyning and Dahlheim, 1999). More recent studies show killer whales can hear sounds at frequencies as high as 120 kHz (Szymanski, 1999). Greatest sensitivity ranged from 18 to 42 kHz with the least sensitivity to frequencies from 60 to 120 kHz (Szymanski, 1999).

Sound Production Frequency Range

The frequency of killer whale whistles ranges from about 0.5 to 40 kHz (Richardson, 1995 as per A. Bowles), with peak energy at 6 to 12 kHz (Wartzok and Ketten, 1999).

Types of Sounds Produced

- Killer whales produce clicks, whistles and pulsed calls for the purposes of echolocation and social signaling (Ford, 2000).
- Studying northern resident killer whales, researchers found that the whales produced more whistles when they were close to other individuals and only sporadically emitted them when the whales were dispersed over larger areas (Thomsen *et al*., 2002).
- Pulsed calls are the most common vocalization of killer whales. Experts think these calls function in group recognition and coordination of behavior (Deecke *et al*., 2005). Killer whales make these calls at

frequencies of about 0.5 to 25 kHz, with peak energy at 1 to 6 kHz (Wartzok and Ketten, 1999).

- Whistles are used for close-range, or "private" communication and coordination of behavioral interactions between animals. They are high pitched, show a high degree of directionality and are highly modulated. As a result, they don't carry far underwater (Reisch and Deecke, 2011).
- Transient killer whales also use whistles, but more sparingly and have a smaller repertoire in comparison to residents (Reisch and Deecke, 2011).
- A calf is most likely to develop calls like those of its mother (Ford, 2009). Vocal development studies at SeaWorld have determined that a calf learns its repertoire of calls selectively from its mother, even when other killer whales may be present and vocalize more frequently than the mother (Bowles *et al*., 1988).
- Calls that sound the same time after time are called stereotyped calls. All of a killer whale's stereotyped calls make up a whale's repertoire. The individuals of any particular pod share the same repertoire of calls, a vocalization system called a dialect (Ford, 2009). Although scientists have noted that there is some type of structure to the calls, a dialect is not the same thing as a language.
- No two pods share an entire repertoire. Thus, each pod has its own unique dialect (Tyack, 1999). In fact, the vocal repertoires of each pod are distinct enough that scientists can identify pods by the calls they produce (Ford, 2009).
- Pods may share a certain level of their repertoire with other pods while other portions are unique. The more similarities they share may indicate the degree the pods and individuals are related (Ford, 2009).
- Killer whales that are separated by significant geographical distances have completely different dialects. An analysis of Icelandic and Norwegian killer whale pods revealed that the Icelandic population made 24 different calls and the Norwegian whales made 23 different calls, but the two populations did not share any of the same calls (Moore *et al*., 1988).

Echolocation

- Killer whales often need to navigate in the absence of light/good visibility. Therefore, hearing is essential to them. The killer whale's primary sensory system is the auditory system. It is a highly-developed system that includes biological sonar ability or echolocation. The animals emit high-frequency sounds, and detect and analyze returning echoes from those sounds, to determine the size, shape, structure, composition, speed and direction of an object (Au, 1993; Au, 2009).
- Like other dolphins, echolocating killer whale use internal nasal structures called "phonic lips" to produce directional, broadband clicks in rapid succession, called a train. Each click lasts less than one millisecond. One study of resident killer whales measured broadband, bimodal echolocation clicks that typically showed low frequency peaks between 20 to 30 kHz and high frequency peaks between 40 to 60 kHz (Au *et al*., 2004).
- The use of echolocation and calls may vary greatly between fish-eating and mammal-eating ecotypes of killer whales (Barrett-Lennard *et al*., 1996).
    1. In the North Pacific, resident killer whales are more vocal (Ford and Ellis, 1999) and 27 times more likely to be producing click trains for echolocation (Barrett-Lennard *et al*., 1996).
    2. These differences are likely due to the fact that transients attempt to prey upon other types of marine mammals, which have more acute hearing in the frequency range of sonar clicks compared to fish (Barrett-Lennard *et al*., 1996).
    3. In an attempt to go unnoticed, studies suggest that transient killer whales use passive listening more to detect and locate marine mammal prey instead of relying on echolocation (Barrett-Lennard *et al*., 1996).

Vision

- Killer whale vision is well developed (White *et al*., 1971).

