Title: Large-scale cooperation in small-scale foraging societies

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Abstract:

We present evidence that people in small-scale, mobile hunter-gatherer societies cooperated in large numbers to produce collective goods. Foragers engaged in large-scale communal hunts, constructed shared capital facilities; they made shared investments in improving the local environment; and they participated in warfare, alliance, and trade. Large-scale collective action often played a crucial role in subsistence. The provision of public goods involved the cooperation of many individuals, so each person made only a small contribution. This evidence suggests that large-scale cooperation occurred in the Pleistocene societies that encompass most of human evolutionary history, and therefore it is unlikely that large-scale cooperation in Holocene food producing societies results from an evolved psychology shaped only in small group interactions. Instead, large scale human cooperation needs to be explained as an adaptation, likely rooted in the distinctive features of human biology, grammatical language, increased cognitive ability, and cumulative cultural adaptation.

Keywords: collective action, communal foraging, cooperation, foragers, hunter-gatherers, mismatch hypothesis, public goods

1. Introduction

Contemporary people cooperate in large unrelated groups to produce collective goods. They construct shared capital facilities like roads and irrigation works, and they risk their lives in war. In contrast, large-scale collective action by unrelated individuals is very rare among other species. Some vertebrates like communally nesting birds and chimpanzees cooperate with weakly related individuals in small groups, but very few species cooperate in larger groups, and those that do, like African mole rats, are genetically related.[1]

The absence of large-scale cooperation in most vertebrate species is consistent with explanations of cooperation based on kin selection and reciprocity.[1,2] The reproductive biology of most mammals and birds limits the number of close relatives and thus the scale of cooperation supported by inclusive fitness benefits. Explanations of cooperation among nonrelatives rely on reciprocity and direct enforcement. Reciprocity can only support cooperation in very small groups. To prevent defectors from benefiting from collective action, reciprocators must be intolerant of defection.[2] This means in large groups, reciprocity is sensitive to errors and cannot easily increase when rare.[3]

Direct sanctions solve this problem because they can be targeted at defectors. However, two new problems must be solved. First, why should individuals punish? Imposing sanctions motivates others to contribute to a collective good that benefits both punishers and non-punishers. Second, unlike reciprocity, there is no necessary connection between the collective good and punishment. Punishment can be directed at individuals who do not contribute to the collective good, or who wear the wrong clothes, or anything else. In small groups, both of these problems are easy to solve. The increase in collective benefits created by an additional punisher can be enough to compensate her for the costs of punishing[4–6] and as a result people will seek to motivate behavior that benefits the group. Singh et al[6] call this the "self-interested enforcement" hypothesis.

The self-interested enforcement is not a plausible explanation for large-scale cooperation.[2,3] How large depends on the costs and benefits of cooperation. Think of 300 individuals in a battle. One person hangs back reducing his risk of injury. His action will have hardly any effect on the chances of victory, but if you undertake to punish him, you bear the full cost. This free-rider problem can be important in modest sized groups when the costs of contributing are high---Zefferman and Mathew[1] set the lower limit at three dozen for warfare. For lower cost activities, self-interested sanctions can work in larger groups.

The free rider problem can be mitigated if punishment is coordinated, but models suggest cooperation is still limited to band-sized groups.[7,8] Other authors have argued that enforcing collective action norms creates individual benefits as a side effect of enforcement.[9,10] When somebody hangs back in battle, you confront him and your own social prospects improve or because he is your rival in mating competition. The difficulty here is that there is no causal connection between the benefits that punishers receive and the production of public goods. Once there are shared norms that legitimate punishment, the mechanisms studied by Jordan et al[9] and Raihani and Bshary[10] can be effective. Without them, enforcement is just interpersonal conflict. These mechanisms may expand the range of group sizes or cost benefit ratios which support collective action, but are not plausible explanations of its origin.

So, we have an evolutionary puzzle. Unlike most other vertebrates, people in contemporary human societies engage in costly collective action in large unrelated groups. The psychology that gives rise to this cooperation[11,12] must have been shaped by natural selection in Pleistocene foraging societies, but the mechanisms used to explain cooperation in other species do not explain the scale of contemporary collective action among humans.

Many authors believe that the psychology that supports large scale cooperation in contemporary societies evolved in Pleistocene foraging societies, and based on a reading of the ethnography of Holocene foraging societies, think that cooperation was usually limited to band-sized groups of 20 or 30 people[2,5,6,13–16] and only rarely extended to groups of 100 or more.[15] If this were true, then the ultimate explanation for contemporary human cooperation would not be a problem. In band-sized groups, kin selection, reciprocity, and self-interested enforcement can favor the evolution of costly behaviors that benefit other group members, and so favored psychological mechanisms that support cooperation. For example, experiments suggest that people, but not chimpanzees, have other-regarding preferences that lead to cooperation in anonymous settings.[12] A number of authors[14,17] have suggested that such motives evolved in band-sized groups in which they were adaptive, and that contemporary behavior represents a maladaptation resulting from the huge increase in group sizes caused by the switch to agricultural subsistence systems in the Holocene. This kind of explanation is often called the "mismatch hypothesis" because modern human cooperation results from a mismatch between current social environments and those in which our psychology evolved.

Here we present evidence that, contrary to the conventional wisdom, people in late Pleistocene and Holocene hunter-gatherer societies regularly cooperated in large groups to produce collective goods. Foragers worked together with hundreds of others in communal hunts and the construction of shared capital facilities like drivelines, hunting nets and fish weirs. They made shared investments in improving the local environment through burning, irrigation and other habitat modifications, and they participated in warfare, peace-making and trade on tribal scales. In many foraging societies, such large-scale collective action played a crucial role in subsistence. The provision of public goods involved the cooperation of hundreds of individuals, so relatedness was very low, and the incremental effect of each person on the outcome was small.

The evidence comes from historical accounts and archaeological data—mainly from North America, Australia and Pleistocene Europe---and from ethnographic descriptions of foragers in Western North America, the Arctic and Australia where hunting and gathering persisted until recent times. We do not include data from so-called "complex" hunter-gathers because many authors[5,13] believe that such societies do not provide a useful model for ancestral human environments. Other authors believe that Upper Paleolithic societies might have been socially complex.[18]

We describe the evidence in some detail. Much of the historical and archaeological data that we rely on is incomplete, and any single example is suspect. We freely acknowledge that this is not a random sample of the literature. We do not discuss sources that do not provide evidence of large-scale cooperation because the absence of evidence is difficult to interpret. Large-scale cooperation might not have existed in these cases, or it might have existed but left no archaeological or historical record. This kind of research is like fossil hunting. Paleontologists don't usually search the world at random, they look where they think they are most likely to find informative specimens. We have done the same.

On the basis of this evidence, it seems likely that Pleistocene foragers regularly cooperated in large groups, perhaps for several hundred thousand years. This suggests that the mismatch hypothesis is incorrect and that the psychology that supports contemporary cooperation evolved to support cooperation in large groups in the past. Given that cooperation in large unrelated groups is rare among vertebrates, this evidence further suggests that the evolutionary mechanisms that gave rise to human cooperation likely depend on the peculiarities of human biology like exceptional cognitive ability, combinatorial language, and cumulative cultural evolution.

2. Communal Hunting

There is much evidence that hundreds of hunter-gathers regularly cooperated in communal hunts. Structures like drivelines, jumps, and corrals once dotted much of North America. In the less-developed regions, ancient structures have survived and archaeologists can estimate the number of people involved in communal hunts. Moreover, historical accounts and early ethnography help us understand how Native Americans hunted communally. There is also historical evidence and archaeological evidence for communal hunting in South America, Australia, and Africa, and archaeological evidence for communal hunting in Middle and Upper Paleolithic Europe and Middle Stone Age Africa.

2.1 High latitude caribou hunting

Inuit and Athabascan speakers hunted caribou (*Rangifer tarandus,* called reindeer in Eurasia) communally throughout the Arctic. Caribou played an important role in the subsistence economy. The meat was an important food source, particularly in the fall, and caribou hides were essential for winter clothing and bedding.[19] An Inuit household required 30 hides every year, all harvested in the early fall.[20]

Communal hunts mainly used one of two methods. The simplest was to mobilize enough people to surround a portion of a herd and drive the caribou into a lake or river where hunters waiting in kayaks or canoes could easily lance the swimming animals. Historical accounts indicate that such drives could employ hundreds of people.[21] Both Inuit and Athabaskans also built concentrating structures like drivelines and corrals. The tundra-living Inuit typically constructed drivelines made of rock cairns (called *inukshuk*) supplemented with organic materials like willow branches, turf and hides. In the boreal forest, Athabaskans built substantial wood and brush fences often anchored to living trees.[21]

Historical accounts make it clear that Inuit and Indian groups built drivelines across high latitude North America (Table 1). These structures varied in length from a few hundred meters to up to 50 km.

