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# Do Wild Polar Bears (*Ursus maritimus*) Use Tools When Hunting Walruses (*Odobenus rosmarus*)?

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ABSTRACT. Since the late 1700s, reports of polar bears (*Ursus maritimus*) using tools (i.e., pieces of ice or stones) to kill walruses (*Odobenus rosmarus*) have been passed on verbally to explorers and naturalists by their Inuit guides, based on local traditional ecological knowledge (TEK) as well as accounts of direct observations or interpretations of tracks in the snow made by the Inuit hunters who reported them. To assess the possibility that polar bears may occasionally use tools to hunt walruses in the wild, we summarize 1) observations described to early explorers and naturalists by Inuit hunters about polar bears using tools, 2) more recent documentation in the literature from Inuit hunters and scientists, and 3) recent observations of a polar bear in a zoo spontaneously using tools to access a novel food source. These observations and previously published experiments on brown bears (*Ursus arctos*) confirm that, in captivity, polar and brown bears are both capable of conceptualizing the use of a tool to obtain a food source that would otherwise not be accessible. Based on the information from all our sources, this may occasionally also have been the case in the wild. We suggest that possible tool use by polar bears in the wild is infrequent and mainly limited to hunting walruses because of their large size, difficulty to kill, and their possession of potentially lethal weapons for both their own defense and the direct attack of a predator.

Key words: polar bear; *Ursus maritimus*; walrus; *Odobenus rosmarus*; tool use; traditional knowledge; TEK

RÉSUMÉ. Depuis la fin des années 1700, des signalements d'ours polaires (*Ursus maritimus*) se servant d'outils (comme des morceaux de glace ou des pierres) pour tuer des morses (*Odobenus rosmarus*) ont été communiqués verbalement par des guides inuits à divers explorateurs et naturalistes. Les guides en question se fondaient sur les connaissances écologiques traditionnelles (CET) locales de même que sur les interprétations de traces dans la neige ou les récits d'observations directes des chasseurs inuits ayant fait les signalements. Pour évaluer la possibilité que les ours polaires puissent parfois se servir d'outils pour chasser les morses en milieu sauvage, nous résumons : 1) les observations décrites aux premiers explorateurs et naturalistes par les chasseurs inuits au sujet de l'utilisation d'outils par les ours polaires; 2) la documentation récente attribuable aux chasseurs inuits et aux scientifiques; et 3) les récentes observations de l'ours polaire d'un zoo se servant d'outils spontanément pour avoir accès à une nouvelle source de nourriture. Ces observations, alliées à des expériences publiées au sujet d'ours bruns (*Ursus arctos*), permettent de confirmer qu'en captivité, tant les ours bruns que les ours polaires sont capables de conceptualiser l'utilisation d'un outil pour se procurer de la nourriture qui ne serait autrement pas accessible. D'après les renseignements prélevés auprès de toutes nos sources, cela aurait aussi pu être occasionnellement le cas en milieu sauvage. Nous suggérons que l'utilisation possible d'outils par les ours polaires en milieu sauvage n'est pas fréquente et qu'elle est surtout limitée à la chasse au morse en raison de la grande taille de cette espèce, de la difficulté à l'abattre et des armes potentiellement mortelles qu'elle possède, tant pour se défendre que pour attaquer un prédateur directement.

Mots clés : ours polaire; *Ursus maritimus*; morse; *Odobenus rosmarus*; utilisation d'un outil; connaissances traditionnelles; CET

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## INTRODUCTION

Tool use in the animal kingdom has been the subject of considerable interest for decades and has been documented in a wide variety of species ranging from insects to mammals (see reviews by Alcock, 1972; St Amant and Horton, 2008; Bentley-Condit and Smith, 2010; Shumaker et al., 2011). In their extensive review, Bentley-Condit and Smith (2010) created 10 separate categories within which to classify documentation of tool use, including whether a particular observation was anecdotal, only seen in captivity, or only observed in one subject. They did not indicate whether or how the individual categorizations might influence the overall assessment of the relative significance of such observations. Basically however, most researchers agree that the definition of "tool use" simply constitutes the use of a freely manipulatable object to modify the physical properties of a target object through a complex mechanical interaction (Deecke, 2012).

It is widely accepted that bears (Ursidae) as a group are intelligent, in part because of their large brain size (Holecamp and Benson-Amram, 2017) but also because of a range of sophisticated hunting strategies and behavioral interactions (e.g., hunting strategies in polar bears, *Ursus maritimus*; Stirling, 1974; Stirling and van Meurs, 2015). However, in their literature review of tool use, Bentley-Condit and Smith (2010) reported only one observation from Kiliaan (1974) of possible tool use by a polar bear (a second citation in their paper of Stirling [1974] is incorrect as there is no mention of tool use in that paper). One interpretation of the paucity of observations on bears in their study might simply be that, as a taxonomic group, bear species use tools less often. However, the paucity of observations may partially result from the difficulty of making extended observations of the behavior of wild bears and does not preclude the possibility that bears might infrequently use tools only on an "as needed" basis. Also, to some degree, it likely reflects a general lack of experimental studies of the abilities of captive species of bears to solve different kinds of problems in captive situations.

Since publication of the broad reviews of tool use referred to above, several recent studies conducted under experimental conditions have confirmed the presence of special and cognitive abilities in captive giant pandas (*Ailuropoda melanoleuca*), American black bears (*Ursus americanus*), Bornean sun bears (*Helarctos malayanus uryspilus*), and Indian sloth bears (*Melursus ursinus*) (Perdue et al., 2009; Vonk and Beran, 2012; Vonk et al., 2012; Zamisch and Vonk, 2012; Perdue, 2016; Amici et al., 2017, 2019; Hartmann et al., 2017). Of particular relevance to this study are the experimental demonstration of tool use by captive brown bears (*Ursus arctos*) (Waroff et al., 2017) and a similar experiment with captive Indian sloth bears (Amici et al., 2019) in which the subjects were unsuccessful at demonstrating similar abilities.

For polar bears, there is a consistent historical record in Inuit traditional ecological knowledge (TEK), reported verbally to several early explorers and naturalists. In this paper, we use the term TEK as defined by Berkes (2012:7): "A cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment." A closely related term is local ecological knowledge (LEK). Some researchers have taken the view that LEK is a subset of TEK and presents "current local knowledge acquired more recently over the lifetime of individuals" (Gilchrist et al., 2005:22; Henri et al., 2018). For the purposes of this paper we use the term TEK to include all information sourced from Inuit hunters in historical as well as recent times.

Since 1780 (Fabricius, 1780), reports of polar bears using tools (i.e., pieces of ice or stones) to kill walruses (*Odobenus rosmarus*) have been passed on verbally to explorers and naturalists by their Inuit guides, based on local Inuit TEK, and in some cases, based on direct observations or interpretations of tracks in the snow. Although some writers appear to have considered such reports as myths (e.g., Ellis, 2009) because of the absence of published reports based on conventionally verifiable documentation (i.e., peer-reviewed scientific publications), the persistence of such similar accounts from a diversity of locations and over a long period of time suggests that a more detailed overall review of the subject is warranted. Thus, we summarize both historical information and recent observations from all sources on the behavior of both wild and captive polar bears using tools to access food.

## METHODS

We summarize all available information that we were able to access and confirm on possible tool use by polar bears in three parts. First, we review and summarize historical reports of tool use by polar bears as reported by Inuit hunters to early explorers and naturalists in two categories—secondhand TEK accounts and descriptions reported as having been observed by the hunter reporting them. We then summarize details of recent observations of tool use reported in the literature by Inuit and non-Inuit. Finally, we document recent observations of tool use by a captive male polar bear in the Tennoiji Zoo in Osaka, Japan, and by captive brown bears, their closest ursid relative, in an experimental study in the State of Washington, USA.

