Toleubayev, K., K. Jansen, and A. Van Huis 2007. Locust control in transition: the loss and reinvention of collective action in post-Soviet Kazakhstan. *Ecology and Society* **12**(2): 38. [online] URL: http://www.ecologyandsociety.org/vol12/iss2/art38/

Synthesis

Locust Control in Transition: The Loss and Reinvention of Collective Action in Post-Soviet Kazakhstan

Kazbek Toleubayev [1], *Kees Jansen* [1], *and Arnold van Huis* [1]

ABSTRACT. The inability to organize collective action for pest control can lead to severe problems. This paper focuses on the locust management system in Kazakhstan since the formation of the Soviet State. During the Transition Period after the collapse of the Soviet Union, the Plant Protection Service disintegrated. The principles of central planning were replaced with individualistic approaches with little state involvement in pest control activities or pesticide regulation. The financial and ideological reasons for dismantling the existing pest control system did not recognize the potential impact that policy-induced changes in agro-ecological conditions and control practices would have on pest development. Nature hit back at the induced institutional change that occurred in the Kazakh pest control system: an extremely harmful locust plague took the country by surprise between 1998 and 2001. This paper examines from an interdisciplinary perspective the co-evolution of locust populations, land use systems, knowledge about locusts, campaigns against them, and institutions in Soviet times and in the Transition Period. It argues the need for collective action theory to extend its present focus from local level institutions for resource management to higher level social-technical systems.

Key Words: *collective action; institutional change; Kazakhstan; knowledge; land use; locust; plant protection; public good; Soviet Union; transition period.*

INTRODUCTION

In July 1999, migrating swarms of the Italian Locust (*Calliptamus italicus* L.) invaded Astana, the newly established capital of Kazakhstan. Billions of locusts swarmed along the streets of the capital, terrifying citizens and causing traffic accidents. They roosted on the brand new governmental buildings and entered the offices of high-ranking officials. Locusts also invaded agricultural fields, devastating crops and pastures. The plague that occurred between 1998 and 2001 was probably the worst one experienced in Kazakhstan in the 20th century and had serious economic and political consequences. As the country did not experience such plagues during the Soviet period, it makes sense to ask whether there is any relationship between locust plagues and state organization. This paper examines whether changes in the locust control system, resulting from the collapse of the Soviet Union and the subsequent Transition Period, contributed directly to this locust plague. The history of the changes in the locust control system provides grounds for advancing the theory of collective action in natural resource management. The paper illustrates the importance of the recent discussion about institutional arrangements in collective action theory (Acheson 2006). The results of our analysis suggest that local-level participatory management and market-driven approaches are both inadequate in solving locust problem.

In addressing these issues, this paper first examines the impact of land use changes, and changes in habitat, on locust populations. It then describes knowledge acquisition during the Soviet period and the loss of this knowledge in the Transition Period. The next section portrays how the intensive knowledge system in the Soviet era was coupled to an extensive monitoring and control system. The Transition Period that followed the collapse of the Soviet Union led to an almost complete disintegration of this system. The locust plague that gradually built up in the late 1990s illustrates how these institutional changes were related to the development of locust populations. When the

[1]Wageningen University, The Netherlands

locusts flew into the government offices, high-level policy makers realized the consequences of the almost total dismantling of the plant protection service and started to reconsider public intervention in locust control. The last part of the paper discusses the public good character of locust control and the optimal modes of collective action.

METHODOLOGY, DEFINITIONS, AND THEORETICAL FRAMEWORK

Data were obtained through semi-structured interviews with people involved in locust research and control activities, viz.: plant protection practitioners, researchers, ex-researchers, research managers, agricultural producers, and policy makers. We collected not only hard data on population dynamics and the technical characteristics of control of locusts, but also data on the background knowledge of actors involved in locust management and their specific interpretations of the nature and cause of pest problems and the adequacy of specific solutions (Jansen 2008). We also conducted participant observation of meetings involving policy makers, practitioners, and researchers, and we participated in several locust-monitoring activities. Literature, documents, scientific reports, and press coverage on locust events were reviewed and the data from these different sources were crosschecked.

Locusts and grasshoppers belong to the order of *Orthoptera* and are members of the family *Acrididae*. Locusts differ from grasshoppers in that they have the ability to change their behavior and physiology in response to changes in population density (FAO 2001). Locust populations have two distinct phases: the solitarious phase when population density is low; and the gregarious phase when population density is high (Uvarov 1966). Adult locusts can form swarms, which may contain thousands of millions of individuals and behave as one unit. Locusts in the non-flying nymphal stage are called hoppers, when gregarious they form cohesive marching bands (FAO 2001).

The following definitions, modified from FAO (2001), are used to distinguish the different states of locust populations:

- Outbreak is characterized by an increase in locust numbers through concentration, multiplication, and gregarization, which can lead to the formation of hopper bands and swarms.
- Plague is a period of one or more years of widespread and heavy infestation by hopper bands and adult swarms.
- Decline is characterized by the dissociation of swarming populations because of natural factors and human intervention.
- Recession is a period when locusts are normally present at low densities in restricted areas and do not cause noticeable crop damage.

The plague of 1998–2001 in Kazakhstan was caused by locusts and grasshoppers. The most destructive of these were the Italian Locust (*Calliptamus italicus* L.) and the Asiatic Migratory Locust (*Locusta migratoria migratoria* L.). These two species provide exemplary cases for examining the co-production of political order and the development of scientific knowledge, decision making, and technologies dealing with locust control (Jasanoff 2004). The analysis of co-production in this paper uses two concepts borrowed from social theory: public good and collective action.

This study explores the extent to which locust control is a public good that requires collective action. Perrings et al. (2002) point out that the control of invasive, alien pest species is a public good when the benefits from the control are neither rival nor exclusive. If one person benefits from such a public good, this does not affect its cost, nor does this reduce the benefits to others (Ostrom 1990). If left to the market, the control would be undersupplied (Perrings et al. 2002). The supply of public goods requires collective action; or in the words of Olson (1992:Foreword), who challenges Adam Smith's notion of the market as an "invisible hand": "*...only a guiding hand or appropriate institution can bring about outcomes that are collectively efficient.*"

If locust control should be considered as a public good, as we argue below, then the subsequent question is how it can most effectively be provided through collective action. There are many documented forms of collective action in the fields of agriculture, environment, and development (e.g., Agrawal 2003). One important theoretical concern is the lack of agreement about how to distinguish different forms of collective action (Poteete and Ostrom 2004). Much of the current discussion on collective action pays relatively little attention to state-centered development of public goods, but primarily deals with concerted efforts by individuals or groups (Justino 2006). Major contemporary issues in this field include the management of common-pool resources, recently discussed in relation to processes of decentralization of central state control over natural resources (Agrawal and Ostrom 2001, Acheson 2006), and the large scale political activism of social movements (Edelman 2001).

Since 1990, the concept of collective action has played a role in the development of participatory approaches to integrated pest management in order to improve local-level management and learning processes, often through farmer field schools (Van Huis and Meerman 1997, Norton et al. 1999, Van den Berg 2004, Van den Berg and Jiggins 2007). This approach has proved to be very successful in fostering resilience management (Walker et al. 2002) by farmers, who by learning through discovery come to understand better the agro-ecological relationships in their fields. The farmer field school approach transforms farmers from passive recipients of crop protection instructions to active, self-reliant practitioners of integrated pest management. Major successes have been obtained in protecting high value crops with a history of resurgence and secondary pest outbreaks (Morse and Buhler 1997).