Substantial investments of time and labor were required to build, operate and maintain such drivelines, especially north of tree line where wood and stone often needed to be carried long distances.[21] For example, in 1771 Thomas Hearne observed between 350 and 600 people using a driveline near the Coppermine River.[21]

Communal hunts were an essential part of the yearly subsistence round. Caribou migrate north in the spring and south in the fall. Large communal hunts were concentrated during the fall. In the spring, the caribou were very lean, and their skins were much less useful because they were perforated by emerging fly larvae, while in the fall the caribou were much fatter, the holes in their skin had healed, and their coats were much thicker.[19]

Only communal hunting could satisfy subsistence requirements before rifles were available.[22:41] Blehr[20] presents ethnographic evidence that solitary, non-communal hunts using bows had a low success rate. Communal hunts were not commonly observed by 20th century ethnographers probably because firearms made small-scale non-communal hunting much more effective.

Communal caribou hunting has been going on for a long time in North America. Archaeologists have studied a number of drivelines on Victoria Island[23] some built by the by Dorset people who lived there more than 800 years ago. A series of structures closely resembling drivelines used to hunt caribou in the Canadian Arctic have been found under Lake Huron. These would have been on a narrow isthmus crossing the lake from 7500 to 10,000 years ago.[24] Communal hunting at water crossings is also ancient. In the Canadian Barrenlands, water crossings have been used continuously for the last 6000 years. Some sites have more than two meters of uninterrupted strata with tools and caribou bones.[21:279]

2.2 Great Plains bison hunts

Until the middle of the 19th century, immense herds of bison (*Bison bison*) lived in the plains and woodlands of much of North America. The densest populations lived in the Great Plains, ranging from northern Alberta to northern Mexico. These animals, colloquially called buffalo, were large, males weighing 544–907kg and females 318–545kg. Bison are fast and agile with an excellent sense of smell, but poor eyesight.[25]

Before the arrival of horses, Great Plains foragers used a variety of communal methods to drive bison into a confining space where they could be killed. They were driven into arroyos which narrowed and steepened leading to ravines where hunters waited on the banks above and into deep snowdrifts and sand dunes where they were unable to escape. Where there was sufficient relief, bison were driven over cliffs; in places without relief, they were driven into corrals.[26:62-121,27:215-288]

Communal hunts often involved hundreds of people. The number of animals butchered can give an estimate of the number of people involved in a hunt. For example, the Olsen Chubbuck site in eastern Colorado preserves the remains of a single event 8500 years ago in which about 200 *Bison occidentalis* (an extinct species that was 25% larger than *B. bison*) were driven into a ravine and killed. Wheat et al.[28] estimate that about 57,000 pounds of flesh was harvested producing an estimate of 150 participants. There are many carefully excavated sites where the evidence indicates that more than 100 people were involved in communal hunts.[29] Historical accounts do not provide much detail about numbers but sometimes suggest that large numbers of people were engaged in hunts.[28]

Bison jumps involved large numbers of people. For a jump to be successful, hunters had to stampede a large group of bison over a cliff edge.[30] Despite their great mass, bison are agile and can turn rapidly even when running at full speed.[26] This means that bison will plunge over a cliff only if propelled by a mass of bison stampeding from behind them. The site of Head-Smashed-In in southern Alberta provides a good example of how this worked.[30] A system of long drivelines extended many kilometers behind the cliff. Small piles of stones marked the paths of the lines, and these were augmented with willow branches, hide, and other temporary additions, and backed by large numbers of men and women. The bison were persuaded to enter the converging drivelines, and proceed slowly toward the jump. Finally, when the herd was a few hundred meters from the jump, a mass of people converged behind the animals causing them to stampede over the cliff. This yielded tens of thousands of kilograms of meat and large amounts of fat and hides. It took many people to process this bounty fast enough to prevent spoilage. Hundreds of 500 kg animals had to be dragged down from the cliff face, rapidly skinned to reduce the temperature of the carcass, disarticulated, defleshed, and butchered into thin strips for drying.[30] Bones were broken into small pieces and boiled to extract bone grease, an important component of pemmican.[31] This was done in in hide-lined pits using thousands of quartzite cobbles carried from a riverbed 6 kilometers away. Brink[30] suggests that this work was done assembly-line style with cooperative division of labor.

People have acquired bison using communal methods for as long as they have been in North America. Hundreds of sites have been identified.[29,32] The earliest date to the Clovis period, shortly after the arrival of people in the Great Plains.[25:217-219,27] Larger sites with the remains of more than 100 animals become common in the Folsom and Paleoindian periods about 12 ka, and very large communal hunts utilizing cliff jumps became common about 6000 years ago.[26:79] For example, people used the Head-Smashed-In jump from 5700 to about 700BP. Driver[31] argues that the invention of pemmican for storage and the arrival of the bow 2000 years ago made large-scale hunts more profitable. Communal hunting declined in the Southern Plains as people became semi-sedentary villagers who mixed farming and foraging.[25]

Many archaeologists believe that annual communal hunts played a crucial role in the yearly subsistence round.[25,29,30] Most large communal hunts occurred in the northern plains where winters are long and severe. Frison and colleagues[27:284] argue that communal hunts occurred in the fall and meat and fat were preserved as pemmican for use during the winter. Historical accounts suggest that such fall harvests occurred frequently and archeological analyses of a number of sites is generally consistent with this model.[32:138] However, there is also evidence for communal hunts during the late winter and spring when bison were very lean, possibly because thinner hides were useful for making tipi covers.[30]

2.3 Communal pronghorn hunts

Pronghorns (*Antilocarpa americana*) are small (50kg) antelope-like herbivores that were common throughout the Great Plains and Great Basin until the late 19th century. They are extremely fast, able to reach speeds of 100 kilometers per hour in short bursts, have excellent eye-sight, and are accomplished broad-jumpers, but very poor at jumping vertically over obstacles. They aggregate during the winter in large herds and into smaller groups the spring.[33]

Native Americans hunted pronghorns throughout western North America, but they were most important in the Great Basin and Southwest.[34:34-36] Pronghorns were hunted individually by stalking, from behind blinds, and using disguises,[34:71-75] but the pronghorn's speed and wariness made this difficult,[35:34] and communal drives were common.[34:54,36:28] Typical drives utilized large corrals and drift fences or drivelines.[37] The Whisky Flat pronghorn trap northeast of Mono Lake provides a well-studied example.[38] A fence 2.3 kilometers long channeled the pronghorn into a large circular corral where they were shot by hunters armed with bows. The fence and corral were built from about five thousand juniper posts spaced about 50 cm apart and braced with stones. At other sites, corrals and fences were built using stone.[30,39] For example, the Fort Sage drift fences are built with dry stone masonry. When the fences were new they were about 1 m high, 1m thick, and about 1.1 km long.[39]

Several lines of evidence suggest that communal pronghorn hunts involved sizable numbers of people. Five ethnographic sources report group sizes ranging from 18 to more than 100[36:77] (Table 2). A larger number of ethnographic sources (Table 3) and archaeological data (Figure 1) give the size and construction method for corrals used in communal hunts. The sizes of juniper traps in the ethnographic and archaeological samples roughly match.[36:116] Jensen[40:74] used the archaeological and ethnographic data to estimate the number of people involved in the construction of corrals, assuming that corrals were built in one 12-hour day and that it took between one and two hours to build each 1.5 meters of fence. These corrals ranged in length from 66 m to 1600m, yielding estimates of group size that range from six to almost 300 individuals, with an average of about 78. Measured lengths for 43 archaeologically known corrals in northeastern Nevada range from 600 to 4475m (data from Jensen[36:124] and McCabe et al[34:66]). According to Jensen's method, this corresponds to a mean group size of 143 people. Stone corrals were more labor intensive. Hockett et al[39] experimentally constructed a replica of the Fort Sage drift fence, and found that they could build 0.66 m of wall per person per hour, about 1/6 of the rate for juniper fences.

The Shoshone and Paiute peoples in the Great Basin were classic mobile foragers. Julian Steward's census data indicates that population densities range from 4.4 to 114 square kilometers per person with a mean of 31.[36:14] The frequency of communal hunts was not affected by population density,[41:34] and sometimes people had to travel as far as 90km to participate.[41:430] These communal hunts usually occurred in the fall,[34:54] and often lasted more than two weeks.