Using our own cumulative and extensive scientific knowledge of the behavior and ecology of both polar bears and walruses, the history of Arctic exploration, and TEK publications that include aspects of hunting of polar bears and marine mammals by Inuit in the marine ecosystem, we focused on 1) books and reports written by explorers or scientists who had been active in the Arctic from the 19th century through the first half of the 20th century, especially those who had remained in areas frequented by both polar bears and walruses for extended periods of

time and had frequent contact with Inuit hunters; and 2) published TEK and scientific reports from recent decades that included aspects of polar bears hunting walruses and seals. We searched the polar collections of the University of Alberta Library (Edmonton) and the Danish Royal Library (Copenhagen; including some sources in Danish, German, and Swedish). In both those institutions, we were aided by competent and motivated librarians. Searching the internet and the Web of Science for papers that listed both polar bears and walruses in the key words revealed no relevant references that we were not already aware of. Ian Gjertz, a former employee of the Norwegian Polar Institute and the Norwegian Natural Science Foundation, searched both published and unpublished sources (e.g., journals of Norwegian trappers and hunters living in Svalbard and East Greenland) for records of polar bears using tools but found none. Lastly, we consulted widely with colleagues who had significant personal experience in both scientific and TEK research collaboration with Inuit groups in areas where the distributions of polar bears and walruses overlap and who had knowledge of unpublished TEK reports from various administrative agencies. There may be additional TEK held by Inuit hunters that was not reported to explorers in historical times or those conducting TEK studies in more recent times. However, the extensive nature of our search and the internal consistency of the content of the events reported suggest to us that our coverage of the available information is comprehensive.

## RESULTS

Within Inuit TEK from both the eastern Canadian Arctic and SW Greenland, there is a long oral history dating back more than 240 years of bears using blocks of ice or stones (i.e., "tools") to aid in killing walruses. It is unclear whether all the reports are of independent observations or whether there might also be some overlap resulting from similar TEK being passed down over generations or to different areas. However, it was not possible to assess the uniqueness of some observations so we tabulated all reports separately under the following categories: secondhand accounts from non-attributed TEK sources, firsthand accounts from Inuit hunters, and direct observations reported by those who published them.

### *Secondhand Accounts from TEK*

1. In *Fauna Groenlandica*, Fabricius (1780:22 – 24) who lived in SW Greenland from 1768 to 1773 (as a clergyman and naturalist) reported that, "It [the polar bear] attacks every living creature, especially seals and the walrus. Cunning makes up for its lack of force against the mighty tusks of the latter. Grabbing pieces of ice and launching them against the walrus' head, the bear makes it lose its balance [or "stagger" is more literal] and thus kills it easily. However, sometimes it is bested by the walrus, or both of them die from their wounds." (Translated from the original Latin document by L.M. Stirling, University of Manitoba).

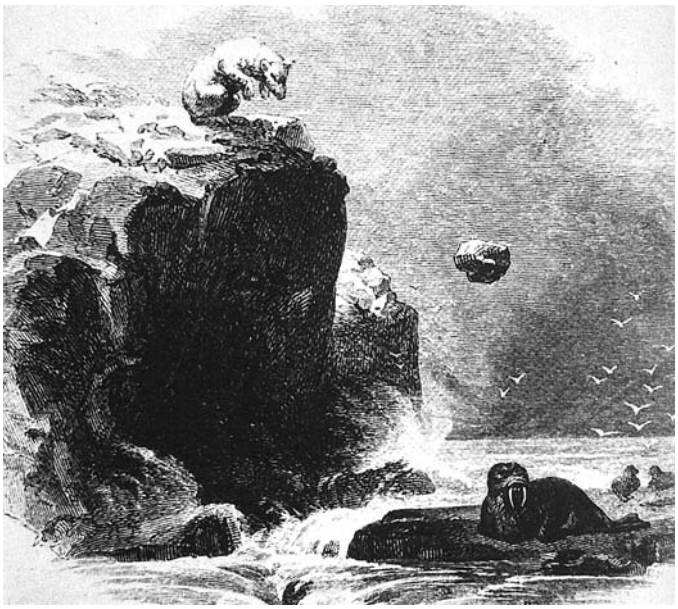

FIG. 1. This illustration, titled "Bear killing walrus" (Hall, 1865:581), depicts the use of a rock as a tool to try to kill a walrus, as described to the explorer Charles Francis Hall by a local Inuk hunter.

2. Probably the best-known account of polar bear tool use is the one illustrated by the engraving in Hall (1865:581) of a polar bear on top of a cliff hurling a stone down at an unsuspecting walrus (Fig. 1). Hall's Inuk guide and companion from SE Baffin Island told him that, "In August, every fine day, the walrus makes his way to the shore, draws his huge body up on the rocks, and basks in the sun. If this happen [sic] near the base of a cliff, the ever-watchful bear takes advantage of the circumstance to attack this formidable game in this way: The bear mounts the cliff, and throws down upon the animal's head a large rock, calculating the distance and the curve with astonishing accuracy, and thus crushing the thick bullet-proof skull. If the walrus is not instantly killed—simply stunned—the bear rushes down to the walrus, seizes the rock, and hammers away at the head till the skull is broken."

3. Munn (1932:242) reported the following but provided no additional detail: "The natives of different tribes widely separated have told me they have watched a bear stalk a young walrus out on the ice, taking advantage of a hummock to get within striking distance, and then hit the walrus over the head with a piece of ice held in one paw." Munn accumulated his information during several years working closely with Inuit in Arctic Canada including SE and NE Baffin Island and Southampton Island in Hudson Bay, Nunavut, Canada, all of which have resident walrus populations (e.g., Born et al., 1995).

4. In a posthumously published account, Haig-Thomas (1956) reported being told by an unidentified Inuk hunter that "long ago some Eskimos saw a herd of walruses sleeping on the ice and a polar bear approaching them. When the bear was close he lifted a large boulder of ice and dashed it down on the head of one of the walruses. This story I believe is told all over Greenland and the Canadian Arctic." In another anonymous account, he was told "An Eskimo killed a walrus with skin hanging from its skull. When he had pulled it up on to the ice and examined the wound carefully he thought that a bear must have tried to kill it with a large boulder and had only struck it a glancing blow, scraping the skin off the skull, though this might have occurred by ice falling off a glacier. If, however, one does not accept this account, it is difficult to see how a bear could kill a large walrus before it got into the sea."

5. Perry (1966) reported that, "Within our own times, a Southampton Island Eskimo, Tonga by name, has declared that he drove off a bear that had killed a sleeping walrus in this way [by hitting it on the head with a piece of ice], and that he subsequently butchered the walrus's carcass." However, his information was secondhand, and we have been unable to confirm the source.

6. In a recent unpublished interview as part of a TEK study relating to polar bears in Arctic Bay, Nunavut, P. Wong, Trailmark Systems, Toronto, Canada (pers. comm. 2020) recorded the following from an Inuk hunter from Arctic Bay in reference to polar bears hunting walruses: "They're [polar bears] the only species we know, that can think…that can have weapon. Like, we know that they can design a…piece of ice, make it round, they can use that to smash walrus head…for instance. They can think, when they're pursuing a prey, like humans" (AB15, anonymous identification of Interviewee).