- The strongly convex (spherical) lens of a marine mammal differs from that of a land mammal (Mass and Supin, 2007).
  1. In the eye of a land mammal, the cornea focuses light rays toward the lens, which further focuses the light rays onto the retina. Underwater, the cornea isn't able to adequately focus waves into the lens because the refractive index of water is similar to that of the interior of the eye (Mass and Supin, 2007).
  2. The eye of a marine mammal compensates for this lack of refraction at the cornea interface by having a more strongly spherical lens. It is more similar to the lens of a fish's eye than the lens of a land mammal's eye (Mass and Supin, 2007).
  3. In air, a marine mammal's eye compensates for the added refraction at the air-cornea interface. At least in bright light, constricting the pupil helps, but it doesn't fully explain how a whale achieves visual acuity in air (Mass and Supin, 2007). Research is ongoing.

Color Vision
DNA analysis of several other species of toothed whales indicated that the eyes of these whales do not develop pigment cells called short-wave-sensitive (S-) cones, which are sensitive to blue light. Researchers theorize that all modern cetaceans, including killer whales, lack these visual pigments and therefore aren't able to discriminate color in the blue wavelengths (Peichl *et al*., 2001; Levenson and Dizon, 2003).

Smell (Olfaction)
Olfactory lobes of the brain and olfactory nerves are absent in all toothed whales (Pabst *et al*., 1999), indicating that they have no sense of smell. Being air-breathing mammals that spend a majority of time under water, a sense of smell would go largely unused in killer whales.

Taste (Gustation)
In zoological parks, killer whales show strong preferences for specific types of fishes. Overall, however, little is known about a whale's sense of taste. Behavioral evidence suggests that bottlenose dolphins, a closely related species, can detect three if not all four primary tastes. The way they use their ability to "taste" is unclear (Friedl *et al*., 1990). Scientists are undecided whether dolphins have taste buds like other mammals. Three studies indicated that taste buds may be found within 5 to 8 pits at the back of the tongue. One of those studies found them in young dolphins and not adults. Another study could not trace a nerve supply to the taste buds. Regardless, behavioral studies indicate bottlenose dolphins have some type of chemosensory capacity within the mouth (Ridgway, 1999).

Tactile
Anatomical studies and observations of behavior indicate that a killer whale's sense of touch is well developed. Studies of closely related species (common dolphins, bottlenose dolphins and false killer whales) suggest that the most sensitive areas are the blowhole region and areas around the eyes and mouth (Wartzok and Ketten, 1999).

Swimming, Diving and Thermoregulation

Maximum Swimming Speed
Killer whales are among the fastest swimming marine mammals. Killer whales can swim at speeds of up to 45 kph (28 mph), but probably only for a few seconds at a time (Williams, 2009).

Average Swimming Speed
Killer whales usually cruise at much slower speeds, less than 13 kph (8 mph). They can cruise slowly for long

periods of time (Nowak, 2003).

Average Dive Duration

- Estimates of dive durations vary.
- In a study done in the eastern North Pacific, resident killer whales repeated a pattern, usually making three or four 15-second dives followed by a dive that lasted about 3-4 minutes (Bigg *et al*., 1987).
- In another study, average dive duration for North Pacific resident killer whales was approximately 2.3 minutes (Baird *et al*., 2005).
- Transient killer whales in the North Pacific have been recorded diving for up to 11.2 minutes (Miller *et al*., 2010).
- In another study, transient whales in the eastern North Pacific often stay submerged for more than 5 minutes and occasionally for more than 15 minutes in a single dive (Bigg *et al*., 1987).
- North Pacific fish-eating resident adult male killer whales dive more often and deeper than adult females (Baird *et al*., 2005).

Average Dive Depth

- Although not generally deep divers, foraging resident killer whales can dive to at least 100 m (328 ft.) or more (Baird *et al*., 1998).
- Resident killer whales spend the vast majority of the time (>70%) in the upper 20 m (65.6 ft.) of the water column (Baird *et al*., 1998).
- Over 80% of dives recorded were less than 20 m (65.6 ft.) deep; 70% of dives were less than 10 m (33 ft.) deep (Baird *et al*., 2005).
- Overall the whales (transient mammal-eating whales) spent 50% of their time 8 m (24 ft.) or shallower and 90% of their time 40 m (130 ft.) or shallower (Miller *et al*., 2010).

Maximum Dive Depth Recorded

The deepest dive known for a killer whale, performed under experimental conditions, was 259 m (850 ft.) (Bowers and Henderson, 1972). A group of seven killer whales were fitted with time-depth recorders in 2002 to study natural dive behaviors. One of these whales, a juvenile, twice dove to a depth of more than 228 m (748 ft.) (Baird *et al*., 2003).