Pronghorns were an important component in the foraging economy in the Great Basin for many thousand years. It seems likely that communal hunting dates as far back as 12,000 years ago.[27:291] The oldest dense bone beds that are consistent with mass kills associated with communal hunting, at Trapper's Point, Wyoming date to the Archaic period (10-12ka). However, the oldest evidence for a trap is at the Laidlaw site in Alberta which dates to about 3000 years ago.[26:140] It is uncertain how often these sites were utilized. Steward[35:33] argued that the large kills depleted herds so much that drives could only be held once a decade. However, Steward's observations were made during the early 20th century when herds had been depleted, and some authors argue that when pronghorn densities were higher, drives were held annually.[36,42: 26]

2.4 Rocky Mountain alpine drivelines

Native Americans built stone drivelines to intercept big horn sheep and elk herds as they migrated eastward through passes over the Front Range of the Rock Mountains.[43] Archaeologists have discovered 70 sites at elevations above 3000 meters in Colorado that have stone blinds or walls that were used to aid hunting. The oldest sites date to 8000 years ago and they became more common about 3000 years ago.[44] Some of these sites are large. For example, an 8-kilometer stone wall blocked Rollins Pass. Given the size and location of the site, LaBelle and Pelton[43] argue that hunters from multiple bands gathered to wait for the sheep herds to arrive, encouraged the sheep to enter the drivelines, and then killed them. It is not certain sheep were the prey because there is little faunal material due to rapid weathering.

There is little doubt that mountain sheep were hunted communally at sites in Wyoming and Montana that date to the 18th century.[26:155-161,27:306-307] These sites have the remains of substantial fences made of logs that average 30cm in diameter and extend for hundreds of meters. The fences leaned inwards so that the agile sheep could not clamber over them.[27:305-306] According George Frison[26:156] "The effort needed to move, even over short distances, timbers the size of those used in constructing the traps soon convinces one that they were not constructed for the procurement of small numbers of animals." We don't know how far this practice extends back in time because these structures are constructed from perishable materials.

2.5 Large-scale communal hunting outside of North America

Southwest Asia

There is much archaeological evidence for drivelines in desert environments in southwestern Asia. These structures, called *kites*, typically consist of two stone walls that converge on a fenced corral, much like the pronghorn traps used in the Great Basin. Many hundreds have been detected using satellite imagery[45] in the Levant, Arabian Peninsula, Armenia, and central Asia. These very large stone structures were used in communal hunts of gazelle. A few of them have been dated to about 4000 BCE,[46,47] and so may have been constructed by people living in farming and herding societies. However, they may also have been built and used by foragers. Until the first part of the 20th century, a foraging group called the Solubba lived throughout much of the Arabian Peninsula.[48] They built kites up to three kilometers in length, and used them to harvest gazelle, their main source of subsistence, in large communal hunts.[49]

South America

There is evidence for communal hunting in Tierra del Fuego. The explorer-ethnographer Charles Furlong spent two years in Tierra del Fuego and Patagonia living with indigenous groups[50] including the Selk'nam (also called the Ona) a hunting and gathering group that specialized on hunting guanaco (*Lama guanicoe*). These medium sized camelids aggregate in sizable groups in the fall and winter, and disperse into territorial one-male groups and bachelor herds in the spring and summer. The Selk'nam stalked guanacos individually, ambushed them using blinds, and hunted them communally. Furlong[51] describes two large-scale drives (Figure 2) in which the Selk'nam used natural features to concentrate and harvest substantial numbers of guanacos. This ethnographic account is supported by archaeological work in eastern Tierra del Fuego, the region occupied by the Selk'nam. Archaeologists excavated a site on a peninsula between two small lakes where they found the remains of a large number of mainly male guanacos.[52,53] The characteristics of the assemblage suggests it is the result of a single event consistent with the kind of communal hunt described by Furlong.

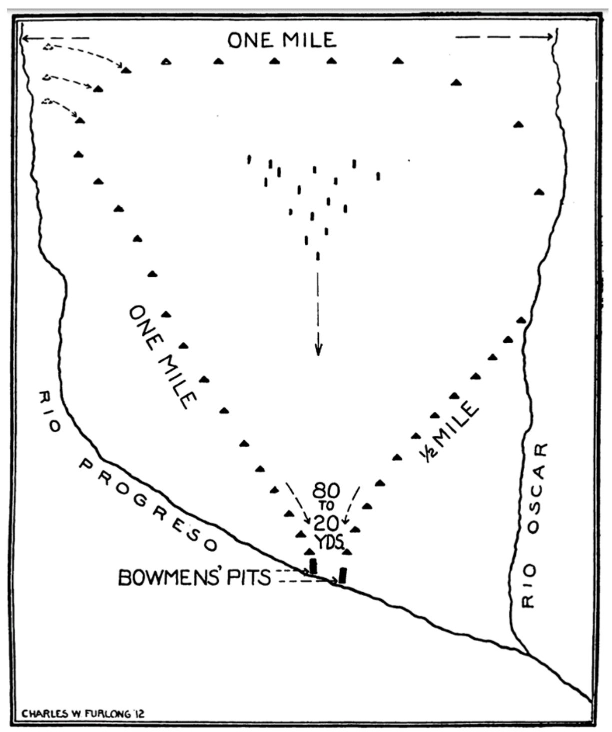

Figure 2. A diagram portraying communal guanaco hunting by the Selk'nam. From Furlong (2012).

There are also two ethnographic reports of large-scale communal hunts in South America. Kim Hill (personal communication) observed more than 80 Ache foragers in Paraguay engage in communal fishing, and among the Hiwi of Venezuela, Hill saw communal capybara drives in residential camps of greater than 100 people which involved more than a dozen canoes, each with several men.

Africa

Recently, a number of V-shaped stone walls, similar to those used to hunt pronghorns in the Great Basin have been discovered in the Nama Karoo region of South Africa.[54] These structures are difficult to date, but the presence of pottery and the absence metal in the associated material, suggests that they were built after the arrival of Koekhoe herders in the area but before the arrival of Bantu speakers. In addition, the stonework resembles structures made in the region before the Bantu arrived. Lombard and Badenhorst [54] argue that these structures were used by /Xam San foragers to hunt springbok, a small antelope. Large herds once undertook seasonal migrations in response to changing availability of water. Ethnohistorical research in the early 20th century indicates that springbok played a crucial role in the /Xam San foraging economy and that the /Xam San had a deep knowledge of springbok behavior. Lombard and Badenhorst[54] suggest that during seasonal events several bands of /Xam San camped and worked the drive lines together. The largest of these structures is about 300m in length so these groups need not have been extremely large. Rock art also suggests that southern African foragers may have used nets to hunt communally.[55]

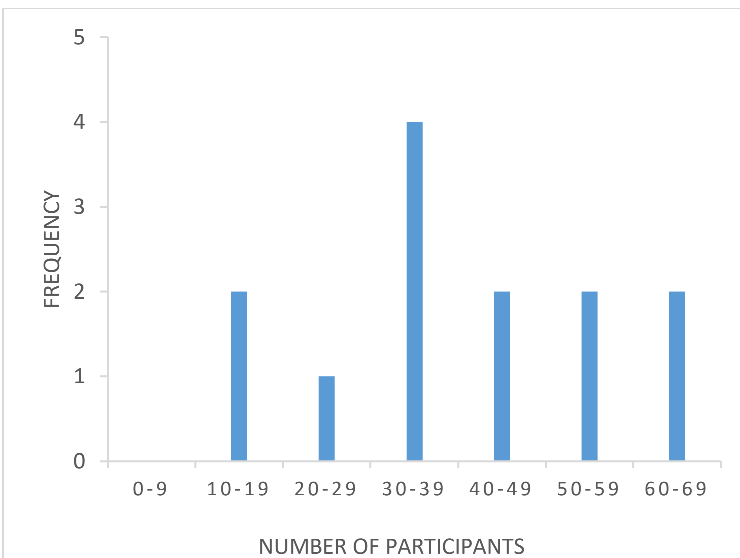

Figure 3. Number of participants in Congo Basin net hunts.[36:8]

Congo basin foragers also engage in communal net hunting.[56] Individually owned nets are combined to form a large circular or semi-circular barrier, and animals, principally duiker, are driven into the nets. Both men and women own nets and participate in these hunts. Net owners own the game caught in their nets. The number of participants in a sample of hunts is given in Figure 3. The largest groups involved more than 60 participants, but in all cases, hunters were drawn from a single residential band.

Australia

Aboriginal foragers in Australia hunted a number of species communally, including kangaroos, wallabies, emus, and waterfowl. There are some reports of the use of V-shaped wood and brush drivelines to hunt wallabies that are much like those constructed elsewhere. In one case, the wings were 0.4 km long.[57:117] Aboriginal foragers also used various kinds of nets as concentrating devices in communal hunts. For large terrestrial prey like kangaroos and emus, a number of loosely woven linear nets with a combined length of about 1 km were arranged to form a large semi-circle. One group of hunters held the net, while the rest, often including men, women and children would drive the animals toward them. Resulting yields could be very large.[58,59]

Much time and effort went into production of the large nets used in communal drives. For example, one early account[59] reports that a 7.2 x 4.6 m kangaroo net took an entire local camp three weeks to make. This is consistent with modern experiments. A 52 x 0.8 m emu net in the South Australian Museum contains 350m of 5mm cordage which would have taken four weeks to construct.[58] These estimates do not include the time and effort needed to acquire and process the fiber and spin it into cordage.