*Inuit Hunter Accounts*

We define firsthand accounts as ones given by an Inuk hunter who could be identified by name and where he lived and who said he had personally witnessed a polar bear using a tool to kill a walrus.

1. While his ship was frozen in for the winter in Foxe Basin, Nunavut, Lyon (1824:375 – 376) shared his cabin with an Inuk hunter named Ooyarra. During that time, the hunter told him that, "On one occasion he saw a bear swim cautiously to a large piece of rough ice, on which two female walruses were lying asleep with their cubs. The wily animal crept up some hummocks behind this party, and with his forefeet loosened a large block of ice; this, with the help of his nose and paws, he rolled and carried until immediately over the heads of the sleepers, when he let it fall on one of the old animals, which was instantly killed. The other walrus with its cub rolled into the water, but the young one of the stricken female remained by its dam; on this helpless creature the bear now leaped down, and thus completed the destruction of two animals which it would not have ventured to attack openly."

2. Rae (1883) reported the following hunt of a walrus by a polar bear, reported to him by "an eye witness, a very truthful and honest Eskimo" who claimed to have witnessed the event on drifting ice in Foxe Channel, east of Southampton Island. A swimming bear climbed out on the ice that three walruses were sleeping on and "I and two or three other Innuits [sic] were attempting to approach some walrus in winter, lying on the ice close to the water kept open by the strong current in Foxe's Channel. As we were getting near we saw that a large white bear was before us. He had reached, in the most stealthy manner, a high ridge of ice, immediately above where the walrus was lying. He then seized a mass of ice in his paws, reared himself on his hind legs, and threw the ice with great force on the head of a half-grown walrus, and then sprang down upon it." After the bear was killed with a spear, the walrus was found to be almost dead.

3. Rasmussen (1925:81 – 82) was in the Igloolik area in northern Foxe Basin, where the *angakok* (shaman) Aua told him that he had once seen a polar bear sneaking up to a group of walruses. It had a massive lump of ice between its forepaws and hid itself behind this piece of ice so that its yellowish body was never detected by the walruses. If the walruses moved, the bear remained completely motionless looking like the hummocky sea ice. However, the walruses had hardly calmed down before it started to creep towards them again—raised up on its hindlimbs. Then it finally carefully selected a young walrus and threw the ice block down upon it with such a force that it became immobilized while all the other group members moved into the water. (Translated from the original Danish by E.W. Born).

4. Nelson (1969:191) was told by an unnamed hunter from Ulguniq (Wainwright, Alaska) that he saw a polar bear approach some walruses sleeping on the ice and try to attack a calf but the adults would not leave it. The bear then picked up a chunk of ice (or several chunks) with both paws, stood up on its hind legs, and threw it at the walruses in a vain attempt to drive them away from the calf. In a summary statement, Nelson reported that, "Walrus hunting [in Alaska] by bears is often said to involve pieces of ice and rock," but no additional observational information was provided.

Lastly, for the last century, after the introduction of skiffs and larger vessels in the subsistence walrus hunt in Canada and Greenland, the majority of the annual catch of walruses has been taken in offshore pack ice (e.g., Born et

al., 1995, 2017) where the distribution of walruses and polar bears overlap. In several instances the hunt targets both species (Born et al., 2017). However, despite an apparently increasing opportunity to observe interactions between the two species in their natural habitat, reports from Inuit hunters of polar bears using tools to kill walruses are very few. The small number of reports suggests to us that the use by polar bears of tools to kill walruses is an unusual event.

*Published Direct Observations*

1. In April 1972, Kiliaan (1974) was sledging with two Inuit hunters across Sverdrup Inlet on Devon Island, Nunavut, conducting a denning survey, when one hunter reported having just observed a place where a polar bear had smashed in the snow roof over a ringed seal (*Pusa hispida*) *aglu* (breathing hole) with a piece of ice. An inspection of the site revealed a piece of freshwater ice, approximately 20 kg in weight and 80 cm long, lying at the edge of the snow cover that had been dug away from the *aglu*. From tracks that were estimated to be about 6 h old, it was determined that the bear had broken the ice block from a larger piece of frozen-in freshwater ice about 6.5 m away and that it appeared to have dragged the ice block to the dig site. In the end, they were unable to confirm exactly what happened but suggested three possibilities: the bear used the ice block to break through the firm snow cover overlying the *aglu*, it had used the ice block to try to kill a seal that surfaced to breathe or, after being unsuccessful, it had broken the piece of ice off in frustration and rolled it to the site of the *aglu*.

2. Kiliaan (1974) also cited a personal communication observation of possible tool use by one or more polar bears by the late bear biologist, Charles Jonkel, University of Montana. In 1971, Jonkel was using foot-snare traps to capture polar bears for tagging studies on the western coast of Hudson Bay near Churchill, Manitoba. From tracks in the snow, it appeared that one or more bears had used rocks beside a trap site to set the foot snare off in order to obtain the bait without being captured. After Jonkel removed the rocks and covered the area around the trap with boards, the bear (or bears) apparently used rocks from up to 2 m away to spring the trap again and access the food.

3. Born et al. (2011:88) reported an interview for a TEK study about polar bears in NW Greenland, in which a 44-year-old highly experienced Inuk hunter from Qaanaaq (Inglefield Bredning, NW Greenland) reported his personal observation of possible tool use. For this paper, the hunter's original account, recorded on tape in Greenlandic and transcribed into Danish, was further checked and edited by E.W. Born. In the late 1990s, the hunter was returning from hunting in the Kane Basin (a body of water between Ellesmere Island, Canada, and NW Greenland) region with two companions during a very cold period in late February or early March. He saw two walruses on the ice (at about 78.347˚ N, 72.685˚ W) and approached them with the intention of harvesting one for dog food. When he got closer he saw blood on the ice from a female walrus that a bear had just killed. He put his finger on the bear's urine in the snow and found it unfrozen, indicating it was still very fresh. He thought that the bear got nervous when it heard him approaching by dogsled and urinated before running away. It was clear that the bear had killed the walrus. However, from the fresh tracks in the snow, it appeared that before the bear sat down to wait for the walrus to return to the breathing hole, the bear had fetched a piece of saltwater ice from the nearby coastal tide crack (estimated size not specified) and had manipulated it until it was smooth all over its surface. The manipulations were not described. The bear then had a tool with which to kill the walrus with a blow to its head. The bear then sat on some frozen bergy bits and when the walrus surfaced to breathe it had leapt towards it, leaving deep scratches in the new ice with its claws. On examination of these observations with his two companions, he concluded that the bear had attacked the walrus and hit it on the head with its weapon (the ice block). The blow had smashed its skull from a little above the upper lip all the way to the back of its head. The skull had been hit so hard that the skin was torn open. After the bear had hauled the walrus out of the water, it had dragged it some distance from the breathing hole where it had surfaced. The walrus was reported to be an old pregnant female with nice tusks.

   In a separate interview (Born, 2011:490), but related to the first because both referred to manipulation of the shape of an ice piece by a polar bear, the same hunter "reported having observed the tracks of two small cubs with their mother in the vicinity of Sermersuaq (Humboldt Glacier in NW Greenland) in April during the 1990s. Their mother had made a ball for them out of a piece of saltwater ice, which she had taken from the area between an iceberg and the sea ice. The ice ball was completely spherical and approximately twice the size of a soccer ball (ca. 45 cm in diameter). The hunter described it as follows: "If mathematicians had measured it, they would be amazed at how perfectly round it was." The bear cubs played with the ball (and had slid down the iceberg for a long time). According to the hunter, the ball was probably made of sea ice in order to make it more solid than if it had been fashioned out of freshwater ice from the iceberg, which would have been more brittle and would have broken more easily. It was smooth and rounded so that it would not crack and was, in the hunter's opinion, an implement devised and fashioned by a polar bear (Born et al., 2011).