Behavior

Social Grouping

- Resident populations of North Pacific killer whales, particularly around coastal British Columbia, Washington, and Alaska, have been studied since the early 1970s. Based on long-term studies, the basic social unit of resident killer whales in these areas is called a matriline (Ford, 2009).
- A matriline is a group of killer whales connected by maternal descent, such as a female with her son and/or daughters. The matriline may also include the offspring of her daughters as well (Ford, 2009).
- This core group is highly stable with bonds that appear to be extremely strong—individuals are rarely seen apart for more than a few hours. Individuals have not been seen to permanently leave any of these observed resident matrilines (Ford, 2009).
- Some matrilines may consist of only one generation—others may include as many as four generations of related whales (Ford, 2009).
- A pod is the next level of social structure observed in resident whales of the North Pacific. A pod contains a group of related matrilines that travel together. Likely they share a past, common maternal ancestor (Ford, 2009). Pods are less stable and it's not unusual for a matriline to break away from the pod for an extended period, perhaps for weeks or months at a time (Ford, 2009).
- A further social level is called a clan. Clans are made up of pods in an area with similar vocal dialects

and are thought to be related. These pods may have developed from one ancestral pod that grew and fragmented over time. Clans inhabit overlapping geographic areas, and pods from different clans are frequently seen traveling together (Ford, 2009).

- The top social level described for resident killer whales of the North Pacific is called a community. A community is not based upon maternal links or vocal similarities but rather it is a group of killer whales that share a common range and regularly associate with one another (Ford, 2009).
  1. Pods within one community rarely, if ever, travel with those of another community. However, their ranges can overlap in some areas (Ford, 2009).
  2. Along the coastal waters of British Columbia, Washington and Alaska, three communities of residents have been documented; southern Alaskan (11 pods, 2 clans), southern (3 pods, 1 clan), and northern (16 pods, 3 clans) (Ford, 2009).
  3. Occasionally there is an exchange of pod members, such as for breeding purposes (Ford *et al*., 1994).
- Group size can vary. Resident pods usually include between five and 50 whales (Ford and Ellis, 1999). In general, resident pods are larger than transient pods (Bigg *et al*., 1990).
- Transient pods usually include seven whales or less (Ford and Ellis, 1999). In fact, some transient "pods" observed in the North Pacific consist of a solitary adult male (Bigg *et al*, 1990). Rarely, transient pods come together to form groups of 12 or more (Ford and Ellis, 1999).
- Offshore killer whales in the wild are sighted in groups of less than 20 to more than 100 individuals (Dahleim *et al*., 2008).
- Off Alaska and Antarctica, groups of more than 100 animals have been observed (Heyning and Dahlheim, 1999). Larger groups of 130 to 500 individuals have also been seen, with one report of a gathering of some 2,500 individuals (Ellis, 1989). These larger groups may be due to seasonal prey aggregations, for social interaction, or for mating (NOAA, 2013). Researchers are uncertain why killer whales form such large groups at times.

Foraging

- Killer whales are known to hunt cooperatively when foraging for food (Ford, 2009). At times they work together to encircle and herd small prey before attacking. The comparatively large pod size of resident whales is an advantage when herding a school of fish (Van Opzeeland *et al*., 2005).
- Researchers observed Norwegian killer whales hunting cooperatively using a "carousel-feeding" technique. They cooperatively herded small fishes into a tight ball close to the surface. Then the whales stunned the fishes with their tail flukes and ate the stunned fish (Similä, 1997).
- To hunt a large baleen whale, a pod of killer whales may attack the whale from several angles. One such documented attacked was witnessed between a group of about 30 killer whales and an 18.2-m (60-ft.) blue whale. Two killer whales stayed ahead and two brought up the rear while the others surrounded the blue whale from the sides and underneath in an apparent effort to prevent escape. Some leaped onto its back. The whales took turns biting flesh and blubber from their prey. After five hours, the pod broke off the attack (Tarpy, 1979).
- Around New Zealand a group of seven killer whales were observed hunting a shortfin mako shark (*Isurus oxyrhinchus*). As the shark attempted to retreat, it was bitten and held by its tail and then around its girth and head until consumed (Visser *et al*., 2000). Another group of killer whales was filmed attacking a blue shark (*Prionace glauca*) by striking it hard at the surface of the water with their tail flukes (Visser *et al*., 2000).
- Transient pods are known to "sneak-attack" other marine mammals. These small groups of transients most often hunt quietly or silently as sound could alert potential prey to their presence. It's believed that these transients locate marine mammal prey by passively listening for sounds (Ford, 2009).