Communal hunts in Australia were often associated with large seasonal gatherings that brought together people from many residential groups. Historical accounts speak of “whole tribes” gathering. Sometimes people gathered to hunt, but other times people gathered for ceremonial reasons or to harvest seasonally available plant resources. For example, groups of 3000 people gathered to harvest bunya fruits in Queensland.[58] Communal hunts were important for large gatherings because they were capable of producing sizable surpluses.

2.6 Communal hunting in the Pleistocene

So far, we have presented examples of communal hunting that occurred during the Holocene where food production was rare or absent. These events did not occur in ancestral times, and are unlikely to have shaped the evolution of shared human psychology. They show that large-scale communal foraging occurs among mobile foragers, and augment the picture of foraging life provided by ethnographic work on Holocene foragers. However, it is clearly of great interest to know whether Pleistocene foragers also participated in large-scale communal hunts. Two lines of evidence suggest that this is the case.

Archaeological studies suggest that communal foraging dates back to the lower Paleolithic (400 ka) and that large-scale drives occurred in Europe during MIS5, about 124ka. The oldest evidence of communal foraging comes from Gran Dolina cave in the Sierra de Atapuerca, Spain.[60] A dense accumulation of bison bones with butchery marks, stone tools, indicates that hominins killed and processed the animals in quantity. The age profile of the bison and tooth wear patterns indicate that these bones were the result of least two mass kills. This site dates to about 400ka and so the hunters were likely *Homo heidelbergensis*. Rodriguez-Hidalgo et al conclude, "… our data on mortality, seasonality, skeletal profiles, taxonomic diversity and taphonomy support at least two overlapping mass predation events in which a large number of people had to participate."[60]

At a number of younger sites there is stronger evidence for large-scale communal hunting.[61] The Middle Paleolithic site of Salzgitter Lebensted in Germany provides a good example. This site dates to about 54ka and preserves the remains of a large number of reindeer, probably killed in a single hunt.[62] Adult male bones predominate reflecting reindeer herd composition before the fall rut. The bones of larger males were intensively processed while those of smaller animals were skinned, but not processed for marrow. Intensive processing is consistent with the fact that reindeer males are in best condition during the fall. This site is in a narrow valley close to where it opens up onto a wider flood plain suggesting that the Neanderthals drove the reindeer into the narrowing valley and then killed them, much the like arroyo hunts of bison in North America.[61,62] White and Schreve[62]suggest that the width of the flood plain would have required "every member of the society" to participate in the drive. A number of other sites at which the remains of only a single species are found are thought to be the result of communal hunts, including Les Pradelles and Facies 2[63] (reindeer), Mauran[62,63] (bison), Soultré[64] (horses) and Zwoleń[62] (horses).

There is also suggestive evidence for communal foraging in East Africa during the Middle Stone Age (MSA). There are many archaeological sites in East Africa with MSA tools, but only a handful have faunal assemblages large enough to allow inferences about foraging behavior.[40] Two of these, Lukenya Hill[65] (GvJm-22 and GvJm-46) and Bovid Hill at Rusinga Island,[40] both in Kenya, provide evidence for communal hunting. The Bovid Hill site is a dense assemblage of bones of an extinct antelope (*Rusingoryx atopocranion*) closely related to contemporary wildebeest and MSA tools that date to 35-100ka. Based on the age profile of the fossils, the presence of stone tool markings on the bones, and the geology of the site, Jenkins and her coauthors conclude that the site results from a single, large-scale collective hunt in which the antelope were driven into a seasonal stream and killed there.[40] However, they acknowledge that a long-term accumulation cannot be excluded with certainty. Similarly, the assemblage at Lukenya Hill is consistent with communal hunting, but other explanations are possible.[65]

A second line of evidence comes from cave paintings at Lascaux and Altamira. Thomas Kehoe,[66] an authority on Great Plains bison hunts, has argued that these images contain elements that picture drivelines and communal hunts. At Lascaux, one of the famous "Chinese" horses stands below a fence-like structure, and on either side of the horse are feathery leaves like those used to augment drivelines in North America (Figure 4a). Other images contain lines of dots that may represent lines of cairns used in drivelines. For example, on the Axial Wall at Lascaux, a horse and a reindeer run parallel to lines of dots, and one of these ends in a square box perhaps indicating a corral (Figure 4b). Many other images contain features that could represent drivelines.


a


b

Figure 4. (a) One of the “Chinese” horses at Lascaux showing a fence that Kehoe[66] argues represents a corral, and feathers or leaves like those used to lie drivelines in North America. (b) Images from the Axial Gallery at Lascaux. Kehoe argues that the dots represent the lines of cairns used in drivelines, and the box a corral.

3. Fish traps and weirs

Coastal and riparian foragers in North America and Australia constructed fish traps. Most of these were stone walls that enclosed an area adjacent to the shore. The tops of these walls were underwater at high tide allowing fish to swim in, but above the water surface at low tide trapping the fish. A survey of fish traps in Queensland and the Torres Strait Islands, Australia[67] shows that they varied in length from 10 meters to more than 600 meters (figure 5). In this area, the oldest traps date to about 7500 years BP.

Substantial labor was required to construct these coastal traps. On the island of Mer, traps were constructed from lava rock carried from the bush. Rowland and Ulm[67] estimate that each meter of wall required about 500kg of stone. The traps on Mer averaged about 300 meters in length, so 150,000 kg of stone needed to be carried from the bush to the coast. They assume that one person could carry 35kg of stone per trip. This means that the construction of a trap required about 4300 trips. Notice that until completed, fish can escape at low tide, and so an incomplete trap is much less useful than a finished one.

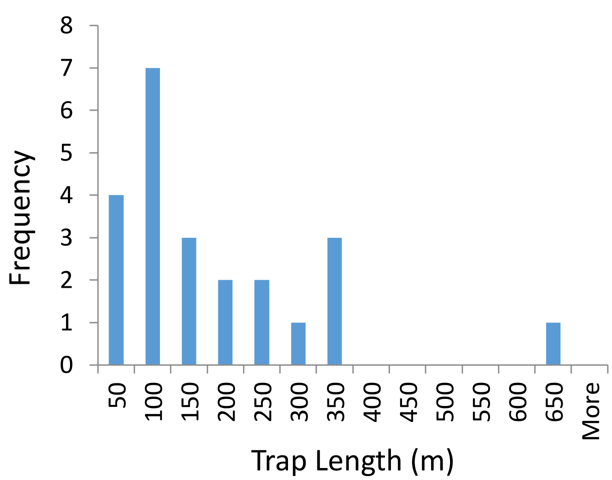

Figure 5. The distribution of lengths for stone fish traps from Queensland and the Torres Islands as listed in Rowland and Ulm.[67] We omitted any traps possibly constructed by Europeans. Some lengths were calculated under the assumption that the traps were semicircles.

Foragers used weirs to harvest fish on inland waterways in both Australia and North America. For example, Native Americans built redwood weirs across sizable rivers in northern California to capture salmon. Every spring, the Yurok built a weir across the Klamath River. Wooden pilings were driven into the riverbed every couple of meters and then fencing was added to prevent salmon from proceeding up river during the yearly run. Several hundred men were needed to cut the timber, and about 70 to build the weir. The weir was dismantled after ten days to allow the run to proceed up river.[68,69]

Weirs used to harvest silver eels throughout southeastern Australia.[70:39-41] During the eel migration, 800–1000 people gathered at the most productive sites.[71] The oldest of these traps date to 6600 BP.[72] Aboriginal people constructed two large facilities to aid in harvesting eels. Near Mount William, a weir redirected the river into a large maze of trenches that covered about 6 hectares and involved thousands of meters of trenches.[71] At Toolondo, Aboriginal people built a 2.5km long canal, 2.5m wide and 1m deep, which linked two natural swamps. The canal increased eel habitat because it linked one of the swamps to the ocean where the eels breed.[71]

4. Investments in habitat improvement

People in many foraging societies undertake activities aimed at increasing the productivity of the local habitat.[73] For example, Native American groups along the Mississippi and the Colorado Rivers sowed the seeds of wild grasses on mudflats exposed after seasonal floods. Other groups transplanted tubers and fruit trees. The Aché of Paraguay cut down trees and returned months later to harvest beetle larvae from the dead tree trunks.[74] The Owens Valley Paiute in California built diversion dams and canals to irrigate land and increase the growth of water-loving plants with edible roots. The largest of these irrigation areas covered about ten square kilometers and was fed by canals that were several kilometers long.[75]

In many places, people use fire create more productive plant communities by shifting nutrients from old inedible plants and plant parts to fresh growth that herbivores can utilize. For example, the Mardu, an Aboriginal group living in Australia's Western Desert, set fires in grasslands during the winter season that increased higher foraging returns for small game like monitor lizards.[76] The environmental changes induced by burning are likely to be public goods because the people who manage the burning experience costs, and the benefits of their efforts are shared by everyone in the community.[76]

5. Warfare

There has been much debate about whether warfare occurs among hunter-gatherers.[1,77–79] Comparative data[80] make it clear that violence was common among foragers, and much of the debate is about what constitutes warfare. Here we focus on whether foragers engaged in intergroup conflict in groups large enough to create a collective action problem, about three dozen warriors on a side.[1] Twentieth century studies of foraging groups support the view that large-scale conflict is rare among hunter-gatherers. However, there are good reasons to suspect that these societies are not representative of our evolutionary past because they are surrounded by powerful farmers or herders, and because they are often embedded in states that seek to suppress warfare.[81]

We present data on warfare among foragers who lived among foragers and were not subject to control by a state. We believe that these historical accounts support three claims about forager warfare. First, conflict occurred on all scales ranging from small-scale raids to battles involving hundreds of warriors on each side. Second, large-scale conflict caused many casualties and much mortality. Third, larger scale conflict was more common between members of different ethnolinguistic or tribal groups than within such groups. Ethnolinguistic groups typically numbered from 500 to a few thousand, indicating the scale of cooperation was larger than the size of war parties.