4. In 2010, a journalist (Hiroyuki Ueba, pers. comm. 2010) with the Yomiuri Shimbun newspaper in Osaka, Japan, sent photographs to the senior author of a 5-year-old male polar bear named GoGo (originally from a zoo in

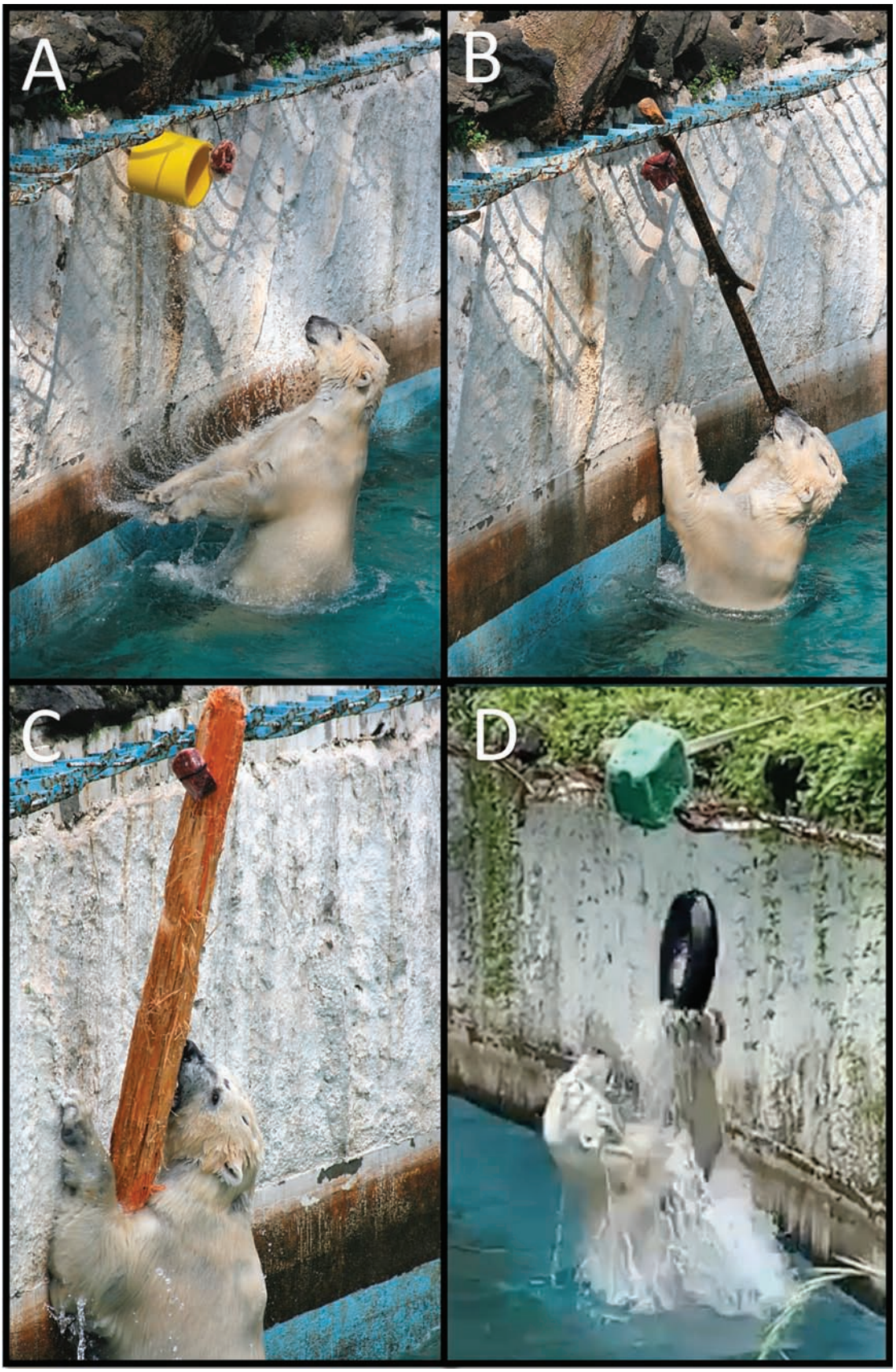


FIG. 2. Five-year-old GoGo, a male polar bear in Tennoji Zoological Gardens, Osaka, Japan, using tools to access a food source suspended above his reach. Panels show GoGo (a) throwing a piece of plastic pipe, (b) holding a 2 m piece of tree branch, (c) using a small log and, (d) throwing a small dense buoy-shaped tool using both forepaws at the same time (Photos © Tennoji Zoological Gardens, Osaka, Japan).

Russia) at the Tennoji Zoo in Osaka. In these photos, GoGo demonstrated an exceptional and previously undocumented degree of conceptual creativity to facilitate access to a food item hanging from the air (Stirling, 2011:148). The circumstances that led to the bear beginning to use tools, as described below, were not part of a planned experiment; unfortunately, no written records of observations were made at the time or since. Thus, the following brief notes are based on the recollections of the Animal Coordinator for the zoo (Takahiko Ide, pers. comm. 2019) of the initial development of GoGo's behavior and its continuation over a 10-year period. Initially, zoo staff had been trying to improvise forms of behavioural enrichment to keep the bear from becoming bored and possibly developing repetitive stereotyped behavior. Thus, to provide stimulation and distract his attention, they hung a piece of meat about 3 m above his pool, which was too high for him to grasp. Initially GoGo tried to get to the meat by jumping but was unsuccessful. However, about a month later, the bear invented two tools from "toys" originally placed in his cage for his entertainment. First, he began to throw a short, hard piece of plastic pipe at the meat until he knocked it down (Fig. 2a). Second, although it is not known exactly how much later, he picked up the remains of a tree branch, about 2 m long, and used it to slap the meat off the hook (Fig. 2b). When he first developed these methods, it took him a "couple of hours" to get the meat by using either technique but after a while his skills improved and he was able to retrieve the meat in only 5 minutes. He later began to use a much larger piece of wood (Fig. 2c), which he apparently preferred when both wood pieces were available, although the possible reason was not clear. As time went on however, he continued to prefer to throw things at the meat and ultimately stopped using the pieces of wood. At the time of this writing, after about 10 years, his preferred tool is a hard, dense, circular, and negatively buoyant buoy-shaped object, similar in size to the initial pipe, which he throws very accurately at the meat target, using both front paws to direct it, much like shooting a basketball (Fig. 2d). In 2019, a meat bait was suspended at a similar height above a 6-year-old female bear (also from a Russian zoo and raised in captivity) named Icchan. She has not been able to observe GoGo using tools. Although she sometimes threw a buoy, a tire, and a basket into her pool and then dove in for them, so far she has not tried to use any of the objects as tools to obtain the suspended food.

## DISCUSSION

### *TEK Historical Perspective of Polar Bear Tool Use*

Over a period of at least 240 years, there is a striking recurrence of highly similar but independently reported accounts given by Inuit hunters to early explorers and naturalists visiting SW and NW Greenland and the eastern Canadian Arctic of polar bears using pieces of ice or (in one case) stones as tools to kill walruses, as well as one similar record from Alaska (Nelson, 1969). Conversely, in other areas where large numbers of walruses and polar bears also overlap in distribution, there have been no TEK accounts or direct observations made by local Indigenous hunters in Chukotka, Russia, or by foreign hunters or trappers in Svalbard, Norway, of tool use by polar bears hunting walruses that we are aware of despite considerable field research, documentation of TEK, and hunting of both species (e.g., Ovsyanikov, 1996; Kochnev et al., 2003, pers. comm. 2020; Øren et al., 2018; I. Gjertz, pers. comm. 2020).