- Other observed transient hunting techniques include driving and trapping groups of Pacific white-sided dolphins in confined bays and ramming sea lions with their heads or stunning them with tail fluke swats before taking the animal underwater and drowning it (Ford, 2009).
- Killer whales sometimes hit ice floes from below to knock penguins and pinnipeds into the water (Fraser, 1949). When an ice floe was too big to be overturned, killer whales were seen to swim by and create a wave large enough to wash a hauled out seal back into the water (Guinet, 1990)
- Killer whales also hunt individually. In the Antarctic, killer whales slide out onto ice floes to hunt penguins. Similarly, killer whales sometimes slide up onto sand bars or beaches to hunt pinnipeds such as juvenile elephant seals (Lopez and Lopez, 1985; Guinet, 1990).
- An encounter between a great white shark (*Carcharodon carcharias*) and killer whales was documented off of Southeast Farallon Island near San Francisco, California. Two killer whales were in the area feeding on a California sea lion (*Zalophus californianus*)–a favored food of great whites. Perhaps the smell of fresh sea lion blood drew the shark to the area, but once one of the killer whales sighted the great white it immediately charged and contacted the shark under water. The killer whale pulled the 3 to 4 m (10-13 ft.) shark to the surface in its mouth and the killer whales consumed sections of the great white such as its enormous liver. This is certainly no indication of what may happen every time killer whales face great whites, but it does demonstrate the variety of a killer whale's diet (Visser *et al*., 2008; Pyle *et al*., 1999).
- Sometimes killer whales feed in connection with fisheries operations, eating fishes that slip from the nets and bycatch (nontarget fish caught during a fishing operation) discarded by fishermen. In some areas, killer whales congregate near longline boats and feed on the hooked fish (Couperus, 1994).

Sleep State

- Several species of cetaceans, including the bottlenose dolphin and beluga whale, have been shown to engage in unihemispheric slow wave sleep (USWS) during which one half of the brain goes into a sleep state, while the other maintains visual and auditory awareness of the environment and allows the animal to resurface for respiration. This ability may help to avoid predators as well as maintain visual contact with cohorts/offspring. Dolphins have one eye closed during USWS (Lyamin *et al*., 2008; Lyamin *et al*., 2004; Ridgway, 2002; Ridgway, 1990).
- Observers note that killer whales typically rest, motionless, at various times throughout the day and night for short periods of time or for as long as eight hours straight. While resting, killer whales may swim slowly or make a series of three to seven short dives of less than a minute before making a long dive for up to three minutes (Jacobsen, 1990).
- When sleep researchers studied two newborn killer whale calves and their mothers at SeaWorld, they discovered that the mothers and calves didn't appear to sleep or rest at all for the first month of a calf's life (Lyamin *et al*., 2005). During this period of "exceptional wakefulness" calves were not seen to close one eye, indicating that they were not engaged in unihemispheric slow wave sleep. Over the next several months, the whales gradually increased the amount of time they spent resting to normal adult levels. Four bottlenose dolphin calf-mother pairs showed the same sleep-behavior pattern. Staying active and responsive after birth may be an adaptation for avoiding predators and maintaining body temperature while the calf builds up a layer of blubber (Lyamin *et al*., 2005).

Reproduction and Maternal Care

Sexual Maturity

- Depending on the geographic area studied, females are estimated to become sexually mature when they reach about 4.6 to 5.4 m (15-18 ft.) in length, which roughly corresponds to ages between 7 to 16 years (Christensen, 1984; Perrin and Reilly, 1984; Olesiuk *et al*., 1990).
- Age at first estrus for 1st-generation SeaWorld killer whales was calculated as 7.5 ± 0.3 years

(median = 7.4, range: 5.7–8.5 years, n = 9). Total body length at 1st estrus was 483.7 ± 10.5 cm (median = 485, range: 435–523 cm) (Robeck *et al*., 2015).

- Depending on the ecotype, males become sexually mature when they reach body lengths ranging from 5.2 to 6.4 m (17-21 ft.) in length, which corresponds to ages between 10 to 17.5 years (an average of about 15 years) (Christensen, 1984; Perrin and Reilly, 1984; Duffield and Miller, 1988; Olesiuk *et al*., 1990).
- Based on serum testosterone concentrations in zoological parks, killer whales males reached puberty from 8 to 12 years of age at 16 feet and were sexually mature from 13 years of age and greater than 18 feet in length (Robeck and Monfort, 2006).
- In males, dorsal fin length is influenced both by sex linked hormone production (most notable testosterone) and genetics. Captive studies demonstrate that a dorsal fin height to length ratio of 1.4 was associated with sexual maturity in wild males (Olesiuk *et al*, 1990), but it has more recently been demonstrated that males can reach this ratio 1 to 2 years prior to reaching sexual maturation (Robeck and Monfort, 2006).
- Female killer whales exhibit reproductive sensense (menopause). Resident female killer whales in the north Pacific have not been known to reproduce after 46 years of age, and 50% of the females do not reproduce after 38 years of age (Olesiuk *et al*., 2005).