Farmers have also attempted to combat locusts to protect crops. However, when locusts arrive *en masse* in agricultural fields they have already reached plague proportions and it is beyond the capacity of individual farmers to deal with them. Then farmers resort to prayer or turn to politicians for solutions (Lockwood 2004). Locusts from plagues originate from outbreak areas that are natural habitats in which they multiply and gregarize. When fully gregarious, they are capable of migrating in swarms to agricultural areas, where they can inflict considerable damage (Van Huis 2007). A preventive control strategy aims to control locusts in the restricted, often remote, and not properly monitored outbreak areas (Van Huis et al. 2007). However, monitoring and controlling locusts in these areas is clearly beyond the capacity of individual farmers.

Collective action theory provides a framework to rethink the institutional successes or failures of market-driven, private-property regimes, government-controlled resources and interventions, and local-level management (Acheson 2006). This study of the transformations in Kazakhstan and the impact on locust and locust control illustrates the need for collective action theory to go beyond its current focus on decentralization and illustrates the need to rethink the role of governments in the delivery of public goods.

Scott’s review of the literature on Soviet collectivized agriculture pictures it as an “authoritarian” and “high-modernist” system that failed in all its aims and incurred massive costs through stagnation, waste, demoralization, and ecological disasters (Scott 1998:201). The Soviet system embraced the Baconian ideal of “technoscience” (Busch 2000:34), in which humans are subservient to the findings of science and the innovations of technical engineers. This body of literature equates the centralist, authoritarian political order with a technoscience that functions to control the citizenry, but is unable to deal with ecology or the heterogeneity of environments. This paper does not disagree with the broad thrust of this analysis, but identifies that it has one shortcoming: that the scientific and technological past was not as homogeneous as portrayed. Our study reveals that a very complex and dynamic system of locust management was developed during the Soviet era. By understanding the interactions between a political order, scientific knowledge, and technological practice we intend to contribute to a rethinking of the potential forms of collective action in providing public goods, such as locust control. To this end, and to identify the critical changes that occurred over time, this study examines how land use practices influenced locust habitats and population dynamics, how knowledge about locusts developed and, how locust control was practiced.

LAND USE, HABITATS, AND LOCUST POPULATIONS

The effect of the anthropogenic factors, particularly of agricultural practices, on the population dynamics of locusts has been widely acknowledged (Chetyrkina 1958, Uvarov 1962, Farrow 1987, Kopaneva 1987, Popov 1987).

Land use and the Italian Locust

Chetyrkina (1958) carried out comparative quantitative surveys of populations of the Italian Locust in many habitat types in areas subject to mass outbreaks in eastern Kazakhstan. Although these surveys were conducted in the recession years of locust populations, they revealed striking differences in densities, which are related to land use (Table 1).

The Italian Locust occurs in low densities in undisturbed habitats, and disappears completely when the land is plowed up (Table 1: 1, 2, and 3). It occurs in high densities when land has been left fallow for four to five yr and is invaded by *Artemisia*, (Table 1: 4 and 5). In the later stages of plant succession, when weeds are gradually replaced by secondary grass, densities of locusts are very low (Table 1: 6). On overgrazed and trampled communal pastures with weeds and much bare ground, the locusts are as numerous as they are on fallows (Table 1: 7). Thus, human patterns of land use, which affect soil structure and plant succession, affect the development of Italian Locust populations (Uvarov 1977).

Habitat reconstruction and the Asiatic Migratory Locust

The breeding habitats of the Asiatic Migratory Locust in Kazakhstan are linked to natural thickets of reed (*Phragmites australis*) along sea, lake, and river basins (Antonov and Kambulin 1997, Sivanpillai et al. 2006), which provide a source of food. Such habitats cover an area of about 1,120,000 ha in the country (Tsyplenkov 1970). In plague years, swarms migrate an average of 500 km from these breeding habitats, destroying almost all the vegetation on the way. As such this species is one of the most harmful agricultural pests.

Natural periodic fluctuations of the water level in lake and river basins influence locust population dynamics: when the water level decreases the area for locust breeding increases, and vice versa. The mass construction of dams, irrigation channels, and artificial reservoirs in the 1960–1970s, reduced the water level in the lake and river basins, favoring the intensive growth of reed beds and increasing the locust breeding area. For example, after the construction of Kapchagai reservoir halfway along the River Ili in 1971, the water inflow into Balkhash Lake diminished, and the water level gradually diminished (Popov 1987, Kambulin 1992), enlarging the locust breeding habitats. At the same time, reclamation of lands for rice and cotton production along river basins (e.g., in the lowlands of the Syr-Darya and the Amu-Darya Rrivers) reduced the natural growth of the reed beds and created unfavorable conditions for locust breeding (Popov 1987). As soon as significant parts of these cultivated lands (including the irrigation infrastructure) were abandoned in the 1990s these areas became mass locust breeding habitats, and most likely contributed to the locust plague of 1998–2001.

Impact of land use practices on locust population dynamics

The 1998–2001 locust plague in Kazakhstan mostly involved the Italian Locust. A historical perspective can help explain why the plague developed. Locust problems started in the second half of 19th century onwards when large numbers of Russian settlers began to colonize and cultivate the territory of present-day Kazakhstan. From then on the cultivation of virgin lands, i.e., lands that had never been used for crop production, continued under the Tsarist regime, after the Bolshevik revolution, during Stalin's collectivization period, and during World War II. By the end of 1940s, the total area of reclaimed virgin and idle lands amounted to about 7×10^6 ha (Gossen 1998).

In 1953 the Soviet leader Nikita Khrushchev initiated the ambitious Tselina/Virgin Land Program to turn the traditional pasturelands of Kazakhstan into a major grain-producing region for the Soviet Union. From 1954 to 1964 about 25×10^6 ha of virgin and idle lands were plowed for wheat production in Kazakhstan. Such extensive changes considerably reduced the natural habitats of the Italian Locust. As illustrated in Fig. 1, the implementation of the Virgin Land Program between 1956 and 1965 made these cultivated lands unsuitable for the Italian Locust. From 1965 onwards, long fallow-wheat rotation systems became prevalent in Kazakhstan, and the large areas under fallow became important breeding grounds for the Italian Locust, which repeatedly invaded crop fields. This suggests that the recurrent pattern of serious infestations every four or five years might be connected with the periods when the fallow fields reached the succession stage (Table 1), which is the most favorable for the insect. Moreover, a reduction

Table 1. Mean adult densities of non-swarming populations of *C. italicus* in different habitat types in eastern Kazakhstan.

	Type of habitat	Number/m^2
1.	Virgin land; dense short grass (*Festuca sulcata*)	3.5
2.	Patches of *Artemisia maritima* surrounded by short grass	7.6
3.	Current year's cultivations, e.g., wheat, etc.	0
4.	Early fallow, with some grass, sparse *Artemisia* and other herbs; bare patches	20
5.	Older fallow, with tall weeds including *Artemisia*	26
6.	Very old fallow, with dense grass turf (*Festuca sulcata*)	0.25
7.	Overgrazed communal pasture, with *Festuca, Artemisia, Polygonum aviculare, Alyssum*, etc.	20

Source: adapted from Uvarov (1977).

of pasturelands, now cultivated, increased the number of livestock per unit area, leading to overgrazing and land degradation. This created favorable conditions for an increase in the population of the Italian Locust (Table 1). The relation between plant type cover and occurrence of the Italian Locust is not only based on food preferences, but also on the physical properties of the soil (Chetyrkina 1958). They prefer moderately compact soils for egg laying, very compact (virgin) and very loose (recently broken) soils are less favorable for this. Thus the soil structure and vegetation of fallow lands in long fallow-wheat rotation systems presumably contributed to an earlier Italian Locust plague in 1970–1971 (Fig. 1).