While reports of polar bears using ice blocks or rocks to kill walruses have been known for some time, there has not been any previous attempt to collate and assess these observations collected over the past 200+ years. Some writers (e.g., Ellis, 2009:97) simply concluded that the stories were mythological while, in contrast, Nelson (1969:191) noted that "Most authors have questioned whether this [tool use] occurs, however, apparently doubting that the hunters are able to view their own surroundings objectively. Yet it is worth remembering that Eskimos are highly reliable observers of animal behavior, and many of their least believable statements have been proved to me by personal observation."

As field scientists, our personal experience over several decades of working with Inuit hunters in Canada and Greenland is that that reports of direct observations of wild animals by experienced individual Inuit hunters are highly reliable. The statement above by Nelson (1969) is particularly relevant in relation to the detailed observation reported personally by a highly experienced polar bear and walrus hunter in NW Greenland (Born et al., 2011:88). He and two companions interpreted exceptionally fresh tracks, apparently made immediately before their arrival at the site, to determine that a polar bear had killed a walrus by using a piece of ice (Born et al., 2011:88). We suggest that the interpretation of the recent observation of this highly experienced Greenland hunter should be considered plausible, as should the longer-term historical record of similar observations.

### *Tool Use by Captive Brown Bears and Polar Bears*

The closest living relative of the polar bear is the brown bear, from which the former evolved about half a million years ago (Liu et al., 2014). There are two recent reports in the literature of tool use by brown bears. In the first, Deeke (2017) observed a brown bear on a single occasion repeatedly pick up barnacle-encrusted rocks in shallow water, reorient them in its forepaws, and use them to rub its neck and muzzle. The purpose of this behavior was not apparent, which weakens the interpretation. Although feeding by brown bears in salmon streams has been observed extensively in several situations for many

years (e.g., Shardlow and Hyatt, 2013; Lincoln and Quinn, 2019), no observations of tool use in that or other feeding circumstances have been reported.

In the second, a unique controlled experiment (Waroff et al., 2017) demonstrated that six of eight captive brown bears taught themselves to use three previously unfamiliar objects (large log, small log, and box) as tools to access a food reward suspended too high to be reached without moving one of the objects to a position below the food and then standing on it in order to be able to reach it. Successful individuals exhibited different preferences for tools and techniques but all were able to independently use a new and unfamiliar tool in a similar manner. Because the two bears that did not learn to use tools were both born and lived in the wild prior to being in captivity, Waroff et al. (2017) suggested that having been raised in captivity may have contributed to the ability of six of the bears to learn to use tools.

It is difficult to compare the observations of tool use by six of the eight brown bears in controlled experimental conditions to those of GoGo, the five-year-old captive male polar bear in the Tennoji Zoo in Osaka, because of the limited and anecdotal nature of the descriptions of tool use by the latter. However, similar to the brown bears, once GoGo was successful at using the first tool to access the food suspended out of his reach, he recognized that new and unfamiliar tools might also be used to accomplish the same task. Additionally, when all his tools were available to him at the same time, he showed preferences and, in his continuing use of tools through the past decade, has apparently developed a particular affinity for a small, dense, and negatively buoyant buoy-shaped tool that he throws with considerable accuracy with both paws (Fig. 2d). Despite the fact the observations of GoGo were qualitative, it is clear that he was capable of independently solving the problem of accessing a food source he could not reach in any other way than by using a tool. Furthermore, he was able to apply more than one type of tool to solve the same problem and retained the ability to apply the behavior over a period of 10 years. To date, however, although having been raised in captivity like GoGo, the 6-year-old female polar bear (Icchan) has not yet been able to use a tool to access the meat bait, first suspended above her pen in a similar fashion in 2019.

In contrast to evidence from captive polar and brown bears, Amici et al. (2019) experimentally demonstrated that captive sloth bears were unable to recognize that they could access an out-of-reach food source by simply moving a familiar bucket and standing on it (see also Waroff et al., 2017). Despite behavior that they interpreted as indicating high motivation, and in contrast to their predictions, Amici et al. (2019) found that none of the sloth bears tested tried to access the food by standing on the bucket, even after they either observed a human experimenter modeling the behavior or after being given direct relevant experience about how to reach the goal. The authors suggested that sloth bears failed to cognitively recognize the problem and use available tools to solve it.

*Ecological Context of Possible Tool Use*

The diversity of TEK reports of polar bears using ice blocks or rocks as tools with which to successfully kill prey all involved hunting walruses. The body mass of adult walruses is on average about three times larger than that of polar bears (Knutsen and Born, 1994; Wiig and Gjertz, 1996; Derocher and Wiig, 2002) and walruses are usually found in groups of variable size (Born et al., 1995; Stewart et al., 2014). Furthermore, walruses have 2–4 cm of thick skin on the head and neck (Fay, 1982) that is difficult to tear even with a sharp knife (E. Born, pers. observ.) and likely also with sharp canines, plus a dense skull (Kastelein and Gerrits, 1990) that can withstand blows or attempts to penetrate the braincase by a bear biting it with its canine teeth. In addition, walruses are armed with tusks that are formidable weapons and probably sufficient to protect adults from polar bears in most situations (Fay, 1982). Not surprisingly, the majority of published reports of polar bears hunting walruses reported in the literature suggest their primary focus is on calves and younger (smaller) animals, although adult animals are occasionally killed as well (Loughrey, 1959; Kiliaan and Stirling, 1978; Fay, 1982; Calvert and Stirling, 1990; Øren et al., 2018; Miller and Kochnev, 2021). However, even small walruses have large, heavily constructed skulls (Kastelein and Gerrits, 1990) as well as thick skin on the head and neck so that, in most cases, even killing a calf would require multiple bites (Fig. 3a) and probably blows to the head with the front paws as a polar bear's bite is not capable of crushing the skull and brain. Similarly, because of their relatively impenetrable skulls, even smaller subadult walruses may require an extended period to kill (e.g., Fig. 3b) compared to a ringed seal which may be quickly dispatched with a single bite, although multiple bites usually follow, presumably to eliminate the chance of it recovering sufficiently to escape (I. Stirling, unpubl. observ.). It is also apparent from tracks and blood in the snow near breathing holes that some walruses have escaped after being attacked (e.g., Calvert and Stirling, 1990) and, some cases, it appears that the bear may even be killed by the walrus (Freuchen, 1935; Pedersen, 1962; Kiliaan and Stirling, 1978). Stirling (1984) also documented a group threat behavior by walruses in the water to a bear hunting walruses along the ice edge in a polynya, sufficient to cause the bear to run from the ice edge and leave the area quickly, which further illustrates the possible direct danger to a polar bear when hunting walruses. The possible risk of harm to a bear from attacking a walrus was also first reported by Fabricius (1780).