Gestation

Gestation is about 17 months. Killer whale pregnancies at zoological parks have ranged from 15.7 to 18 months (Duffield, *et al*., 1995; Robeck, 2004; Walker *et al*., 1988).

Ovulation Cycle

Based on studies in zoological facilities it has been demonstrated that killer whales have a 41 day estrous cycle with an 17 day follicular phase and a 21 day luteal phase (Robeck *et al*., 1993; Robeck *et al*., 2004).

Birthing Season

Calves are born throughout the year, with no statistical evidence for birth seasons (Duffield *et al*., 1995). However, specific regions may have peak birth months. For example, in the northeast Pacific Ocean, many calves are born between October and March (Boyd *et al*., 1999). While males produced sperm throughout the year, peak testosterone and sperm production corresponded to months from March to June in North American Zoological facilities (Robeck and Monfort, 2006; Robeck *et al*., 2011).

Nursing Period

Killer whale calves born at zoological parks generally nurse for about a year, but may continue to nurse occasionally for as long as two years. This corresponds with observations in the wild (Ford, 2009).

Killer whale calves observed under human care began nursing several hours after birth. First successful nursing attempts ranged from 1.8 to 29.3 hours after birth (S. Clark personal communication, 2014). Killer whale milk is very rich in fat–an efficient energy source to drive a calf's high metabolism. The fat content fluctuates as the calf develops.

Average Years Between Births

Based on limited data collected from populations at sea and in zoological facilities, a female may bear a calf every 2 to 14 years, with an average of about every five years (Ford, 2009).

AMMPA Standardized Information:
Killer Whale

Longevity and Mortality

Survivorship in the Wild

- Different methods exist for estimating the life spans of killer whales. While some researchers believe they know conclusively how long killer whales live, the scientific community does not yet fully agree on this topic.
- By counting growth layers in teeth, scientists find that killer whales in the North Atlantic may live to 35 years (Ford, 2009). Studies are still refining this method of aging (Ford, 2009).
- The photo-identification of killer whales in the Pacific Northwest began in 1973 and provides one of the longest cetacean field studies ever (Olesiuk *et al*., 2005).
  1. When factored in at birth, the average life expectancy of southern and northern resident killer whales is about 29 years for females and 17 years for males (Olesiuk *et al*., 2005).
  2. If a killer whale survives the first six months, a female's average life expectancy is within the range of 46 to 50 years and a male's is 30 to 38 years (Ford, 2009; Olesiuk, 2012).

Survivorship in Marine Life Parks

- New research shows there is no difference in life expectancy between killer whales born at SeaWorld and a well-studied population of wild killer whales (Robeck *et al*., 2015).
- Data collected on life-history parameters of known-age animals from the northern (NR) and southern resident (SR) killer whales of the eastern North Pacific were compared with life-history traits of killer whales located at SeaWorld (SEA) facilities. Annual survival rate (ASR) for SEA increased over approximately 15-year increments with rates in the most recent period (2000–2015 ASR: 0.976) improved over the first 2 periods of captivity (1965–1985: 0.906; 1985–2000: 0.941) (Robeck *et al*., 2015).
- The survival rate (SR) (0.966) and ASR for the combined data for both the southern residents and whales of the eastern North Pacific (0.977) were higher than that of SEA until 2000, after which there were no inter-population differences (Robeck *et al*., 2015).
- Based on ASR, median and average life expectancy were 28.8 and 41.6 years (SEA: 2000–2015), 20.1 and 29.0 years (SR), and 29.3 and 42.3 years (NR), respectively (Robeck *et al*., 2015).
- The ASR for animals born at SEA (0.979) was higher than that of wild-caught SEA animals (0.944) with a median and average life expectancy of 33.1 and 47.7 years, respectively (Robeck *et al*., 2015).
- These data present evidence for similar life-history parameters of free-ranging and captive killer whale populations and the reproductive potential and survivorship patterns established herein have application for use in future research concerning the overall health of both populations (Robeck *et al*., 2015).
- Currently at SeaWorld, five killer whales are older than 30 with one being close to 50 (2015, http://www.wsj.com/articles/ad-targets-seaworld-over-killer-whales-1405703464).

