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Wheat pest management (Aphid and Armyworm) through natural enemies in climate change scenario

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ABSTRACT

A study was conducted in two successive seasons during 2020 and 2021 at Adaptive Research Farm Rahim Yar Khan. The objective was to control the wheat aphid and armyworm through natural enemies. Aphids are major pests of wheat crop in Pakistan. The dominant aphid species i.e. *Schizaphis graminum*, *Rhopalosiphum padi*, R. *maidis* and *Sitobion avenae*. Various species of natural enemies, mainly *Coccinella septumpunctata*, C. *undecimpunctata*, *Menochilus sexmaculata*, *Chrysoperla carnea*, Syrphidae and parasitoid mummies were inconsistently observed in agro-ecological zones of wheat. It is concluded that the population of aphid was controlled much by the lady bird beetles (grub & adults), syrphid fly and yellow jackets (hornets), while armyworm was controlled much by the yellow jackets (hornets), chrysoperla and lady bird beetles during both years.

Introduction

Wheat (*Triticum aestivum* L.) is the primary food source and use as a staple food contains 13% protein providing 20% world food calories. Wheat is used as a food for nearly 40% of the world's population (Ahmad & Shaikh 2003).The wheat crop is grown on 23% global cultivated land having utmost importance in international trade for worldwide market (Husti, (2006). During 2017-18 the total yield of wheat grown in Pakistan was 26.7 million metric tons, and their consumption was 25.3 million tons (Palmer). Wheat production has been severely affected by so many factors such as improper seedbeds, low quality seeds and fertilizers, water shortage and most importantly lack of IPM techniques to manage insect pests (El-Gizawy 2009 and Khattak et al., 2007).