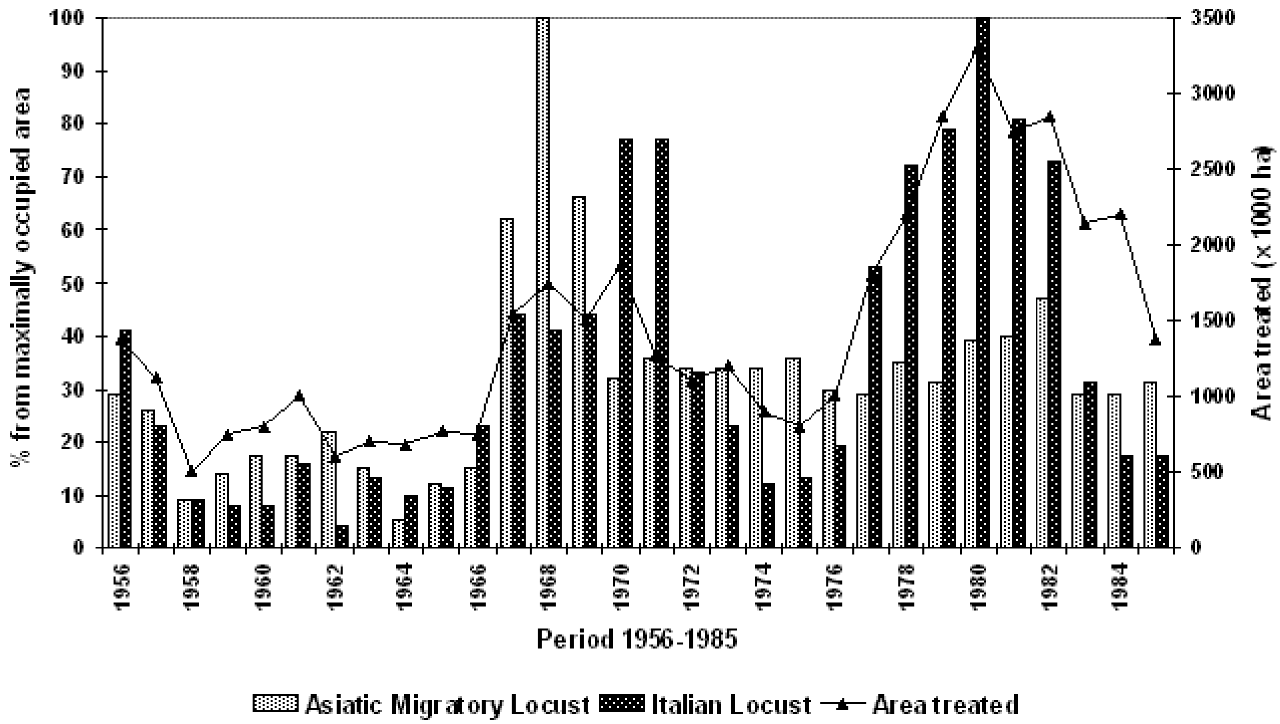
Plowing up virgin and idle lands led to another agro-ecological problem, that of wind erosion. To deal with this problem anti-erosion cultivation systems were implemented in the beginning of 1970s, which involved disturbing the soil as little as possible and by sowing crops in strips. These new systems of soil cultivation seem to have increased the size of the habitats favorable for breeding of the Italian Locust, particularly since these areas were located next to the specie's natural breeding habitats. This is likely to have contributed to the 1978–1982 plague (Fig. 1).

After the break up of the USSR in 1991, vast areas of cultivated land were abandoned. Areas under cereals in Kazakhstan decreased from about 25 to 12×10^6 ha between 1992 and 1995 (Azhbenov 2000). These idle lands became a perfect habitat for the Italian Locust after 4–5 yr of vegetation succession (Table 1), and may have caused a population increase that started in 1996, and led to the plague of 1998–2001.

Popov (1987) argues that in general, the population dynamics of swarming locusts, particularly the Italian Locust and the Asiatic Migratory Locust, depend on periodic climatic fluctuations, and that the outbreak periods of both species coincide (Fig. 1). He also indicates that the scale of outbreaks depends on agricultural practices. His study of locust population dynamics in the USSR since 1925 reveals a pattern of a periodic increases and decreases in locust numbers.

Figure 1 shows that the infested area expanded over the years despite the locust campaigns, which only led to a temporary reduction in locust populations. This illustrates the influence of ecological and climatic factors, and agricultural practices on population fluctuations, but this does not imply that control is useless as it may be effective in protecting standing crops.

Fig. 1. Area (%) occupied by the Asiatic Migratory Locust and the Italian Locust, and area treated (ha) against all species of locusts in the USSR in 1956–1985. Source: Popov (1987) and Latchininsky et al. (2002).



LOCUST KNOWLEDGE AND EXPERTISE

Knowledge formation

The branch of entomology studying grasshoppers and locusts is called Acridology. Its founder was Boris Uvarov (1888–1970), a scientist of Russian origin. After his graduation from Saint-Petersburg University in 1910 he worked as the senior entomologist for the Trans-Caucasian region and southeast Russia, where he set up one of the first entomological bureaus in Russia. In 1920 he emigrated to England and became a senior researcher at The Imperial Bureau of Entomology in London. But his interest in *Orthoptera* fauna of the Soviet Union did not vanish. He continued to keep in touch with colleagues from Russia, and published a number of books in the Russian language *Locusts and Grasshoppers* (Moscow 1925), *Locusts of the European part of the USSR* (Moscow 1925), and *Locusts of Middle Asia* (Tashkent 1927). Uvarov also became involved in research on the Desert Locust (*Schistocerca gregaria* Forsk.) after its plagues in 1929 in Africa and southwest Asia. In 1945, he established the Anti-Locust Research Centre in London, and managed it for 14 yr until his retirement, during which time it developed an international reputation. His book *Grasshoppers and Locusts: A handbook of general Acridology* (Volume I 1966, Volume II 1977) became a standard reference book for acridologists worldwide. This book includes details about locust and grasshopper species in the Soviet Union, and particularly in Kazakhstan.

Knowledge acquisition during the Soviet period

During the Soviet period the biology, taxonomy, ecology, and population dynamics of the locust and grasshopper species were the focus of study by many scientists. One comprehensive study on the Italian Locust coupled with control campaigns was carried out between 1945–1957 in central Kazakhstan by a large team of Soviet researchers and practitioners (Vasil'ev 1962). It monitored population recessions and outbreaks of the Italian Locust over a territory larger than Italy and England put together. The study identified the permanent breeding sites of this locust species, thereby contributing to future preventive control strategies.

In 1981 the All-Union Institute for Plant Protection (VIZR) initiated a research program to develop a complex of effective and environmentally benign methods for locust control aiming at preventing mass breeding. The program was based on research results obtained by VIZR entomologists, who had spent many years studying the locust species in the Soviet Union, and particularly Kazakhstan. Researchers recognized the drastic changes in the breeding habitats of the Asiatic Migratory Locust and the Italian Locust in Kazakhstan and concluded that this would lead to these locust species growing in significance as agricultural pests. The results of this research program were published in the book *Locusts: ecology and control methods* (Shumakov 1987), which turned out to be the last comprehensive publication on locusts and grasshoppers in Soviet history.