Recognizing the ongoing difficulties that wild polar bears experience when hunting walruses (a substantial but dangerous food source) suggests the possibility that a small number of individuals might make the conceptual mental link between the need for a potential tool that might facilitate an improvement of hunting success and a possible solution. It is in this context that the observations of GoGo, the polar bear in the Tennoji Zoo in Osaka,

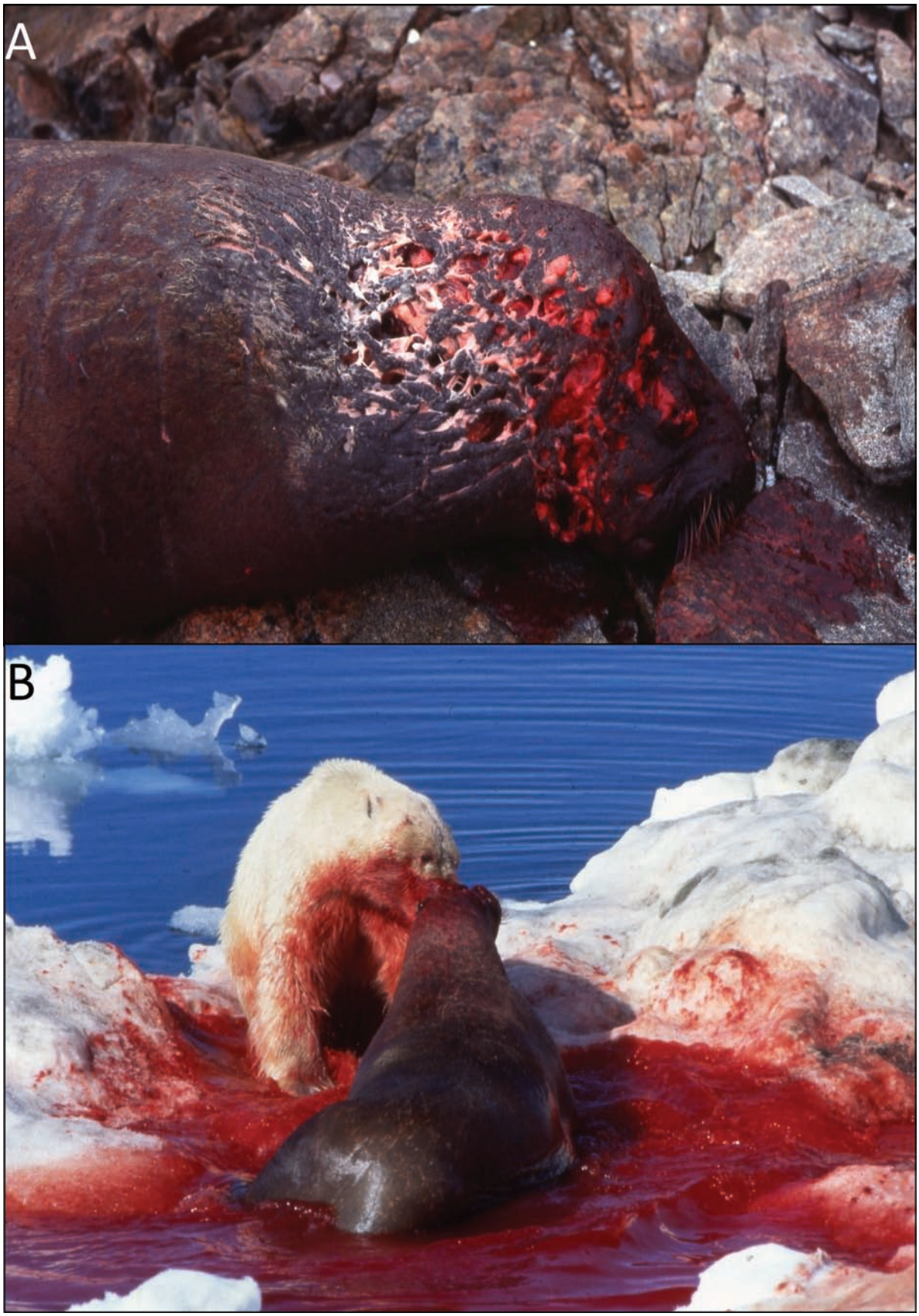


FIG. 3. (a) head of a walrus calf killed by a polar bear illustrating multiple bites from a polar bear attack without breaking the skull (photo © M.K. Taylor) and (b) a bloody ongoing attack by a polar bear on a subadult walrus that illustrates the bear's inability to kill the walrus quickly by biting its head (photo © Rod Vallee).

may be most relevant. Clearly, polar bears are intelligent animals and are able to quickly learn to perform tasks for research purposes (e.g., Øritsland et al., 1976) or in circus situations (e.g., Engelhard, 2017) that relate to no obvious function in the wild. No training or deliberate experimental designs were used to stimulate or test GoGo's potential abilities. However, in captivity, with free time and few other distractions, GoGo's desire to access the meat was apparently sufficiently strong for his brain to somehow conceptualize using a tool to successfully knock the bait down. Furthermore, after success and positive reinforcement from use of the first tool (a piece of plastic pipe), he then conceptualized the use of a second quite different tool (a 2 m long stick) to similarly access the meat that had been deliberately suspended on a hook beyond his reach. Lastly, and of particular importance with respect to whether a polar bear might be able to use a tool to kill or at least partially disable a wild walrus, GoGo demonstrated a remarkable ability to conceptualize the use of a tool to solve an access problem and, importantly, to be able to coordinate the use of both forepaws to throw his tool at least 2 m with considerable accuracy. The ability of polar bears to conceptualize how to solve a problem to access food with a tool is further illustrated by the non-hunting example of the polar bear that used a rock to set off a foot snare so it could get the bait without being caught (C. Jonkel, cited pers. comm. in Kiliaan, 1974).

When hunting for ringed seals at their lairs or *agluit* (breathing holes) beneath the windblown snow in spring, polar bears must stand completely motionless over the site, in order to not make even a tiny noise that would immediately frighten a seal in the water below. To have any chance of success, the bear must remain absolutely motionless, usually for an extended period, prior to a seal possibly surfacing to breathe at an *aglu* and being vulnerable to attack. Even the noise created by a small movement needed to pick up or move an ice block as a tool is sufficient to warn a seal to flee instantly well before an attack could be initiated. Thus, it seems unlikely that the polar bear tracks described by Kiliaan (1974) around a ringed seal *aglu* were made by a bear trying to use a tool to hunt a ringed seal beneath the snow. Consequently, because *agluit* or haulout and birth lairs are protected by a covering of windblown snow (Smith and Stirling, 1975; Stirling and Øritsland, 1995), the ongoing lack of success of tool use in that circumstance would likely result in negative reinforcement.

In the case of the captive brown bears, it is impressive that the intensity of the motivation to access a small food item suspended beyond their reach was sufficient to stimulate six of the eight individuals to independently conceptualize using the same tools in different ways to solve the problem of how to access the bait (Waroff et al., 2017). Even more interesting was that each bear exhibited alternative techniques and displacing of tools (log, stump or box) to facilitate being able to reach for the food reward. In stage three of the study, four of the six bears also chose to use novel objects that were not present in earlier stages of the experiment, which indicates the presence of a problem-solving concept rather than simply a rote memory of what had been done before. Similar to the use of different tools by GoGo, Waroff et al. (2017) further suggested that "This capacity to use different tools for the same purpose is suggestive of an elaborated cognitive understanding of the environment." In a possible parallel to GoGo's experience, part of the explanation for the brown bears' ability to invent a tool may have been that being in captivity with few distractions, possibly bored, and with an abundance of time to contemplate the problem, made it possible for all six bears to independently conceptualize solutions from the potential tools available at the time.