Calf Survivorship

- For unknown reasons, researchers suspect killer whale calf mortality within the first six months to be "very high" (Olesiuk *et al*., 2005). In the Pacific Northwest, for example, an estimated 43% of all calves die in the first six months. In other killer whale populations, calf mortality may be as high as 50% during the first year (Olesuik *et al*., 1990; Olesuik *et al*., 2005).
- Data collected on life-history parameters of known-age animals from the northern (NR) and southern resident (SR) killer whales of the eastern North Pacific were compared with life-history traits of killer whales located at SeaWorld (SEA) facilities. Average calf survival rate to 2 years of age for SEA animals (0.966) was significantly greater than that for SR killer whale populations (0.799) (Robeck *et al*., 2015).

Predators

Killer whales are a top predator. Healthy adult killer whales have no natural predators of note (Ellis, 1989).

Diseases and Parasites

- Killer whales and other whales develop stomach ulcers, skin diseases, tumors, respiratory disorders and heart disease (Heyning and Dahlheim, 1988). Hodgkin's disease has also been seen in killer whales (Yonezawa *et al*., 1989).
- Parasites–including roundworms, tapeworms and flukes–may affect a killer whale's health (Heyning and Dahlheim, 1988).
- Recently described disease conditions include *Salmonellosis* in a neonatal stranded calf (Colegrove *et al*., 2010) and West Nile Virus in an adult (St. Leger *et al*., 2007). Endogenous retroviruses has also been documented within the killer whale genome (LaMere *et al*., 2009). The significance of these viruses on the health of killer whale populations is yet unknown.
- Killer whales suffer from viral, bacterial, and fungal infections (Heyning and Dahlheim, 1988). In most cases, parasite infestations alone are unlikely to debilitate otherwise healthy animals, but they may harm animals that are already weakened by other illnesses or injuries.

Conservation

Hunting

Killer whales have never been consistently exploited on a large-scale basis. They have been hunted on a small scale for their meat, hides, blubber and internal organs, which are processed into fertilizer and used as bait (Heyning and Dahlheim, 1999). Native tribes, such as Inuits around eastern Greenland, hunt killer whales for meat and whale skin (called muktak) (2014, http://www.cbc.ca/news/canada/north/greenland-hunting-more-killer-whales-as-climate-changes-1.2782297).

Views from the Past

- A killer whale image was found carved into a rock in northern Norway and is estimated to be some 9,000 years old, making it the earliest known depiction of a cetacean (Carwardine *et al*., 1998).
- Some human cultures have long been fascinated by killer whales, but until recently their lives were shrouded in misinformation–in the past, this has led to the persecution of these whales (Ford, 2002).
- A few cultures respected killer whales, yet much of the ancient world did not. During the first century A.D., a Roman scholar named Pliny the Elder wrote that killer whales "...cannot be properly depicted or described except as an enormous mass of flesh armed with savage teeth." (Ford *et al*., 1994).
- In 1835, R. Hamilton wrote that the killer whale "...has the character of being exceedingly voracious and warlike. It devours an immense number of fishes of all sizes...when pressed by hunger, it is said to throw itself on everything it meets with..." (Ellis, 1989).
- Many civilizations envisioned killer whales as terrifying threats to humans, with a 1973 U. S. Navy diving manual warning that killer whales "...will attack human beings at every opportunity." (Ford *et al*., 1994).

Confrontations with Fishermen

- In some areas, killer whales feed in connection with fishing operations, "stealing" fish from the fishermen. They eat fish from commercial longlines in New Zealand (Visser, 2000) and Alaska (Ford, 2009). In Brazil, observers reported that more than 50% of the daily swordfish catch may be eaten by killer whales, and that occasionally the whales eat the entire catch (Secchi *et al*., 1998).
- Some fishermen blame the destruction of millions of dollars of equipment and fish loss on killer whales, and on rare occasions some have taken to shooting killer whales. Recently, researchers have attempted to develop non-lethal killer whale deterrents, including acoustic harassment devices, electric currents, sparker devices (emits a flash of light to startle whales), rubber bullets, bubble screens, chemicals such as lithium chloride ether (to induce nausea) and reducing the sounds caused by the fishing operations. None of these deterrents have been very effective (Dahlheim, 1988).

- Fishermen shooting killer whales is believed to be one of the contributing factors to the unusually high mortality experienced by one pod off Prince William Sound–whales known for their habit of taking black cod off long-lines (Matkin *et al*., 1986).