Knowledge loss after the collapse of the USSR

In the wake of the collapse of the USSR, the plant protection system in Kazakhstan lost much of the knowledge and experience that had been acquired over many years, including that about locusts. There was little intergenerational conveyance of knowledge, because the older generation of researchers and practitioners retired or passed away, the majority of the mid-generation researchers and practitioners went into the private sector or emigrated, and only a few young people were recruited for public service.

In 1996, the Plant Protection Faculty at the Kazakh State Agrarian University was shut down and the intake of students specialized in plant protection was completely stopped. Previously the faculty annually produced 50–75 graduates specialized in plant protection. As a result the research and applied part of the plant protection domain was left without new recruits and continues to suffering from an alarming scarcity of staff.

The very few locust research projects that were carried out in Kazakhstan after the collapse of the Soviet Union were mainly based on the knowledge accumulated in earlier publications by Soviet authors. With the collapse of the Soviet Union's academic networks, access to these publications became difficult; for instance, much of the locust literature is only available in libraries in Moscow or Saint-Petersburg. Academic libraries in Kazakhstan have not been acquiring new stock or modernizing, and possess only a limited amount of literature on locusts.

Modern locust information gathering, monitoring, and forecasting technologies are all knowledge intensive, which require trained researchers and practitioners, who are currently not readily available in Kazakhstan. Although today there is ready access to international knowledge via the Internet, there is a significant language barrier, as very few researchers master languages other than Kazakh or Russian. Moreover, the differences in climatic and ecological conditions and locust species mean that the international knowledge is not always applicable to Kazakhstan.

It is generally assumed that knowledge increases over time, but as this study shows the production of knowledge in Kazakhstan was severely affected by the collapse of the Soviet system. In the past the science was well developed, and theory and practice were both applied in controlling locust populations, as elaborated in the next section.

STATE-PLANNED SCIENCE-BASED LOCUST MANAGEMENT SYSTEMS

Locust plagues were one of the triggers for the Tsarist Government to set up plant protection units in Central Asia at the end of the 19th century. The first entomological station in central Asia was founded in 1911 in Tashkent. After the Bolshevik Revolution in 1917, massive outbreaks of locusts and other agricultural pests in Kazakhstan and other Soviet republics, led the Plant Protection Services to function as entomological units and plant protection bureaus, to secure food provision for the newly established Soviet State. Thus controlling locusts was recognized as a public good since the early days of the Soviet State. In the 1920s teams of Soviet researchers organized scientific expeditions to locust affected areas in Kazakhstan. They observed that outbreaks of the Asiatic Migratory Locust and the Italian Locust, tended to originate from relatively restricted areas with peculiar ecological conditions. This suggested that future plagues might be prevented by closely monitoring these outbreak areas. This would allow swarms to be identified while they were forming, and for them to be destroyed before they migrated to agricultural areas. Thus, from 1934 onwards, special technical organizations known as Anti-Locust Centers were established at Balkhash, Alakol, Syr-Darya, and West Kazakhstan, each of which are locust breeding sites. These Anti-Locust Centers were called "Expeditions," as in early days scientists were expedited to suspect areas (Tsyplenkov 1970:5). By 1950 there were nine such centers in Kazakhstan (Fig. 2): Gur'ev (1), West-Kazakhstan (2), Kostanay (3), Central Kazakhstan (4), Karatal–Alakol (5), Balkhash–Ili (6), Zhambul (7), South-Kazakhstan (8), and Kzyl–Orda (9).

From 1960 onwards, the dynamics of locust populations were investigated by the Anti-Locust Centers, the Research Institute for Plant Protection, the Monitoring and Forecasting Service, and the regional plant protection stations, all working together in a unified plant protection system. Scientists and practitioners worked in close collaboration on the anti-locust campaigns; researchers' expertise in biology, ecology, and population dynamics of locust was combined with that of practitioners about local conditions, contributing to the success of anti-locust campaigns. The Monitoring and Forecasting Service worked in cooperation with the Research Institute for Plant Protection. Locust control operations in breeding areas were based on data from the annual monitoring and forecasting. Data on locust occurrence in remote areas were obtained from local herders and agro-technicians, trained in monitoring locusts. They informed the district plant protection stations. As one locust researcher said in an interview: "*...in the past, information on locust presence was collected literally from everywhere.*" This implies that information could be cross checked to make an evidence-based assessment of the locust situation for forecasting purposes.

The anti-locust teams consisted of permanent, regularly trained, and skilled staff. During anti-locust campaigns they had spraying equipment, insecticides, machinery, and aircraft at their disposal. Aerial pesticide application was first developed in the USSR in the 1920s and was applied in combating locusts (Pukhov 1931, Tsyplenkov 1970). In Soviet times, aircraft were available within 24 hr to any hot spot in any former republic of the Soviet Union during anti-locust campaigns.

In the 70 yr of Soviet history the state provided a collective response to locust problems, which according to available data seems to have been successful. The collapse of the Soviet Union led to disintegration and abandonment of the locust control system, as illustrated below.

TRANSITION PERIOD

A set of articles by influential practitioners and researchers in the domain of plant protection (Kambulin 1997, Migmanov 1997, Sagitov 1997, Temreshev 1997, Khasenov 1999, Temirgaliev 1999, Uakhitov 1999) identified the difficulties faced by the Kazakhstan Plant Protection Service in the 1990s, including the problem with locusts. Despite these expert views, the national agricultural development policy did not give sufficient attention to plant protection and quarantine issues. The government was engaged in a process of decentralization and liberalization, and prioritized reforms in selected sectors of the economy. The Plant Protection Service was abandoned as a state entity. The Central Plant Protection Station of the Ministry of Agriculture, responsible for the plant protection activities, almost stopped functioning as a result of severe budget cuts in 1990s, which led to a significant reduction in employees at both the central and regional level. In 1973 the Plant Protection Service employed 13,796 people and this fell to 1200 in 1997 (Ministry of Agriculture of Kazakhstan).