The data is mainly ethnohistorical. There is ample data from bioarcheology indicating that violence was common among foragers, but not reliable quantitative estimates of how many people were involved on each side. Most military weapons can also be used for hunting, and shields and armor were made from perishable materials. Mobile groups, including mobile foragers, rarely construct masonry fortifications.[82] Rare fortifications and rock art provide some indication, but for the most part we have to rely on the accounts of travelers and the memories of informants. The best data come from Australia, a continent of foragers until the arrival of Europeans at the beginning of the nineteenth century, but there is also useful data from western and arctic North America, places where foragers predominated until the middle of the 19th century.

5.1 Australia

Until the beginning of the 19th century, Australia was occupied only by hunter-gatherers, and there is considerable evidence that they sometimes fought large scale battles. William Buckley, a young man transported to Australia in 1803, escaped and lived with an Aboriginal group for most of the next thirty-five years. His account is saturated with interpersonal violence on all scales, including murder, small-scale raids, and large battles in which whole tribes were mobilized. In one conflict, 300 men from an enemy tribe, attacked his group leading to a bloody general fight.[83:1011] When he was younger, Buckley fought with the British army, and was seriously injured in battle. He found the hand-to-hand combat he witnessed among Aborigines “much more frightful” than European warfare. After two hours, the fighting ended, and during the night, the other tribe withdrew from the area. Buckley’s tribe followed them, and made a surprise attack on their camp. They fled, leaving three dead.[83:1011–1024] Buckley describes several other large-scale intertribal conflicts with substantial mortality.

More scholarly accounts of Aboriginal life confirm Buckley's picture—intergroup conflict was common, war parties were sometimes large, and death rates were substantial throughout Aboriginal Australia. Some of the larger scale conflicts were prearranged ritualized battles, but others were raids or pitched battles in which many people were wounded or killed. [79,84,85] According to Basedow[86:183] whole tribes frequently engaged in warfare in central Australia, ambushing their foes with goal of massacring them. Strehlow[87] describes one such conflict in which a war chief assembled a large war party from the Matunara area to ambush another group with the goal of killing everyone so that there would be no witnesses. An evening ambush was successful and men, women and children were slaughtered. W. L. Warner[88:457] begins a paper devoted to Murngin warfare as follows: "Warfare is one of the most important social activities of the Murngin people and the surrounding tribes." The Murngin recognize three types of large-scale conflict, a *maringo*, a night raid in which an entire camp is surrounded, a *milwerangel,* an open, formalized fight between at least two groups, and *gaingar* a large-scale regional conflict in which several tribes are involved. Maringo and gaingar fights led to large numbers of casualties.[88:458]

Accounts of battles with large number of casualties also provide evidence for large-scale conflict. Gat[89] describes an attack on the Finke River in 1875 in which 80 to 100 men, women, and children were killed. Similarly, Meggit[90:42] describes a conflict in the Western Desert over access to wells. In a pitched battle more than 20 warriors on each side died. Unless casualty rates were extremely high in these battles, sizable numbers of warriors must have been involved.

Rock art suggests that large-scale conflict is at least 6000 years old in Arnhemland. During the "Simple Figures" period (> 6000 BP) there are many sites at which groups of thin, stick-like human figures are shown opposing each other. In many, boomerangs and spears fly overhead, and some figures appear to drop their weapons.[91] In one spectacular case, there are 68 figures in two opposing groups.

5.2 North America

5.2.1 Pre-horse, pre-gun Plains Indians warfare

There is ethnohistorical evidence that Great Plains and Great Basin groups engaged in large-scale infantry conflict before the arrival of horses. At the time of first contact with Europeans, various Numic speaking groups on the eastern periphery of the Great Basin were engaged in persistent military conflict with non-Numic groups, and these conflicts drove the Numic expansion.[92] The preferred military tactic was to assemble a large war party, sneak up on an encampment during the night, and then attack at dawn. Camps had 10–30 families, so attacking war parties would need substantially larger than that number to achieve overwhelming force.[93,94:1-2] Successful attacks could lead to many deaths. In one battle between the Shoshone and the Blackfoot that occurred about 1726, the Blackfoot numbered 350 warriors.[95: 34-35,96:431]

5.2.2 Modoc warfare

The Modoc lived in the plateau country of northeastern California and southern Oregon. They were semi-sedentary hunter-gathers. Horses were used for transport but not hunting and didn't play the same central role that they did in Great Plains groups.[97:181-200] Modoc society was somewhat more complex than the nomadic foragers of the Great Basin, but lacked the hierarchy and tribal institutions seen in many other groups in California and the Northwest Coast.

The Modoc frequently fought with their neighbors over territorial incursions, retaliation for past attacks, and to capture slaves. Men known as formidable warriors organized raiding parties of 10 to 100 warriors. Participation was voluntary. Raiders typically traveled 50 km with the goal of launching a surprise attack on an enemy village. The Modoc mainly raided Pit River tribes, and never raided other Modoc villages. Battles were short and bloody. Horses seem to have played little role in these raids.[97: 134-145]

5.2.3 Fortifications in the Interior Northwest

Defensive fortifications are a classic example of a public good that provides a benefit to anyone who takes shelter, regardless of whether they contributed to their construction. An absence of fortifications in the archaeological record is not evidence for the absence of warfare because construction of fortifications often does not pay even where warfare is common. However, the presence of large fortifications is evidence for warfare.

In the plateau region of eastern Washington and Oregon there is ethnohistorical and archaeological evidence for large fortifications.[98] For example, a Numic speaking group (probably Northern Paiute) living on the Crooked River in eastern Oregon created a fortification that could contain sixty or seventy fighters.[98] Farther north, Teit and Boas[99:117-118] describe the fortifications built by Cour d'Alene and Thompson peoples. Stockades were circular structures built from vertical wooden poles about nine meters high with loopholes that allowed archers to shoot out. Bunkers were rectangular structures built from horizontally laid logs banked with earth to create walls about two meters high. Like the Modoc, these peoples were semi-sedentary foragers who lived at low population density largely subsisting on aquatic resources and deer. Archaeological data suggest that fortifications predate the arrival of Europeans and horses.[98]

5.2.4 Iñupiaq in northwestern Alaska

During the first half of the 19th century, Iñupiaq groups in western Alaska conducted regular large-scale warfare against members of other Iñupiaq groups, Athabaskan speakers to the east, and Chukchi people on the Asian side of the Bering Strait. Our knowledge of these events comes from Iñupiaq ethnohistory collected by the anthropologist Ernest "Tiger" Burch[100] who interviewed Iñupiaq elders about 19th century Iñupiaq life, conflict and alliance. By collecting and collating many accounts of the same events, he was able to create a picture of Iñupiaq life before extensive contact with Europeans and North Americans.

The Iñupiaq economy was based on fishing and hunting large game, mainly caribou and marine mammals. They lived in villages during the fall and winter, and then moved to fishing and hunting camps in the spring and summer. Population densities were about 1 person per 20 square kilometers, at the low end of the forager range. Villages ranged in size from 8 to 160 people, but 80% had less than 32 people.[100:70] People were collected into territorial groups that Burch refers to as nations. In the region around Kotzebue Sound there were 10 nations with an average population size of 470 people and average territory size of 8600 km^2.[100:7]

Burch[100:140] recorded accounts of 77 raids and battles that occurred in the first half of the 19th century. Like other foraging groups, attackers preferred surprise, nighttime raids. These occurred mainly in the fall because low temperatures meant that people would be inside at night, frozen rivers made travel easier, and the lack of snow made it difficult to track retreating raiders. Raiding parties armed with bows, lances and knives travelled long distances, sometimes as much as 300km each way, and never less than 80km.[100:80] Villages were centered around a community hall or *qargi* where men spent much of their evenings. Attackers hoped to surprise all the men in the *qargi* and kill them as they exited.