Why the two brown bears that were brought into captivity from the wild did not successfully use a tool to access the suspended bait in a similar manner to the six bears raised in captivity is uncertain. However, there have been no known observations of wild brown bears using any kind of tool similar to the TEK reports on wild polar bears. One possible explanation may simply be that there are not any known situations where a possible tool might improve the success of feeding on primary food sources such as vegetation, spawning fish, or newborn ungulate calves. Thus, the bears that were brought into captivity from the wild probably had no early experience with having a need for access to a food source that might be strong enough to stimulate possible use of a tool to achieve success.

## SUMMARY

The detailed experimental observations of tool use by captive brown bears, when considered in relation to the non-quantitative but clear descriptive and photographic record of tool use by the captive polar bear, GoGo, indicates that both of these closely related species of bears are capable of independently conceptualizing the successful use of tools to resolve access to a unique food-related problem. The documentation of a wild polar bear using a rock to harmlessly set off a foot snare also suggests it may have been captured at an earlier time and, consequently, was also able to conceptualize a solution to the threat of being recaptured and thereby be rewarded with access to the bait. Taken together, these observations, along with GoGo's ability to access a bait suspended out of his reach by coordinating the use of both front paws to throw a tool accurately and thus determine its trajectory, leave us to speculate that an occasional adult polar bear might be capable of mentally conceptualizing a similar use of a piece of ice or a stone as a tool to attack the well-protected brain of a walrus in order to kill it. The long history of similar observations reported from the wild by Inuit hunters, when combined with the observations of captive polar and brown bears, suggests the former may also have the ability to conceptualize the possible use of tools in the wild.

Lastly, the mention of both an adult male polar bear and an adult female with cubs having similarly modified the shape of a block of saltwater ice further suggests, albeit more speculatively, the possibility that the creation and use of a tool might be taught and transmitted between generations. Consequently, we suggest that although tool use by polar bears in the wild is likely a rare event, their possible use would likely be limited to walruses because of their large size, difficulty to kill, and their possession of potentially lethal weapons for both their own defense and to directly attack a predator.

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## REFERENCES

Alcock, J. 1972. The evolution of the use of tools by feeding animals. Evolution 26(3):464–473. https://doi.org/10.2307/2407020

Amici, F., Cacchione, T., and Bueno-Guerra, N. 2017. Understanding of object properties by sloth bears, *Melursus ursinus ursinus*. Animal Behaviour 134:217–222. https://doi.org/10.1016/j.anbehav.2017.10.028

Amici, F., Holland, R., and Cacchione, T. 2019. Sloth bears (*Melursus ursinus*) fail to spontaneously solve a novel problem even if social cues and relevant experience are provided. Journal of Comparative Psychology 133(3):373–379. https://doi.org/10.1037/com0000167

Bentley-Condit, V.K., and Smith, E.O. 2010. Animal tool use: Current definitions and an updated comprehensive catalogue. Behaviour 147(2):185–221. https://doi.org/10.1163/000579509X12512865686555

Berkes, F. 2012. Sacred ecology: Traditional ecological knowledge and resource management, 3rd ed. New York: Routledge.

Born, E.W., Gjertz, I., and Reeves, R. 1995. Population assessment of Atlantic walrus. Norsk Polarinstitutt Meddelelser 138. Tromsø: NPI.

Born, E.W.B, Heilmann, A., Kielsen Holm, L., and Laidre, K.L. 2011. Polar bears in Northwest Greenland: An interview survey about the catch and the climate. Meddelelser om Grønland 351, Man & Society 41. Copenhagen, Denmark: Museum Tusculanum Press.

Born, E.W., Heilmann, A., Kielsen Holm, L., Laidre, K.L., and Iversen, M. 2017. Walruses and the walrus hunt in West and Northwest Greenland: An interview survey about the catch and the climate. Meddelelser om Grønland 355, Man & Society 44. Copenhagen, Denmark: Museum Tusculanum Press.

Calvert, W., and Stirling, I. 1990. Interactions between polar bears and overwintering walruses in the central Canadian High Arctic. Bears: Their biology and management. International Conference on Bear Research and Management 8:351–356. https://doi.org/10.2307/3872939

Deecke, V.B. 2012. Tool-use in the brown bear (*Ursus arctos*). Animal Cognition 15:725–730. https://doi.org/10.1007/s10071-012-0475-0

Derocher, A.E., and Wiig, Ø. 2002. Postnatal growth in body length and mass of polar bears (*Ursus maritimus*) at Svalbard. Journal of Zoology 256(3):343–349. https://doi.org/10.1017/S0952836902000377

Ellis, R. 2009. On thin ice: The changing world of the polar bear. New York: Alfred A. Knopf.

Englehard, M. 2017. Ice bear: The cultural history of an Arctic icon. Seattle: University of Washington Press.

Fabricius, O. 1780. *Ursus maritimus*. Fauna Groenlandica: Systematice sistens animalia Groenlandiae… (in Latin). Hafniae et Lipsiae. Copenhagen and Liepzig: J.G. Rothe. 22–24. https://www.biodiversitylibrary.org/item/48073#page/7/mode/1up

Fay, F.H. 1982. Ecology and biology of the Pacific walrus, *Odobenus rosmarus divergens* Illiger. North American Fauna 74. Washington, D.C.: U.S. Department of the Interior, Fish and Wildlife Service. 279 p. https://doi.org/10.3996/nafa.74.0001

Freuchen, P. 1935. Mammals, Part II. Field notes and biological observations. Report of the Fifth Thule Expedition, 1921–24: The Danish Expedition to Arctic North America in Charge of Knud Rasmussen, Ph.D. Vol. 2(4-5):68–278. København: Gyldendalske Boghandel, Nordisk Forlag.

Gilchrist, G., Mallory, M., and Merkel, F. 2005. Can local ecological knowledge contribute to wildlife management? Case studies of migratory birds. Ecology and Society 10(1): 20. https://doi.org/10.5751/ES-01275-100120

Haig-Thomas, D. 1956. Polar bears: How they live and what they do in the vast ice world of the Arctic regions. Zoo Life, Winter 1956:106–110.

Hall, C.F. 1865. Arctic researches and life among the Esquimaux being the narrative of an expedition in search of Sir John Franklin in the years 1860, 1861, and 1862. New York: Harper & Brothers, Publishers. https://library.si.edu/digital-library/book/arcticresearche00hall

Hartmann, D., Davila-Ross, M., Wong, S.T., Call, J., and Scheumann, M. 2017. Spatial transposition tasks in Indian sloth bears (*Melursus ursinus*) and Bornean sun bears (*Helarctos malayanus euryspilus*). Journal of Comparative Psychology 131(4):290–303. https://doi.org/10.1037/com0000077

Henri, D.A., Jean-Gagnon, F., and Gilchrist, H.G. 2018. Using Inuit traditional ecological knowledge for detecting and monitoring avian cholera among Common Eiders in the eastern Canadian Arctic. Ecology and Society 23(1): 22. https://doi.org/10.5751/ES-09289-230122

Holecamp, K.E., and Benson-Amram, S. 2017. The evolution of intelligence in mammalian carnivores. Interface Focus 7: 2016018. https://doi.org/10.1098/rsfs.2016.0108

Kastelein, R.A., and Gerrits, N.M. 1990. The anatomy of the walrus head (*Odobenus rosmarus*). Part 1: The skull. Aquatic Mammals 16(3):101–119.

Kiliaan, H.P.L. 1974. The possible use of tools by polar bears to obtain their food. Norsk Polarinstitutt Årbok 1972. Oslo: NPI. 177–178.