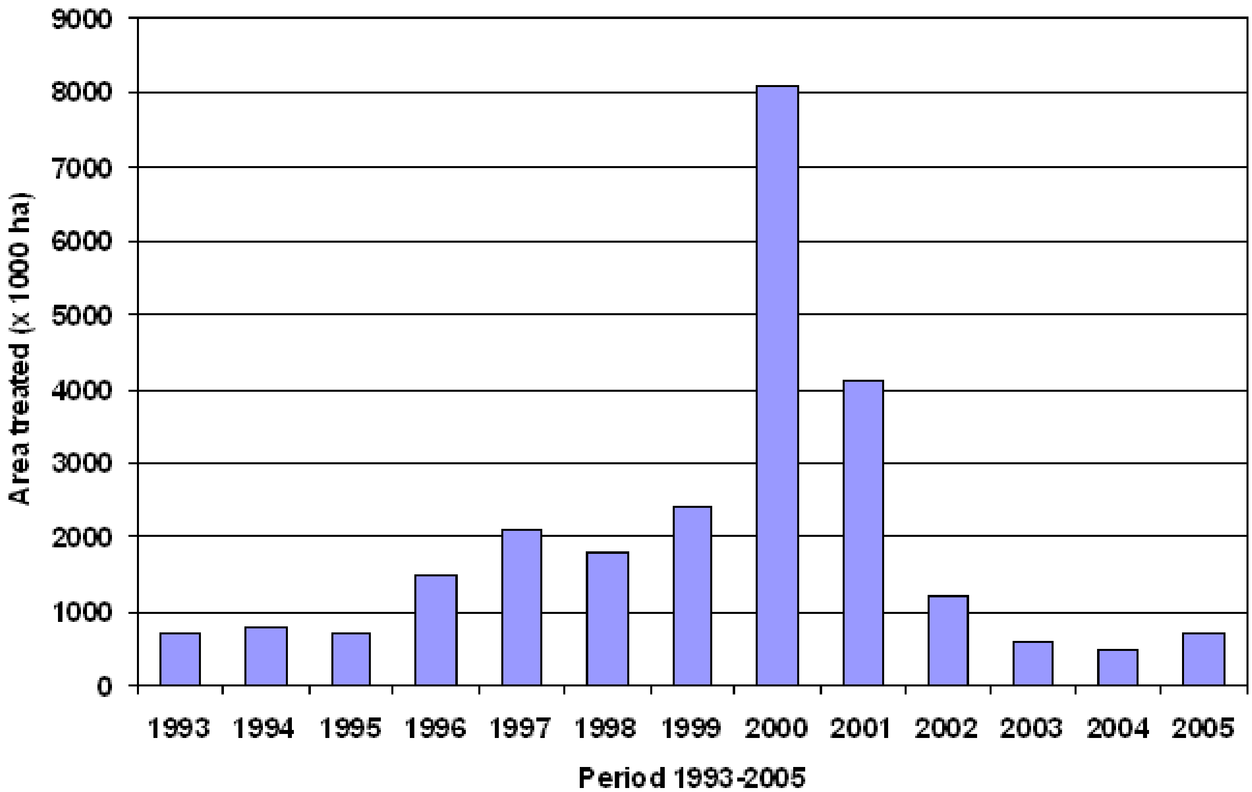
The locust plague of 1998–2001 can be traced back to 1996, when locust densities in wheat fields reached 135/m^2 in northern Kazakhstan (Temreshev 1997). The few plant protection practitioners and locust researchers still active repeatedly warned the authorities about the danger of locust outbreaks throughout Kazakhstan (V. E. Kambulin, *personal communication*). In 1997, the Head of the Central Plant Protection Station, advised by regional plant

Fig. 2. Anti-Locust Centers in Kazakhstan existing in 1950.

protectionists and locust researchers, wrote to the Ministers of Agriculture and of Finance about the increase of locust populations. He stressed the need to purchase insecticides and spraying equipment, and to recruit the necessary personnel in order to control the incipient outbreaks. However, nobody in the Ministries reacted to those concerns, and it then became too late to stop the outbreaks from developing into a plague. Because of this inaction, in 2000, the Government of Kazakhstan had to allocate 20.1×10^6 USD for the anti-locust campaign, which involved spraying 947,000 L of insecticides over an area of 8.1×10^6 ha (Fig. 3) (Khasenov 2001). This was the largest and most expensive anti-locust campaign ever carried out in the history of the former Soviet Union.

The spectacular invasion of the capital by locusts in 1999 made the Minister of Agriculture lose his position, amid jokes about the Minister being gobbled up by locusts. After the largescale anti-locust campaign conducted in 2000, the newly appointed Minister of Agriculture stated that they did not intend to eliminate the locust as a species unless it was necessary, and he stated that they had the experience to do so. Such an assertion, that the locust problem could be solved in Kazakhstan, was based on the success of the campaign that was temporary and only of local significance. Hundreds of thousands of liters of insecticides were applied to suppress the locust plague. However, it is questionable whether the application of pesticides was a key factor in suppressing this plague. A number of environmental and ecological factors may have been responsible for the population decline: temperature, solar activity, rainfall, the water level in basins of lakes and rivers, the quality and availability of food plants, vegetation succession, soil type, and so on (White 1976, Berryman 1987, Kambulin 1992, Antonov and Kambulin 1997, Toleubayev et al. 2003). Uvarov (1977) noted that there was no reason to expect that further organizational advances and technological improvements of locust control measures would, in themselves, provide a solution. However, it appears that decision makers prefer pesticide applications to protect crops from immediate destruction instead of investing in research, which would reveal the

Fig. 3. Total area treated against all species of locusts in Kazakhstan from 1993 to 2005. Source: Ministry of Agriculture of Kazakhstan.



underlying ecological causes for locust outbreaks, and incorporating these findings into a locust preventive control strategy.

To effectively contain locust populations the outbreak areas need to be monitored. The discovery, during Soviet times, of outbreak areas of the Italian Locust and the Asiatic Migratory Locust in Kazakhstan showed that it is possible to prevent mass outbreaks. For some other locust species, the detection and destruction of gregarizing populations in outbreak areas is the key to effective preventive control (Van Huis 2007). In North America, the Rocky Mountain Locust (*Melanopus spretus* Walsh.) became extinct due to the destruction of its very limited breeding and outbreak areas, i.e., riverine habitats (Lockwood and DeBrey 1990). The preventive strategy is still recommended by researchers in Kazakhstan, but its implementation requires considerable resources and long-term commitment from the government. As Uvarov (1977:527) commented:

> *...the records of the preventive organisations show, however, that measures for the repression of incipient multiplication and gregarisation of locusts in their outbreak areas have to be applied very frequently. This means that the level of vigilance of these organisations and their continual operational readiness as well as the annual expenditure that may be needed for control cannot be lowered.*

Failure to carry out monitoring and preventive control activities was one of the major causes of the locust plague of 1998–2001. In the process of decentralization and liberalization, the government did not recognize that the resulting institutional degradation of the pest control system would have an impact on the population dynamics of locust species. This recognition only came with the invasion of the capital of Kazakhstan by locusts in 1999.

POST 1998-2001 PLAGUE: REINVENTING COLLECTIVE ACTION

Locust invasion of capital: a driver of institutional change

Lin (1989) argues that the institutional changes driven by external forces often require collective action facilitated by the state. In our case, the locust invasion of Astana triggered a process of institutional change in the plant protection system. It led to the locust problem becoming a policy priority. The government set up an Emergency Locust Control Headquarters in Astana and the Prime Minister personally supervised the locust problem. Locust issues were discussed in numerous government meetings and scientific gatherings. Government authorities, agricultural producers, and plant protectionists increasingly collaborated to plan control measures. The invasion also brought about longer term changes. The president ordered the Ministry of Agriculture to develop a *National Program on Preventive Measures against Plagues and the Spread of Destructive Pests and Diseases of Agricultural Crops* as quickly as possible. Key legislation about plant protection and quarantine was introduced, viz.: the *Law about Plant Quarantine* in 1999 and the *Law about Plant Protection* in 2002. In the latter, the state recognizes its responsibility for controlling migratory, highly harmful, and quarantine pests, including the Italian Locust and the Asiatic Migratory Locust.

The policy and regulatory measures led to organizational changes in the plant protection system. The Kazakh case confirms Lin's observation that the processes of institutional change often involves the reconstruction of previously existing structures (Lin 1989). In 1999 the Government of Kazakhstan set up a Committee for Plant Protection in the Ministry of Agriculture, based on the remains of the former Central Plant Protection Station. The Plant Protection Service reacquired the status of a state entity that it lost early in the Transition Period. In 1999 the remains of the technical units of the former Plant Protection Service, including the Anti-Locust Centers, were united under a new state enterprise *Fytosanitaria* to monitor and control locusts. In 2003 a state entity called The Republican Centre for Phytosanitary Diagnosis and Forecasting was founded on the remains of the former Monitoring and Forecasting Service.

These legal and organizational changes were supported by a substantial increase in government expenditure on locust control. In contrast to the early transition period, the expenditure for locust control is now included in the annual state budget at the request of the Ministry of Agriculture. For the anti-locust campaign in 2005, the Ministry requested 438×10^6 Kazakhstan Tenge, (approximately 3.3×10^6 USD) to treat about 700,000 ha of land, mostly occupied by the Italian Locust and the Asiatic Migratory Locust.