If the raid was successful, attackers killed everybody in the village. Sometimes young women were taken as slaves, but usually they were raped, tortured and killed[100:104]

The threat of raids prompted people to take defensive action. Some villages had defensive stockades, and others were surrounded by fields of sharpened caribou bones driven into the ground, much like the punji sticks used by Viet Cong fighters. They also built escape tunnels into the qargi. Raiders were sometimes detected and ambushed themselves.[100:71-72] Small villages could be attacked by raiding parties numbering 10 or 20 warriors. However, Iñupiaq sometimes attacked larger villages, and this required much larger raiding parties. It was more difficult to feed a large war party during travel, and larger villages were harder to approach undetected, but nonetheless, raids on large villages did occur.[100:102]

Burch[100:103] gives detailed accounts of several large raids. For example, raiding party of 350–400 men attacked a village of about 600 people. The attackers wore camouflaged clothing and came bare-footed to minimize the chance their approach would be heard. However, they were spotted, and the Point Hope villagers poured out and attacked the raiders who retreated onto a field studded with caribou spikes rendering many of them helpless. Their comrades fled leaving the injured to be killed by the defenders.[100:103-104]

Sometimes the Iñupiaq engaged in large open battles. This could occur when a large raiding party was detected, but sometimes they took place when the animosity between two nations had reached a boiling point.[100:104-105] In open battles, the two sides formed battle lines with the best archers on the flanks. Then the two sides would exchange archery fire, sometimes for hours. If one side was getting the worst of it, they might sometimes flee, experiencing serious casualties. Sometimes the two sides would close and engage in hand to hand combat armed with lances and knives.

5.3 Peacemaking and alliance formation

We don't have the space to treat this topic in the detail of the preceding ones but we think it important to make the point that people in small scale foraging societies can cooperate on cross-cultural scales. Small-scale societies seek to reduce the harm caused by warfare and realize the benefits of cross-cultural trade. They are capable of operating a fairly sophisticated "foreign policy" aided in part by cross-cultural institutions such as law and money.

In his classic book on warfare and diplomacy Thomas Schelling[101] wrote "The power to hurt is bargaining power. To exploit it is diplomacy—vicious diplomacy but diplomacy." He described the complex strategies that modern nations use to exploit the coercive power of arms to gain advantages over other nations, ideally by coercion and deterrence short of actual warfare. Warfare is costly. People are killed and injured, property is destroyed, and survivors experience anxiety, suffering and grief. The weak can drive up the costs of victory for the strong. As Curtin[102] notes in his classic book on cross-cultural trade, traders only operate if they are reasonably certain that they and their goods are safe from violence and theft. Open warfare also disrupts trade and other productive inter-societal activities. Peace favors trade and makes possible the formation of alliances that can help deter and coerce rivals. Peace and alliance require a polity to credibly commit to policy that prevents behavior that would disturb the peace. Local groups can't act as bandits and steal from peaceful traders. Ambitious warriors can't conduct free-lance raids against neighboring societies who are party to a peace. The same basic collective action problem that has to be solved for a polity to make war has to be solved to make peace and, more ambitiously, alliances. A common assumption is our Pleistocene ancestors lived in small bands that were hostile to one another.[103] We think the historical, archaeological and ethnographic evidence suggests that diplomacy on the part of such societies can hold together large alliances and maintain peace over large areas.

Western North America has many examples of peace and trade. Northern California is an example of a region entirely occupied by hunter-gatherers at the time of European conquest in the middle of the 19th century. In the early 20th century ethnographers were able to interview elderly people with some first-hand experience with their still-intact societies and who had substantial second-hand knowledge from people of their parents' and grandparents' generations. Individual ethnographies based on such interviews have limitations but the large number of groups for which ethnographies are available give a fairly comprehensive portrait of aboriginal life.[104–106] Furthermore, the archaeological record in Northern California is relatively good so that we have a general idea about the prehistory of trade and warfare.[107,108]

Peace-making in Northern California was similar across the region. Northern California peoples tended to be suspicious of others, especially, strangers and foreigners. They accumulated property, guarded it zealously, were jealous of people richer than themselves, and energetically pursued grievances. If possible, they would enlist relatives and allies in their quarrels. At the same time everyone recognized that this mind set was a recipe for costly feuds and wars. Third parties could get hurt and hostilities disrupted normal social and economic life. Hence, a set of rules evolved that parties not directly involved in a dispute could use to encourage hotheads to calm down and settle their differences. The basic principle is that people own their own fights. This is most formalized in the Yurok-Hupa-Karok legal system.[104] These three tribes live in the northwest corner of California and the southwest corner of Oregon. The first principle of this system is that all rights, claims, possessions and privileges are individual, not collective. Families and communities have no standing in the system. The second is that there is no legitimate punishment. Any punishment by an individual is an offense itself. The third principle is that any injury or offense can be valued in material terms. Immaterial (insults) and material (theft) transgressions can both be valued. Aggrieved individuals shunned those with whom they had a dispute but generally fell under pressure to resolve the dispute through negotiations aided by a legally knowledgeable "judge" who in essence acted as a mediator. Chiefs with coercive authority were absent in these groups. Shunning affected third party relatives and friends of the focal shunned individual, handicapping the local economy and social life. Once the two individuals reach a mutually agreeable compensation and the agreed upon goods have been exchanged, the grievances were considered to be settled. To harbor any detectable grudge or lingering ill will would be a fresh offense. Compensations were often substantial and individuals could be in debt for years before meeting their full obligation. These concepts of individual responsibility and compensation for offenses were widespread in Northern California, just unusually formalized in the Yurok-Hupa-Karok cluster. In other societies senior male chiefs were recognized and had some more power than judges to encourage settlements, but the autonomy of individuals tended to be substantial. This system meant that aggrieved parties could not recruit friends or kin to retaliated directly for offenses committed against them and so expand a conflict into a feud. Bettinger[106] argues that the past few centuries of political evolution in Northern California was from patrilineal clans in which chiefs had considerable power to the individualistic system that reached its extreme with the Yurok-Hupa-Karok.

The same principles that applied to within community dispute settlement applied to between community grievances, such as trespass on a neighboring groups territory. Goldschmidt[109] describes the situation of the Nomlaki, the Inner Coast Range branch of the Central Wintun. The usual causes of intertribal conflict were transgressions on property rights either individual (over a woman) or collective (encroachment on another tribe's territory). In the former case attempts were made to settle the affair by negotiated compensation of the aggrieved parties, as in within community conflicts. The latter type of transgression generally resulted in a war party from the aggrieved group being organized. Many men in Northern California groups trained as warriors, but there were no formal war leaders. Tactics included surprise raids and short pitched battles. Leading older men accompanied the warriors, but their role was peacemaking. Peacemakers exhorted warriors to consider settlement of the dispute instead of fighting.

This might work or the contending parties might be too angry to settle immediately and fighting would ensue. The desire of warriors to continue fighting was undermined by the knowledge that peace would have to be negotiated eventually and the more killing, the more costly the compensation. The contending parties brought wealth items to use in compensation in expectation that the dispute would be resolved on the day of the battle. Fighting usually stopped after one or a few casualties and compensation for the original transgression was negotiated among the relevant parties. The same was true for the injuries sustained in the fight itself. Once compensations were worked out remaining goods and money were traded.

Thus, although Northern California tribes were wary of strangers from other groups, active hostilities were infrequent and casualties usually few. In times of peace, those with goods to trade could approach a village of another tribe, announce themselves, and request to speak to their trade partners. Molesting, robbing or killing such individuals would constitute a grievance that eventually would have to be compensated, perhaps after a costly war. So, traders could feel reasonably safe in conducting their business.

California was webbed with trade routes.[110] Most tribes traded with their neighbors and for a wide variety of goods. For example, the Coast Range Nomlaki had a surplus of acorns and traded them to their Valley floor neighbors for fish caught in the Sacramento River. California has a wide range of habitats in close proximity and localized sources of important items like salt that motivated trade in everyday necessities between neighboring groups. There were also valuables that moved long distances, such as high-quality obsidian, marine shells, shell bead money, and exotic items from the Pueblo region. These almost always moved by relay trade from one hand to the next, no one trader moving more than a few kilometers. Thus, both subsistence and the prestige economies benefitted from trade.

Archaeologists recover shell beads and toolstone and these allow a reconstruction of trade networks deep in time. Hughes and Bennyhoff[107] describe the history of trade in shell beads for California and the Great Basin. Pacific Coast shells moved in considerable quantity across the Sierra Nevada Mountains, especially in the time period between 4,000 and 2200 years before present, supported by four trade networks.