Kiliaan, H.P.L., and Stirling, I. 1978. Observations on overwintering walruses in the eastern Canadian High Arctic. Journal of Mammalogy 59(1):197–200. https://doi.org/10.2307/1379895

Knutsen, L.Ø., and Born, E.W. 1994. Body growth in Atlantic walruses (*Odobenus rosmarus rosmarus*) from Greenland. Journal of Zoology 234(3):371–385. https://doi.org/10.1111/j.1469-7998.1994.tb04854.x

Kochnev, A.A., Etylin, V.M., Kavry, V.I., Siv-Siv, E.B., and Tanko, I.V. 2003. Traditional knowledge of Chukotka Native peoples regarding polar bear habitat use. Final report. Prepared for the United States National Park Service. The Alaskan Commission, PO Box 946, Nome, Alaska 99762, USA.

Lincoln, A.E., and Quinn, T.P. 2019. Optimal foraging or surplus killing: Selective consumption and discarding of salmon by brown bears. Behavioral Ecology 30(1):202–212. https://doi.org/10.1093/beheco/ary139

Liu, S., Lorenzen, E.D., Furnagalli, M., Li, B., Harris, K., Xiong, Z., Zhou, L., et al. 2014. Population genomics reveal recent speciation and rapid evolutionary adaptation in polar bears. Cell 157(4):785–794. https://doi.org/10.1016/j.cell.2014.03.054

Loughrey, A.G. 1959. Preliminary investigation of the Atlantic walrus, *Odobenus rosmarus rosmarus* (Linnaeus). Wildlife Management Bulletin 1(140. Ottawa, Ontario: Canadian Wildlife Service.

Lyon, G.F. 1824. The private journal of Captain G.F. Lyon, of H.M.S. *Hecla* during the recent voyage of discovery under Captain Parry. London: J. Murray.

Miller, E.H., and Kochnev, A.A. 2021. Ethology and behavioral ecology of the walrus (*Odobenus rosmarus*), with emphasis on communication and social behavior. In: Campagna, C., and Harcourt, R., eds. Ethology and behavioral ecology of Otariids and Odobenid. New York: Springer.

Munn, H.T. 1932. Prairie trails and Arctic by-ways. London: Hurst and Blackett.

Nelson, R.K. 1969. Hunters of the northern ice. Chicago, Illinois: University of Chicago Press.

Øren, K., Kovacs, K.M., Yoccoz, N.G., and Lydersen, C. 2018. Assessing site-use and sources of disturbance at walrus haul-outs using monitoring cameras Polar Biology 41:1737–1750 https://doi.org/10.1007/s00300-018-2313-6

Øritsland, N.A., Jonkel, C., and Ronald, K. 1976. A respiration chamber for exercising polar bears. Norwegian Journal of Zoology 24:65–67.

Ovsyanikov, N.G. 1996. Interactions of polar bears with other large mammals, including man. Journal of Wildlife Research 1:254–259.

Pedersen, A. 1962. Das walross [The walrus]. Wittenberg-Lutherstadt, Germany: A. Ziemsen.

Perdue, B.M. 2016. The effect of computerized testing on sun bear behavior and enrichment preferences. Behavioral Sciences 6(4): 19. https://doi.org/10.3390/bs6040019

Perdue, B.M., Snyder, R.J., Pratte, J., Marr, M.J., and Maple, T.L. 2009. Spatial memory recall in the giant panda (*Ailuropoda melanoleuca*). Journal of Comparative Psychology 123(3):275–279. https://doi.org/10.1037/a0016220

Perry, R. 1966. The world of the polar bear. Seattle: University of Washington Press.

Rae, J. 1883. Intelligence in animals. Nature 27:366.

Rasmussen, K. 1925. Fra Grønland til Stillehavet. Rejser og Mennesker fra 5. Thule-Ekspedition 1921–24 [From Greenland to the Pacific Ocean: Travels and people of the 5th Thule-expedition 1921–24]. Vol I. København: Gyldendalske Boghandel, Nordisk Forlag.

Shardlow, T.F., and Hyatt, K.D. 2013. Quantifying associations of large vertebrates with salmon in riparian areas of British Columbia streams by means of camera-traps, bait stations, and hair samples. Ecological Indicators 27:97–107. http://dx.doi.org/10.1016/j.ecolind.2012.11.011

Shumaker, R.W., Walkup, K.R., and Beck, B.B. 2011. Animal tool behavior: The use and manufacture of tools by animals, rev. and updated ed. Baltimore, Maryland: The John Hopkins University Press.

Smith, T.G., and Stirling, I. 1975. The breeding habitat of the ringed seal (*Phoca hispida*). The birth lair and associated structures. Canadian Journal of Zoology 53(9):1297–1305. https://doi.org/10.1139/z78-149

St Amant, R., and Horton, T.E. 2008. Revisiting the definition of animal tool use. Animal Behaviour 75(4):1199–1208. https://doi.org/10.1016/j.anbehav.2007.09.028

Stewart, R.E.A., Born, E.W., Dietz, R., and Ryan, A.K. 2014. Estimates of minimum population size for walrus around southeast Baffin Island, Nunavut. In: Stewart, R.E.A., Kovacs, K.M., and Acquarone, M., eds. Walrus of the North Atlantic. NAMMCO Scientific Publications 9:141–157. https://doi.org/10.7557/3.2615

Stirling, I. 1974. Midsummer observations on behavior of wild polar bears (*Ursus maritimus*). Canadian Journal of Zoology 52(9):1191–1198. https://doi.org/19.1139/z74-157

———. 1984. A group threat display given by walruses to a polar bear. Journal of Mammalogy 65(2):352–353. https://doi.org//10.2307/1381182

———. 2011. Polar bears: The natural history of a threatened species. Markham, Ontario: Fitzhenry and Whiteside.

Stirling, I., and Latour, P.B. 1978. Comparative hunting abilities of polar bear cubs of different ages. Canadian Journal of Zoology 56(8):1768–1772. https://doi.org/10.1139/z78-242

Stirling, I, and Øritsland, N.A. 1995. Relationships between estimates of ringed seal (*Phoca hispida*) and polar bear (*Ursus maritimus*) populations in the Canadian Arctic. Canadian Journal of Fisheries and Aquatic Sciences 52(12):2594–2612. https://doi.org/10.1139/f95-849

Stirling, I., and van Meurs, R. 2015. Longest recorded underwater dive by a polar bear. Polar Biology 38:1301–1304. https://doi.org/10.1007/s00300-015-1684-1

Vonk, J., and Beran, M.J. 2012. Bears 'count' too: Quantity estimation and comparison in black bears (*Ursus americanus*). Animal Behaviour 84(1):231–238. https://doi.org/10.1016/j.anbehav.2012.05.001

Vonk, J., Jett, S.E., and Mosteller, K.W. 2012. Concept formation in American black bears (Ursus americanus). Animal Behaviour 84(4):953–964. https://doi.org/10.1016/j.anbehav.2012.07.020

Waroff, A.J., Fanucchi, L., Robbins, C.T., and Nelson, O.L. 2017. Tool use, problem-solving, and the display of stereotypic behaviors in the brown bear (*Ursus arctos*). Journal of Veterinary Behavior 17:62–68. https://doi.org/10.1016/j.jveb.2016.11.003

Wiig, Ø., and Gjertz, I. 1996. Body size of male Atlantic walruses (*Odobenus rosmarus rosmarus*) from Svalbard. Journal of Zoology 240(3):495–499. https://doi.org/10.1111/j.1469-7998.1996.tb05300.x

Zamisch, V., and Vonk, J. 2012. Spatial memory in captive American black bears (*Ursus americanus*). Journal of Comparative Psychology 126(4):372–387. https://doi.org/10.1037/a0028081