Pollution

- Both natural toxins and human-made toxins can harm killer whales.
- Chemicals that are used on land enter waterways through runoff and eventually end up in the ocean as pollution (National Marine Fisheries Service, 2008). Industrial pollutants are introduced to the marine environment through mining operations, agriculture, pulp mills and other coastal industrial development. Household and garden pesticides can enter waterways through sewers and storm drains.
- Some pollutants enter the ocean food chain and become concentrated in the bodies of killer whales and other marine predators. Some of these pollutants (which may not be harmful in small quantities) are stored in an animal's body tissues after they are ingested. Prey animals that contain such toxins in their bodies pass the toxins on to animals higher in the food chain. Pollutants can become concentrated and reach dangerous levels in the bodies of large, apex predators such as killer whales (National Marine Fisheries Service, 2008).
- Persistent organic pollutants (POPs) are a group of environmental pollutants that include PCBs (polychlorinated Biphenyls), DDTs (dichlorodiphenyltrichloroethane) and PBDEs (Polybrominated diphenyl ethers) from flame retardants. When ingested, POPs aren't metabolized or eliminated. These fat-soluble molecules accumulate in fats, such as blubber (O'Shea, 1999) and only enter the bodies of killer whales through their diet (Hickie *et al*., 2007). Use and production of PCBs and DDTs in the United Stated were banned in the 1970s, but these POPs continue to be widely used elsewhere around the world (National Marine Fisheries Service, 2008), and all POPs persist in the environment. POPs can reduce reproductive capability and may be one factor in the decline of the 'Southern Resident' killer whale population (Krahn *et al*., 2009).
- Scientists analyzed blubber samples from killer whales of the eastern North Pacific Ocean. Experts have not yet defined a "toxic threshold" of PCBs for killer whales, but they do know at what concentrations these pollutants adversely affect harbor seals. PCB concentrations in most of the killer whale blubber samples surpassed these dangerous levels (Ross *et al*., 2000).
- A mother killer whale transfers PCBs to her calf as the calf develops during gestation and also through fat-rich milk as the calf nurses after birth (Ylitalo *et al*., 2001; Ross *et al*., 2000).
- In a previous study, North Pacific transient whales were more contaminated than resident whales, probably due to differences in diet. Marine mammals (the preferred prey of transient killer whales) have higher PCB levels than do fish (which make up the diet of resident whales) (Ylitalo *et al*., 2001; Ross *et al*., 2000).
- Up to 1,000 new chemicals enter the environment every year (Grant and Ross, 2002), so many other understudied or unknown chemicals could be affecting marine life including polychlorinated paraffins (PCPs), polychlorinated naphthalenes (PCNs), polychlorinated terphenyls (PCTs), personal care products like shampoo and pharmaceuticals such as synthetic estrogens and steroids (National Marine Fisheries Service, 2008).

Oil

- Oil spills can have long term effects on killer whale populations. Populations of a resident and a transient pod inhabiting Alaskan waters near the site of the 1989 Exxon Valdez oil spill experienced major declines in the year following the spill and have failed to recover to pre-spill numbers (Matkin *et al*., 2008).
- Oil spills especially threaten transient killer whale populations since they may hunt prey animals sickened by exposure to the spill (Matkin and Saulitis, 1997; National Marine Fisheries Service, 2008).

- A larger but often overlooked problem is the continuous, small-scale discharges of oil into the ocean which greatly exceed the volume released by major spills (Clark, 1997).

Whale Watching

- Whale watching expeditions bring people close to wild whales and help people learn about them, but the steady growth of recreational whale watching has raised some concerns with killer whale researchers (Hoyt, 2001). In British Columbia and the state of Washington, killer whales are the most popular cetacean of commercial whale watching companies (Hoyt, 2001). Higher concentrations and closer proximity of boats can force whales away from their traditional habitats and reduce a killer whale's echolocation abilities when hunting for prey (National Marine Fisheries Service, 2008).
- The National Oceanic and Atmospheric Administration (NOAA) Fisheries has developed "Marine wildlife viewing guidelines" to protect marine animals. Among other recommendations, the guidelines instruct whale watchers to keep their distance. Impeding the whales' right of way is not allowed. Chasing, harassing, touching and feeding animals also are prohibited (2015, http://www.nmfs.noaa.gov/pr/education/viewing.htm).