According to official statements, the newly established plant protection entities conduct regular locust surveys and treat local outbreaks. However, the interviewees still identify serious problems. Public procurement of goods and services is done on the basis of competitive tendering for which *Article 20, Clause 4* of the *Law about Public Purchases* (2002) specifies "*...the customer [in this case, the Ministry of Agriculture] purchases goods, labor or services from the supplier who proposes the lowest price offer.*" This procedure applies to both the purchase of pesticides and the selection of private organizations to carry out the chemical spraying. In short the government gives priority to price over quality and efficacy: low efficacy and environmental and health risks are generally not taken into account in the tender procedures. In addition many of those we interviewed said that delays in releasing funds, due to complicated transaction mechanisms, led to failures in conducting timely control operations.

Today, there is still a shortage of funding and resources for a truly effective locust control system. Practitioners have to work with outdated equipment and are short staffed. There is still the need for a special locust unit with sufficient researchers and skilled technicians and readily available financial and technical resources.

Locust as a transboundary pest

Since locust swarms very often cross-national borders, one nation's food security concerns can become that of another. In this sense locusts can become a political issue, both creating conflicts between countries and triggering international collective action. The incidents of migration of the Asiatic Migratory Locust and the Italian Locust from breeding habitats located on the territory of Kazakhstan to Russia, Uzbekistan, and China, and vice versa illustrate this point. These countries have accused each other of allowing locusts to breed in mass on each others' territories and infesting neighboring countries. Uvarov (1953:85) stated: *"Locusts recognize no frontiers,"* and he added: *"... in many cases, the ability of locust swarms to cross frontiers is more readily admitted when they are entering a country than when they are leaving it for the neighbouring one."* To solve this problem, these countries have signed a number of intergovernmental agreements. In June 2000, the Ministries of Agriculture of Russia and Kazakhstan signed an agreement on information exchange, monitoring and controlling locusts across frontiers. In August 2000, in Almaty, the representatives of Kazakhstan, Kyrgyzstan, Russia, Tajikistan, and Uzbekistan signed a resolution at a round table meeting, organized by the Government of Kazakhstan and FAO. The resolution requested the FAO to study the possible creation of a Regional Locust Commission for Central Asia; comparable to the FAO Regional Commissions established for the Desert Locust. In February 2001, a round table *"Problems of combating locusts in Central Asia"* was organized at the Institute of Strategic Research in Kazakhstan. Participants included representatives of the Ministry of Agriculture, scientists, and plant protection practitioners from Kazakhstan, Russia, Uzbekistan, and China. In December 2002, Kazakhstan and China signed a number of intergovernmental agreements in Beijing, including one on cooperation over anti-locust activities. In March 2006, the Ministries of Agriculture of Kazakhstan and Uzbekistan signed an agreement to cooperate in controlling locusts along their shared borders. All these actions show the growing importance of the locust problem in the political agenda of the affected countries.

DISCUSSION

This paper has identified several factors that support the thesis that locust control is a public good requiring collective action. Locusts breed and multiply in natural habitats after which they migrate to agricultural areas where they destroy crops during outbreaks and plagues. Agricultural producers are not able to control locusts outside their private plots. This is why many countries treat the control of migratory and highly destructive pests as a public service, comparable with emergency services such as the fire brigade and the police. When faced with disasters or a common enemy, nations, and international organizations, e.g., UN and NATO, often respond with collective action (Sandler 1992). International undertakings to control the Desert Locust exemplify the need for collective action: FAO Regional Commissions have been established in locust-affected countries in Africa, the Middle East, and southwest Asia. In addition, locusts induce international collective action when they cross interstate boundaries, leading states to develop institutions and rules to control this transboundary movement.

What can we learn from the history of locust control in the Soviet Union? The impact of Soviet technoscience is multifaceted. The literature documents periods of scientific stagnation, bureaucracy, and the subsumption of the organization and content of science to political and ideological motives, exemplified by Lysenko's command of the Soviet Academy of Agricultural Sciences (Medvedev 1969). Furthermore, the impact of the virgin land campaign and the expansion of irrigated areas, i.e., typical high-modernist projects, had unforeseen consequences on the amount of land suitable on which locusts could breed.

However, the seventy years of Soviet history also show a collective response to the locust problem. An intensive knowledge system was coupled with an extensive monitoring and control system, which seems to have kept locust populations at manageable levels. Locust damage was largely prevented through substantial scientific research on population dynamics, considerable expenditure on control operations, and the establishment of an extended network in which monitoring agencies, local practitioners, and scientists collaborated to generate operational knowledge that led to an effective control strategy. Above, efforts were made to develop an ecological perspective on locusts and their control. Knowledge building, concerted action, habitat management, understanding ecological relationships, and long-term analysis and planning were key features of these efforts. This does not mean that the system was in equilibrium. It changed continuously and there was a high level of model uncertainty (Peterson et al. 1997), i.e., many of the connections between forms of land use, climate, locust population developments, locust control measures, and so on were uncertain. But for a quite some time there was a substantial capacity for learning and adapting control strategies to ecosystem dynamics, which made the locust control system quite resilient (Walker et al. 2002).

However, this locust control system could not cope with a fundamental uncertainty (Peterson et al. 1997), i.e., its dependence upon an unstable political system. The transformation of the political system led to a new social-technical configuration, which gave very low priority to locust control and changes in the agro-ecosystem. This created more favorable conditions for the development of a locust plague in a less desired state of ecosystem services (Folke et al. 2004). This new political configuration, which swept away concern for delivering many public goods, including pest control, led to a new dilemma over collective action. The official hostility to public action and the glorification of individualist, profit-driven, and market-oriented change during the Transition Period, contributed to the breaking up of the organizations and knowledge structures in the field of plant protection. The knowledge and capability to control locusts quickly disintegrated in Kazakhstan after the collapse of the Soviet Union and plant protection was left to individual farmers. However, it was not in their individual interest, and beyond their capacity, to invest in monitoring and controlling locusts. This resulted in a many more farmers being affected by the subsequent locust plague. In shifting to a market economy, the government did not recognize the dramatic impact that institutional collapse would have on the monitoring and control of locust populations.

The locust plague of 1998–2001 led to a reinvention of collective action. Once the locusts invaded the capital top-level decision makers started to realize that the dismantling and privatization of the plant protection service had unforeseen consequences. They became aware that locust control requires state intervention and some remnants of the Soviet knowledge structure were reinstated. Former chiefs of the regional Plant Protection Stations and influential scientists in the plant protection domain used this opportunity to revive the Plant Protection Service. Their work on locust control regained legitimacy, as did public expenditure to support it. The crisis also had other political repercussions (Hargrave and Van de Ven 2006). The reinstatement of some elements of the former locust control system raises the question of the extent to which this recent form of collective action builds on past forms and the extent to which it differs.