Trade networks in Aboriginal Australia were as extensive as in Western North America and in the north included exchanges with maritime voyagers from New Guinea and Indonesia[111].

The technology and the art of the Upper Paleolithic people of the last ice age suggest that they were behaviorally modern in important respects. Whether the similarity to ethnographically known people extends to social organization is a harder problem. One of the best understood Upper Paleolithic cultural phenomena is the Gravettian Culture that occupied all of Europe from about 30 ka to 21 ka.[112] There was considerable stylistic uniformity across the whole region from the Urals to the Atlantic and from the ice margins to the Mediterranean. As in Western North America long distance movement of toolstone and marine shells testifies to a sub-continent spanning trade system.[113] Abundant archaeological data from Southern Siberia suggest the functionally similar but stylistically distinctive culture there.[112] The ethnic frontiers where conflict was most likely appear to have been far to the east of France and Spain beyond the Urals and south of the Ukraine. Gamble[114] argued that the stylistic similarity of the Gravettian across such a large area could only be maintained by open interaction networks in which ideas and probablly people could flow with little hindrance. Stone and bone plaques elaborately marked with rows of small pits have been interpreted as calendrical devices used to coordinate the movement of dispersed groups.[115] Gravettian burials indicate significant inequality in status[18] as if, at least in some circumstances, strong leadership roles existed perhaps for organizing communal hunts, feasting, or long-distance trade.

6. Discussion

Hunter gatherer groups observed over the last century vary widely in social complexity. At one end of the continuum, there are “simple” foragers who live in small mobile egalitarian bands at low population density, and at the other are “complex” foragers who live in sedentary groups with sizable permanent settlements and substantial social hierarchy. Holocene climates, new technologies and the influence of food producing societies mean that Holocene foragers likely differ from Pleistocene people in important ways. Nonetheless, many authors think that only societies on the simple end of the continuum provide a useful model for ancestral societies in which human physiology and psychology evolved. Such groups live in small egalitarian bands in which food is widely shared, sick and injured are cared for, and other kinds of mutually benefical cooperation are common. Many scholars (e.g. Tooby and Cosmides 2010) believe that large-scale cooperation is rare among simple foragers, and so would have not had much effect on the evolution of our cooperative psychology.

The evidence we have gathered indicates that Holocene hunter-gatherers cooperated on tribal scales. Hundreds of people worked together to build drivelines and harvest game, construct substantial irrigation works, and make shared habitat improvements. In most cases, such cooperation occurred regularly and was an important component in yearly subsistence. Holocene foragers also cooperated in large groups to fight with their neighbors, a high stakes form of cooperation, and were able to maintain peace within large groups. Evidence for large-scale cooperation is geographically widespread, coming from every part of the world where foragers maintained a substantial presence during the Holocene. Of course, Holocene foragers are not human fossils, and likely differ from Pleistocene hominin populations in which the psychological machinery that underpins human cooperation evolved. However, this evidence does indicate that the economics of mobile hunting and gathering do not preclude large-scale cooperation even in mobile societies in which people lived in small groups most of the year.

There is also archaeological evidence for large scale cooperation in mid-Pleistocene societies in Europe and Africa. Faunal assemblages at a number of Middle Paleolithic sites in Europe suggest that Neanderthals engaged in communal hunting of large mammals, reindeer, bison, and horses, and evidence from two MSA sites in East Africa provide circumstantial evidence for communal foraging. Finally, Upper Paleolithic cave art may portray drivelines and corrals like those used in Holocene North America. So, it is plausible that people in the Pleistocene societies that formed the environment for the evolution of human behavior also cooperated in large groups.

This evidence is not consistent with the hypothesis that cooperation among Pleistocene hominins was limited to small band-sized groups, but instead often extended to larger scale groups, even to the cross-cultural scale in the case of military alliances and trade partnerships. This suggests that the psychological mechanisms that support large-scale cooperation in contemporary societies evolved to support large-scale cooperation in Pleistocene societies of mobile hunter-gatherers, and explanations of contemporary cooperation based on mechanisms evolved to support only small-scale cooperation are not correct.

A number of important objections can be raised. First, there are few published ethnographic descriptions of large-scale cooperation among well-studied 20th century foragers. Why should this be the case? Moreover, given the high quality of modern ethnographies, perhaps we should be skeptical about historical and archaeological evidence we have assembled.

A number of factors have conspired to reduce reports of large-scale cooperation among contemporary foragers. Few anthropologists have focused on explaining large scale cooperation. Behavioral ecologists understand the problem, but those studying foragers have focused on smaller scale, within group cooperation, especially food sharing and mutual aid. Such behaviors occur frequently and can be studied using the rigorous quantitative methods of behavioral ecology more easily than rarer and hard to quantify behaviors. Two recent cross-cultural surveys of hunter-gatherer behavior by behavioral ecologists do not mention large-scale communal foraging[5,116] even though they include societies like the Inuit and Iñupiaq where large-scale communal foraging and warfare have been reported, especially in earlier accounts. Another influential synthesis[117] discusses communal foraging and warfare using models that assume that behavior maximizes average payoff and do not take into account the free-rider problem inherent in large-scale cooperation. Scholars outside of human behavioral ecology have not emphasized the free-rider problem inherent in communal hunting, investment in shared facilities like drivelines and fortifications, and participation in large-scale conflict. For example, many archaeologists emphasize the level of cognition necessary to coordinate large hunts and take it for granted that if large hunts pay on average and people are smart enough to organize them, they will occur. Similarly, anthropologists working in the cultural ecology tradition often assume that behavior is adaptive at the group level.

It could also be argued that there is little evidence for large-scale cooperation in Africa the region in which modern humans likely evolved. Modern humans emerged from Africa about 60ka and spread rapidly across the globe. This strongly suggests that the shared psychology that gives rise to large-scale cooperation must have been present in African populations before that date. Moreover, neither large-scale communal foraging nor warfare has been observed among Ju/hoansi or the Hadza, the canonical open country African foragers. However, observations of African foragers have mainly been limited to very dry environments or very moist environments. Moist tropical grasslands in which large, migratory herds of ungulates create natural targets for communal hunting[65] have been dominated by pastoralists for many thousand years. We know very little about foraging behavior in such environments in compared to high latitude environments. Moist tropical grasslands have more resident, non-migratory species and greater availability of plant resources suggesting that communal foraging might be less common.[65] However, two of the three MSA sites in East Africa with sufficient evidence to reconstruct foraging methods suggest communal foraging.[40] Moreover, in some dry environments like those found in southern Africa large migratory herds of springbok were common until recently and may have been harvested using drivelines,[54] and in moist forest environments communal net hunting has been widely observed, although limited to groups less than 60 individuals. Moreover, communal hunting and warfare have been observed in open dry habitats in Australia and North America.

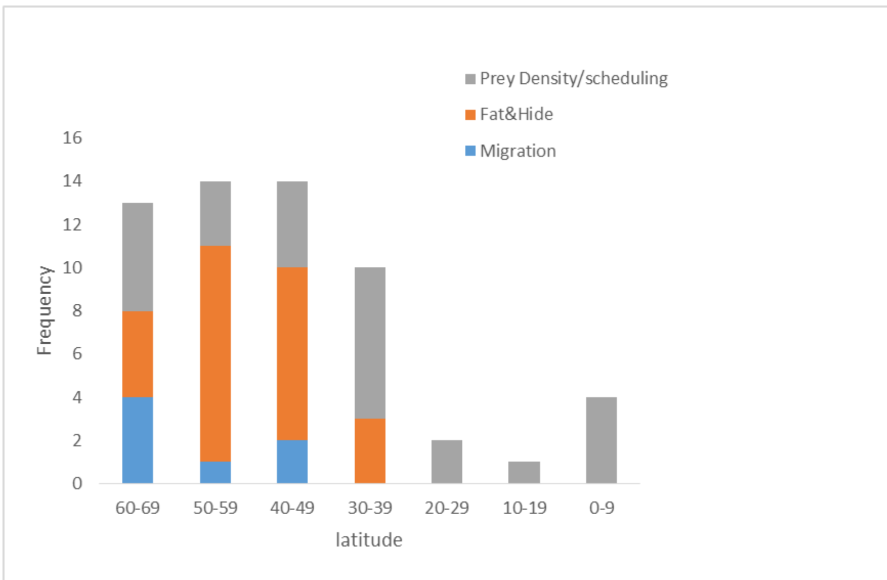

Figure 6: Frequency communal hunts as a function of latitude for a range of societies, including food producing societies.[31] Communal hunts were more common in Arctic and temperate environments. In these environments, communal hunts were motivated by seasonal migrations, the quality of hides, and the fatness of the prey.