Legal Protection

- The U.S. Marine Mammal Protection Act (MMPA) of 1972 made it illegal to hunt or harass marine mammals in the United States. The MMPA does allow for certain exceptions: native subsistence hunting; taking marine mammals for research, education, and public display; and taking restricted numbers of marine mammals incidentally in the course of fishing operations.
- The Endangered Species Act of 1973 (ESA) conserves declining species and their ecosystems. A species is considered endangered if it is in danger of extinction. As defined in the ESA, a protected "species" may include a subspecies or a distinct population segment (DPS). In 2005, the southern resident killer whales of the eastern Pacific Ocean were listed as an endangered DPS under the ESA. The population was estimated at 200 whales in the late 1800s and currently stands at about 85 whales (NOAA, 2013). This DPS faces risks including vessel traffic, toxic chemicals and competition for food, especially salmon. The small DPS is also susceptible to potential catastrophic risks, such as disease or oil spills.
- In Canada, the Species at Risk Act (SARA) became law in 2003. A main purpose of SARA is "to provide for the recovery of wildlife species that are extirpated, endangered or threatened as a result of human activity" (Fisheries and Oceans Canada, 2007). Under SARA, the "West Coast transient" population of killer whales was listed as "Threatened" and issued a recovery strategy to deal with dangers that includes bioaccumulation of toxins in prey items and physical and acoustic disturbances (Fisheries and Oceans Canada, 2007).
- The Convention in International Trade of Endangered Species (CITES) is an international treaty developed in 1973 to regulate trade in certain wildlife species. Killer whales are listed under CITES Appendix II: species that are not necessarily now threatened with extinction, but that may become so unless trade is closely controlled (2015, http://www.cites.org/eng/app/appendices.php).

AMMPA Facilities Contributions to Conservation

Up until the 1970s, killer whales were mainly regarded as a nuisance animal (Olesiuk *et al*., 2005). Attitudes began to change dramatically, thanks to displays at marine life parks that allowed people to learn about and appreciate killer whales like never before (Olesiuk *et al*., 2005).

Marine mammals spend much of their time underwater, making it difficult to observe and quantify certain aspects of their lives (Clark and Odell, 1999). Studying killer whale nursing behaviors in the wild, for example, would require either close, limited observations from a vessel or underwater viewing by humans, either of which would likely cause alterations to the behaviors under investigation (Clark and Odell, 1999; Morisaka *et al*., 2010).

The study of captive cetacean populations in controlled research settings has provided fundamental information on many species-specific aspects of their biology. Observing cetaceans in marine life parks allow for long-term, fine-scale studies that would be difficult to achieve in the ocean (Morisaka *et al*., 2010) and such studies add to our overall knowledge of cetaceans and supplement fragmented information from observations in the wild (Clark and Odell, 1999; Morisaka *et al*., 2010).

A contribution to our understanding of the basic physiological processes in killer whales has been derived from captive populations including adaptations to diving (Hedrick and Duffield 1991), auditory detection, echolocation and learning (Hall and Johnson 1972; Dahlheim and Awbrey 1982; Bowles *et al*. 1988; Szymanski *et al*. 1999; Crance *et al*. 2013), reproductive physiology (Benirschke and Cornell 1987; Walker *et al*. 1988; Robeck *et al*. 1993, 2004, 2006), growth and development (Asper *et al*. 1988; Clark and Odell 1999a, 1999b; Clark *et al*. 2000), metabolic and energy requirements (Kastelein *et al*. 2000; Williams *et al*. 2011; Worthy *et al*. 2013), health status (Cornell 1983; Reidarson *et al*. 2000; Robeck and Nollens 2013), immune system function (King *et al*. 1996; Funke *et al*. 2003), and genetics (Stevens *et al*. 1989).

The utility of these captive studies for health assessment and conservation strategies for free-ranging cetacean populations requires that captive populations are healthy and thriving. In the killer whale and other delphinids, commonly used population health indicators are reproductive success and age-specific survivorship patterns (Wells and Scott 1990; Small and DeMaster 1995; Olesiuk et al. 2005; Matkin et al. 2008; Poncelet et al. 2010; Matkin *et al*. 2013). Recent analysis of captive bottlenose dolphin (*Tursiops truncatus*) populations, a species closely related to killer whales, demonstrated that reproductive success and survivorship patterns are comparable to or exceed those experienced by their wild counterparts (Wells and Scott 1990; Innes 2005; Venn-Watson *et al*. 2011a). As such, these captive populations can provide models for understanding geriatric changes and impacts of unique age or event-specific physiologic stressors to wild populations (Venn-Watson et al. 2011a, 2011b; Robeck and Nollens 2013).

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