The rebuilt Plant Protection System has to operate with far fewer people than before and has to work with market actors, i.e., suppliers of pesticides and spraying services. However, from an ecosystems perspective there are other more fundamental differences. The latest policies tend to assume that the currently available stock of technology, basically pesticide applications, is sufficient to control locust plagues. Decision-makers even express the belief that it is possible to eradicate the locust, i.e., that total control of nature is possible. Past efforts to construct a more ecological view and to build knowledge and knowledge networks for understanding relationships between climatic variability, land use changes, and locust population dynamics have not yet been taken up again. Furthermore, recent policy measures seem to be mainly incident driven and largely take a short-term perspective. If we consider ecosystem and locust population dynamics as a slow variables (Holling 2004) the collapse of the Soviet Union has made sustaining these variables more difficult. This is a major transformation in the sense of Holling (2004) since the interaction between structure and processes have become qualitatively different. The long time frame for responding to locusts, which was previously institutionalized in the long term funding of plant protection services and knowledge building, career perspectives for scientists, and the organization of a multi-agency monitoring network, has been not been reestablished. The most recent transformations have, in fact, institutionalized the short time frame perspective that emerged in the Transition Period.

The reinvention of collective action cannot be seen as a pendulum effect between state provision of a public good and market-oriented approaches. Further development of collective action on locust control cannot lead to return to the previous social-technical system. We can learn from studying past collective action and use this to develop a critique of the present form of locust management, but it is not possible to derive a program of adaptive management from it. This would require what Holling (2004) has identified as a third mode of learning, which refers to new forms of organization that transform the system by developing truly novel strategies and processes.

It also follows from our discussion of knowledge about locusts that locust control requires collective action at a level higher than the local level, e.g., farmer fields or single watersheds. National and even transboundary forms of management have to be established. There is little indication that independent civil society groups with an interest in locust control will emerge in Kazakhstan in the near future. Service companies have been formed that carry out the pesticide spraying at the regional level but, given their objective of trading in pesticides and spraying services, it is unlikely that these will soon convert into advocates for a sustainable, long term and ecosystems perspective on locust control. Although local level participation may be crucial, as in the past when herders were part of the locust monitoring network. These participatory approaches to local level ecosystem management (Walker et al. 2002) and the current market-driven, short-term thinking about locust control in Kazakhstan are inadequate for developing a framework for rebuilding adaptive management of ecological services at a higher level and with a long-term perspective.

CONCLUSION

The comparison of the anti-locust campaign in 2000 in Kazakhstan under the neo-liberal system, the largest ever undertaken, with the history of 70 yr of centrally planned locust control history of the former USSR reveals the problematic impact of the transition upon ecological knowledge and sustainable locust control. Simplified representations of an inherently non-ecological and non-functioning Soviet system (Scott 1998, Busch 2000) need to be modified. Clearly, the large-scale land use changes resulting from high-modernist projects created favorable conditions for locusts. However, the Soviet system was also one that regarded locust control as a public good, built ecological knowledge, and mobilized financial, technical, and intellectual resources for monitoring and control. This system was better able to deal with locust problems than individualistic, purely market-led control based on the idea that an existing, single technology as pesticides can eradicate locusts.

Outbreaks of the Asiatic Migratory Locust and the Italian Locust periodically occur in Kazakhstan. It is only a matter of time before the country may face a locust plague similar to the 1998–2001 plague. This would test whether the recently reinvented collective action, organized around incidents and based solely around pesticides spraying, will provide effective control or whether collective action should be extended and reinstate important lessons from the past, regarding substantial knowledge building and concerted action based on a long term perspective. We conclude that we cannot expect an effective and ecologically sustainable form of locust control either through market-mechanisms or local level ecosystem management through participatory methods with farmers and other local stakeholders. This has consequences for theory on collective action in agricultural development. Public goods such as locust control need a higher level organization for their delivery. Dissatisfaction with centralized, bureaucratic state command-and-control or market-driven organizational forms for delivering such public goods should not lower the level of action to individual actors or very local institutions. We argue that it would be more productive to discuss how higher level social-technical governance systems can be reshaped so that they are able to interact with and respond to the complexities and uncertainties within large-scale agro-ecosystems.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/vol12/iss2/art38/responses/

Acknowledgments:

We would like to thank anonymous reviewers for critical and insightful comments that have improved the paper.

LITERATURE CITED

Acheson, J. M. 2006. Institutional failure in resource management. *Annual Review of Anthropology* **35**:117-134.

Agrawal, A. 2003. Sustainable governance of common-pool resources: context, methods, and politics. *Annual Review of Anthropology* **32**:243-262.

Agrawal, A., and E. Ostrom. 2001. Collective action, property rights, and decentralization in resource use in India and Nepal. *Politics and Society* **29**(4):485-517.

Antonov, A. G., and V. E. Kambulin. 1997. Forecasting seasonal dynamics of the Asiatic migratory locust using the *Locusta migratoria migratoria—Phragmites australis* forecasting system. Pages 81-89 *in* S. Krall, R. Peveling, and D. Ba Diallo, editors. *New strategies in locust control.* Birkhäuser Verlag, Basel, Switzerland.

Azhbenov, V. K. 2000. Mass breeding and migration of locusts in Kazakhstan. *Steppe Bulletin* 6, [*in Russian*].

Berryman, A. A. 1987. The theory and classification of outbreaks. Pages 3-30 *in* P. Barbosa and J. Schultz, editors. *Insect outbreaks.* Academic Press, London, UK.

Busch, L. 2000. *The eclipse of morality: science, state and market.* Walter de Gruyter, New York, New York, USA.

Chetyrkina, I. A. 1958. Italian locust *Calliptamus italicus L.* in eastern Kazakhstan. *Proceedings of All-Union Entomological Society* **46**:5-67. [*in Russian*].

Edelman, M. 2001. Social movements: changing paradigms and forms of politics. *Annual Review of Anthropology* **30**:285-317.

Food and Agriculture Organization (FAO). 2001. *Desert locust guidelines. Second edition.*FAO, Rome, Italy. Available online at: http://www.fao.org/ag/locusts/common/ecg/347_en_DLG1e.pdf.

Farrow, R. A. 1987. Effects of changing land use on outbreaks of tropical migratory locust, *Locusta migratoria migratorioides* (R&F). *Insect Science and Its Application* **8**:969-975.

Folke, C., S. Carpenter, B. Walker, M. Scheffer, T. Elmqvist, L. Gunderson, and C. S. Holling. 2004. Regime shifts, resilience, and biodiversity in ecosystem management. *Annual Review of Ecology, Evolution and Systematics* **35**:557-581.

Gossen, E. F. 1998. Basic groups of weeds in the north Kazakhstan and ways to reduce their harmfulness. *Plant Protection in Kazakhstan* **1:**6-11. [*in Russian*].

Hargrave, T. J., and A. H. Van de Ven. 2006. A collective action model of institutional innovation. *Academy of Management Review* **31**(4):864-888.

Holling, C. S. 2004. From complex regions to complex worlds. *Ecology and Society* **9**(1):11. [online] URL: http://www.ecologyandsociety.org/vol9/iss1/art11/print.pdf/.

Jansen, K. 2008. The unspeakable ban: the translation of global pesticide governance into Honduran national regulation. *World Development* **36**(4), *in press.*

Jasanoff, S. 2004. Ordering knowledge, ordering society. Pages 13-45 *in* S. Jasanoff, editor. *States of knowledge: the co-production of science and the social order.* Routledge, London, UK.

Justino, P. 2006. The impact of collective action on economic development: empirical evidence from Kerala, India. *World Development* **34**(7):1254-1270.

Kambulin, V. E. 1992. Exploratory forecast of mass breeding of the Asiatic migratory locust (*Locusta migratoria L.*) at Balkhash-Alakol habitat. *Ecology* **1**:81-84. [*in Russian*].

Kambulin, V. E. 1997. About locust problem in Kazakhstan. *Plant Protection in Kazakhstan* **2:**9-10. [*in Russian*].

Khasenov, S. S., 1999. Empowering the plant protection service. *Plant Protection in Kazakhstan* **3**:16. [*in Russian*].