More generally, communal hunts are more common above latitude 30 (Figure 6), but most foragers described in mid-20th century ethnography either lived at low latitudes in habitats where communal hunts may not have been profitable, or at very high latitudes where the availability of rifles made individual hunts for arctic reindeer more economic than communal hunts. In other areas, horses provided a better way to hunt bison, and modern hunter gatherers are surrounded by more powerful food producing neighbors, and often live within modern states that suppress intergroup conflict.

It also could be argued that the Holocene is different from the Pleistocene. Warmer, more stable Holocene climates and higher atmospheric $C0_2$ levels likely made agriculture possible and it could be that communal foraging and warfare were made possible by the same environmental changes. There are two reasons to be skeptical. First, the archaeological evidence suggests that Middle and Upper Paleolithic hominins engaged in communal foraging in higher latitude environments in much the same way that they did in the Holocene. There is also evidence that MSA hominins in Africa engaged in communal foraging. Communal foraging and warfare are difficult to detect in the archaeological record so the absence of evidence is not determinative. Second, the argument that Holocene foragers cannot be used as models for Pleistocene foragers applies with equal force to ethnographic evidence about 20^{th} century foragers, and we are left with no behavioral models to illuminate Pleistocene archaeology. It seems more reasonable to cautiously accept convergent evidence from ethnographic, historic and archaeological sources.

Finally, it could be argued that large-scale cooperation occurred during the Pleistocene but was infrequent compared to food sharing and other forms of within group cooperation, and so had little influence on the evolution of human psychology. You can think of this as the Paleolithic mismatch hypothesis. True, Pleistocene foragers sometimes cooperated in large groups, but they did so because, like modern people, because their evolved psychology was tuned to a world of small group cooperation, and this psychology led them to occasionally cooperate in large groups. But they did not find themselves in this situation often enough for natural selection to have reorganized their psychology to prevent it. This argument suffers from several weaknesses. First, there are good reasons to think that warfare may have been fairly common in some environments. Second, even though communal hunting was often seasonal, it played a crucial role in yearly subsistence of mid and high latitude peoples by providing hides and fat crucial for survival. Third, the evidence we have reviewed suggests that cooperative mass hunting is a few hundred thousand years old, leaving plenty of time for selection to act to reduce participation in large-scale cooperation if such cooperation was maladaptive.

The evidence we have presented indicates that mobile foragers regularly engage in large scale cooperation, and that this has been going for a long time. This in turn suggests that the psychological mechanisms supporting large scale cooperation in contemporary environments evolved because they supported large-scale cooperation in ancestral environments in which people lived as mobile foragers. Group sizes, degrees of relatedness and other aspects of population structure of mobile foragers aren't that different from those seen in other social mammals, especially social carnivores and other primates. The mechanisms used to explain the evolution of cooperation in such species, kinship, reciprocity, and direct sanctions suggest that large-scale cooperation among unrelated individuals is an unlikely evolutionary outcome.[1,2] However, humans are unusual in a number of ways. Although interspecies comparisons of intelligence are notoriously difficult, it does seem likely that humans have exceptional abilities in the domains of causal reasoning and theory of mind. Combinatorial language allows us to plan and negotiate in ways that are not available to other creatures. Human societies are regulated by shared, culturally transmitted norms that allow human societies to gradually evolve norms and institutions that can support social behavior appropriate to local conditions. A number of authors have outlined ways in which these peculiarities of human biology can support large scale cooperation.[2,103,118–120]

We think that this historical and archaeological evidence supports the idea that human foragers engaged in large-scale cooperation with unrelated individuals during the Holocene and perhaps much further back in time. There is strong evidence that our species has been fully modern technologically and cognitively for several hundred thousand years, and there is every reason to believe we have been cooperating on large-scales for a good part of this time interval. This in turn suggests that our psychology evolved in such a world and that mechanisms like other-regarding preferences and norm psychology that support large scale-cooperation in the contemporary world are adaptations shaped by natural selection because they support large-scale cooperation.

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Table 1: A summary of historical accounts of communal caribou hunting in the North American Arctic taken from Gordon.[21]

Location	Group	Method
Pt. Barrow	Tikkerarmiut	16 km willow drivelines
Anaktuvuk	Iñupiaq	8km stone and willow driveline sending into water crossing
Kobuk	Noatagmiut	Drive into water crossing, driveline
NE Alaska	Nunamiut	300 people built log and post drivelines 8km long
Mackenzie River	Mackenzie River Inuit	Encircled herd, drove into water
Central Arctic	Copper Inuit	Drove herd between *inukshuk*
Central Arctic	Netsilik	Drove herd into water using 3–5km *inukshuk* drivelines
W. of Hudson Bay	Caribou Inuit	Drove herds into river using *inukshuk* drivelines “many kilometers long”
Southhampton Island	Sadlermiut	Drove herd into water using *inukshuk* driveline
Saputit Fjord	W, Greenland Inuit	Used 600 meter drive fence to drive herd into water
Aasivissuit	W. Greenland Inuit	4km long stone driveline channeled herd to hidden hunters
E. Alaska, Yukon	Chandalar, Peel Kutchin	2km wide log corral with drivelines
Old Crow Flats	Vanta Kuchin	70–100 people, drivelines and water drives
Tanana & Yukon Rivers	Alaskan Tanana	48 km fence between Tanana and Yukon Rivers converging on corral. “Large investment in time and labor”
Upper Koyukuk River	Koyukon	30 km willow and post driveline with snares
Cook Inlet	Tanaina	16 km drives up to 6.4 km apart took 2 years to build
	Han	Corrals and human surround requiring 200 people
S. of Artillery lakes	Yellowknife	Brush corrals up to 2km diameter with 3–5 km drivelines
Fort Prince of Wales to Bloody Falls	Chipewyan Indians	350-600 people at 1.6 km brush corrals in July, 400 people 3-5km brush fences in fall and winter
Thelon River	Chipewyan Indians	32 blinds and 3.3 km of drivelines operated by 200 people
S. of Thelon River	Chipewyan Indians	2km wide pole and brush corral kept animals that fed 300–400 people for most of the winter
Slaughter & Faithful Isles Newfoundland	Beothuk	Wood fences up to 50 km long

Table 2: Ethnographic reports giving number of participants in five communal pronghorn hunts (cited in Jensen 2007:75).

Ethnographic account	Numerical estimate	Basis of estimate
Saline Valley, A few families	12–24	Average family size
All Little Smoky Valley people	96	Census data
Antelope Valley, 40-50 men and women	40–50	Verbatim
All villages in Promontory Point area	47–50	Number families per village, size
Surprise Valley, 15-20 camps, maybe 100 men	90–120	Verbatim, average family size

Table 3: Ethnographic reports giving length of corrals and estimates of the number of participants in a number of communal pronghorn hunts (Jensen[36:75]).

Area	Corral (m)	Material	Labor (hr)	Participants
Deep Creek NV	207	timber	69	6
Varede Valley NM	550	timber	183	16
Yerington NV	864	timber	288	24
Humbolt Sink NV	864	sagebrush	288	24
Pyramid Lake NV	1413	sagebrush	471	40
Morey NV	2513	sagebrush	838	70
Surprise Valley #1 NV	2529	sagebrush	843	70
Honey Lake NV	3141	sagebrush	1047	88
Powder & Snake Rivers OR	3141	sagebrush	1047	88
Surprise Valley #2 NV	3219	brush	1073	89
Reese River NV	5026	sagebrush	1674	140
Ruby Valley NV	5026	sagebrush-pole	3351	280

Figure Legends

Figure 1: The distribution of group sizes estimated from the length of corrals, drift fences and wings recorded ethnographically and measured in the archaeological record. Ethnographical data include both brush and post corrals while the archaeological data include only post corrals which require more labor to construct. Depopulation due to European contact may have also affected corral size (Size estimates from Jensen[36:75,91]

Figure 2. A diagram portraying communal guanaco hunting by the Selk'nam.[51] The vertical marks represent the guanaco, and the triangles Selk'nam foragers. There are 38 individuals pictured, but it is not clear whether this was meant to be numerically accurate as it would mean that the spacing between drivers was approximately 100m.

Figure 3. Number of participants in Congo Basin net hunts.[36:8]

Figure 4. (a) One of the "Chinese" horses at Lascaux showing a fence that Kehoe[66] argues represents a corral, and feathers or leaves like those used to lie drivelines in North America. (b) Images from the Axial Gallery at Lascaux. Kehoe argues that the dots represent the lines of cairns used in drivelines, and the box a corral.

Figure 5. The distribution of lengths for stone fish traps from Queensland and the Torres Islands as listed in Rowland and Ulm.[67] We omitted any traps possibly constructed by Europeans. Some lengths were calculated under the assumption that the traps were semicircles.

Figure 6: Frequency communal hunts as a function of latitude for a range of societies, including food producing societies.[31] Communal hunts were more common in Arctic and temperate environments. In these environments, communal hunts were motivated by seasonal migrations, the quality of hides, and the fatness of the prey.