Khasenov, S. S. 2001. Problem of locusts in Kazakhstan. *Plant Protection and Quarantine in Kazakhstan* **1:**2-6. [*in Russian*].

Kopaneva, L. M. 1987. *Orthoptera* order and level of anthropogenic pressure in agrocenosis. Pages 25-38 *in* E. M. Shumakov, editor. *Locusts: ecology and control methods.* All-Union Institute for Plant Protection, Leningrad, USSR. [*in Russian*].

Latchininsky A. V., M. G. Sergeev, M. K. Childebaev, M. E. Chernyakhovsky, J. A.

Lockwood, V. E. Kambulin, and F. A. Gapparov. 2002. *The acridids of Kazakhstan, Central Asia, and adjacent territories.* Association for Applied Acridology International and University of Wyoming, Laramie, Wyoming, USA. [*in Russian*].

Lin, J. Y. 1989. An economic theory of institutional change: induced and imposed change. *Cato Journal* **9** (1):1-33.

Lockwood, J. A. 2004. *Locust: the devastating rise and mysterious disappearance of the insect that shaped the American frontier.* Perseus, New York, New York, USA.

Lockwood, J. A., and L. D. DeBrey. 1990. A solution for the sudden and unexplained extinction of the Rocky Mountain grasshopper (Orthoptera: Acrididae*). Environmental Entomology* **19**:1194-1205.

Medvedev, Z. A. 1969. *The rise and fall of T. D. Lysenko.* Columbia University Press, New York, New York, USA.

Migmanov, A. 1997. It is time to look at the problem seriously. *Plant Protection in Kazakhstan* **1:**26-27, Pavlodar, Kazakhstan. [*in Russian*].

Morse, S., and W. Buhler. 1997. *Integrated pest management: ideals and realities in developing countries.* Lynne Rienner, Boulder, Colorado, USA.

Norton, G. W., E. G. Rajotte, and V. Gapud. 1999. Participatory research in integrated pest management: lessons from the IPM CRSP. *Agriculture and Human Values* **16**(4):431-439.

Olson, M. 1992. Foreword in T. Sandler. *Collective action: theory and applications.* The University of Michigan Press, Ann Arbor, Michigan, USA.

Ostrom, E. 1990. *Governing the commons: the evolution of institutions for collective action.* Cambridge University Press, Cambridge, UK.

Perrings, C., M. Williamson, E. B. Barbier, D. Delfino, S. Dalmazzone, J. Shogren, P. Simmons, and A. Watkinson. 2002. Biological invasion risks and the public good: an economic perspective. *Conservation Ecology* **6**(1):1. [online] URL: http://www.ecologyandsociety.org/vol6/iss1/art1/.

Peterson, G., G. A. De Leo, J. J. Hellmann, M. A. Janssen, A. Kinzig, J. R. Malcolm, K. L. O'Brien, S. E. Pope, D. S. Rothman, E. Shevliakova, and R. R. T. Tinch. 1997. Uncertainty, climate change, and adaptive management. *Conservation Ecology* **1** (2): 4. [online] URL: http://www.consecol.org/vol1/iss2/art4/.

Popov, G. A. 1987. Dynamics of locust population and their harmfulness. Pages 12-21 *in* E. M. Shumakov, editor. *Locusts: ecology and control methods.* All-Union Institute for Plant Protection, Leningrad, USSR. [*in Russian*].

Poteete, A. R., and E. Ostrom. 2004. In pursuit of comparable concepts and data about collective action. *Agricultural Systems* **82**:215-232.

Pukhov, B. 1931. Combating locust. *Protecting Socialist Yield* **4:**18-20. [*in Russian*].

Sagitov, A. O. 1997. Plant protection: an optimistic view of the future. *Plant protection in Kazakhstan* **1:**12-15. [*in Russian*].

Sandler, T. 1992. *Collective action: theory and applications*. The University of Michigan Press, Ann Arbor, Michigan, USA.

Scott, J. C. 1998. *Seeing like a state: how certain schemes to improve the human condition have failed.* Yale University Press, New Haven, Connecticut, USA.

Shumakov, E. M., editor. 1987. *Locusts: ecology and control methods.* All-Union Institute for Plant Protection, Leningrad, USSR. [*in Russian*].

Sivanpillai, R., A. V. Latchininsky, K. L. Driese, and V. E. Kambulin. 2006. Mapping locust habitats in River Ili Delta, Kazakhstan, using Landsat imagery. *Agriculture, Ecosystems and Environment* **117**:128-134.

Temirgaliev, Z. 1999. Problems of locust management in Pavlodar region. *Plant Protection in Kazakhstan* **3:**18-19. [*in Russian*].

Temreshev, I. 1997. Performance of the plant protection service under conditions of agricultural reforms. *Plant Protection in Kazakhstan* **1:**19-20. [*in Russian*].

Toleubayev, K., G. Woldewahid, A. van Huis, and W. van der Werf. 2003. Effect of nitrogen content of the host plant millet *Pennisetum typhoideum* on fitness of the Desert locust *Schistocerca gregaria* Forsk. *Tropical Resource Management Papers* **48:**107-122.

Tsyplenkov, E. P. 1970. *Locust pests in USSR*. Kolos, Leningrad, Russia. [*in Russian*]. English translation: 1978 Amerind, New Delhi-Bombay, India.

Uakhitov, A. 1999. Organizing plant protection under conditions of market economy. *Plant Protection in Kazakhstan* **3**:14-15. [*in Russian*].

Uvarov, B. P. 1953. International war on locust. *British Agricultural Bulletin* **6:**85-92.

Uvarov, B. P. 1962. Development of arid lands and its ecological effects on their insect fauna. *Arid Zone Research* **18:**235-248.

Uvarov, B. P. 1966. *Grasshoppers and locusts: a handbook of general acridology.* Volume I. Anti-Locust Research Centre, Cambridge, UK.

Uvarov, B. P. 1977. *Grasshoppers and locusts: a handbook of general acridology.* Volume II. Centre for Overseas Pest Research, London, UK.

Van den Berg, H. 2004. *IPM farmer field schools: a synthesis of 25 impact evaluations.* Global IPM Facility, Rome, Italy.

Van den Berg, H., and J. Jiggins. 2007. Investing in farmers: the impacts of farmer field schools in relation to integrated pest management. *World Development* **35:**663-686.

Van Huis, A. 2007. Locust control by early identification of breeding sites. *Encyclopedia of Pest Management* **1**(1):1-3.

Van Huis, A., K. Cressman, and J. I. Magor. 2007. Preventing desert locust plagues: optimizing management interventions. *Entomologia Experimentalis et Applicata* **122:**191-;214.

Van Huis, A., and F. Meerman. 1997. Can we make IPM work for resource-poor farmers in sub-Saharan Africa? *International Journal of Pest Management* **43:**313-320.

Vasil'ev, K. A. 1962. Italian locust *Calliptamus italius L.* in the central Kazakhstan. *Proceedings of the Kazakh Research Institute for Plant Protection* **7:**123-190.

Walker, B., S. Carpenter, J. Anderies, N. Abel, G. S. Cumming, M. Janssen, L. Lebel, J. Norberg, G. D. Peterson, and R. Pritchard. 2002. Resilience management in social-ecological systems: a working hypothesis for a participatory approach. *Conservation Ecology* **6**(1): 14. [online] URL: http://www.consecol.org/vol6/iss1/art14/.

White, T. C. R. 1976. Weather, food and plagues of locusts. *Oecologia* **22:**119-134.