Aphids attack is one of the most crucial factors for wheat disease and low yield. Aphid is an economically significant insect pest damaging a broad variety of crops, fruits, and vegetable plants (Aheer et al., 2008). The bird cherry oat aphid, *Rhopalosiphum padi* (Linnaeus) and grain aphid, *Sitobion avenae* (Fabricius) are deleterious insect pests of wheat crops in Pakistan (Khan et al., 2006 and Khan and Ullah 2005). Wheat insect pests and their predators and parasitoids are evident in many wheat fields in central Pakistan. Insect pests can cause enormous damage in the two important growth stages (heading and flowering phases) (Freier et al. 2007). Wheat yield is dangerously affected by wheat insects. Wheat aphids are considered one of most destructive insects in wheat (Carter 1987; Steffey and Grey 2012). *Rhopalosiphum padi*(L.), *Metopolophium dirhodum* (Wlk.) and *Sitobion avenae* (Fab.) are the aphid species (Dixon 1987; French et al. 2001; Wetzel 2004; Poehling et al. 2007). R. padi and S. avenae are polyphagous sucking insects having worldwide distribution (TaheRi et al., 2010) and cause 15% reduction in the yield of the wheat crop at flowering stage only (Oerke, 2006). These two wheat aphids usually coexist in the wheat crops and cause damage through direct feeding on the sap from shoots and leave, causing distortion, curling, and chlorosis of leaves growth (Khaliq 2003 and Redfearn & Pimm 1988). Wheat crops sown in the late season may have high chances of aphids outbreak if the weather remains cool till the end of March (Bhambhro, 2002). The seasonal fluctuation in their dynamics is determined through the population growth rate and duration at which the population can grow. Aphid growth rate mainly disturbed by the host plant quality, predators, parasitoids and environmental factors (Stark & Banks 2003). Diverse factors were encouraged in search for determining the cyclic dynamic of aphids including long-term trends in agriculture practices (Brault et al., 2007) weather alterations (Biondi, et al.,2013) natural enemy profusion, and intra-specific competition (Fogel et al., 2013). Most biological control agents, including predators, parasitoids and spiders are naturally occurring agents, which provide excellent regulation of many pests (Sigsgaard 2002; Schmidt et al. 2004). Natural enemies either predators (lady beetles, lacewings, syrphids, 1524 N. El-Wakeil and C. Volkmar (2006) dance flies and spiders) or parasitoids (parasitic wasps). Parasitoid wasps were the lowest natural enemy species affected by insecticides; Syrphid flies revealed a moderate decline after spraying as well Coccinellids were affected moderately by insecticides as confirmed by Swaran (1999) and Meena et al. (2002). Temperature plays an important role in the effectiveness of parasites because parasites develop much more slowly below 65 degrees F and adults are not active below 56 degrees F. Greenbugs remain active at cool temperatures and continue to reproduce until the temperature drops to 40 degrees F. As a result, aphids infestation can increase unchecked by parasites during cool weather. Parasite activity in the field can be monitored by looking for aphids mummies on wheat leaves. Weather conditions will largely determine how quickly parasites can prevent aphids outbreak. Remember that aphids that appear healthy may actually have parasites developing within, as the mummy stage does not develop until 8 to 10 days after parasitism. As a general rule, aphids infestation declines rapidly once 20 percent of the aphids are mummies, because at this point most of the living greenbugs are already parasitized though they have not yet entered the mummy stage. The infestation of cereal aphids can be reduced by applying various biological, cultural and chemical control strategies (Desneux, et al.,2007). A hornet is simply a large wasp. Generally, wasps of the class or genus known as Vespa are considered hornets. Interestingly, there are no true hornets (Vespa) native to North America. The European hornet (Vespa crabro) is well established in much of the eastern half of the United States. The AGH is the world's largest species of hornet (Ono et al. 2003), native to temperate and tropical low mountains and forests of eastern Asia (Matsuura 1991). The most common social wasp in the United States is the yellow jacket. The four most common yellow jacket species are the western yellow jacket (*Paravespula pensylvanica*), the common yellow jacket (*Paravespula vulgaris*), the aerial yellow jacket (*Dolichovespula arenaria*), and the German yellow jacket (*Paravespula germanica*) (Berry and Mooney 1998; Landolt and Antonelli 2003). It appears the hornet is well adapted to conditions in the Pacific Northwest. Hornets are part of a large order of insects known as Hymenoptera that include bees, wasps, ants, and sawflies. Worldwide, there are more than 115,000 species belonging to the order Hymenoptera (Hunt and Toth 2017). Most of this group of insects are beneficial for pollination and pest control. There are two types of hornets, solitary and social (Lee et al. 2016). Solitary hornets hunt various insects and spiders. Their 'stinger' is primarily used to paralyze their prey. They often lay an egg on the immobilized victim, and when the egg hatches, the larvae consume the still-living host. Solitary wasps generally do not sting humans and usually are not aggressive unless provoked.

Materials and Methods

Study area

The study was conducted at Adaptive Research Farm Rahim Yar Khan farm without use of pesticides during two consecutive wheat growing seasons in 2020 and 2021. The agro-ecological zone, i.e., cotton zone is established on the basis of average annual rainfall i.e. 156 mm, respectively. The experimental plot of one acre was selected during the both years. All agronomic practices were done according to local recommendations. The aphid population and their natural enemies were observed from the 1st week of February to last week of March. Also observed armyworm population if appear during the both years of study.

Sampling

Weekly visual observations of aphids and their natural enemies were started from 1st February to end of March during both the seasons. Ten sampling points were selected in each replication in zigzag fashion on each observation day. On each sampling point, three consecutive tillers of a wheat plant were randomly selected and visually observed for counting species of aphids (*Schizaphis graminum, Rhopalosiphum padi, Rhopalosiphum maidis* and *Sitobion avenae*) and their natural enemies (*Coccinella septumpunctata, C. undecimpunctata, Menochilus sexmaculata, Chrysoperla carnea,* syrphidae and parasitoid mummies). Only the visually identifiable mummies e.g. having change in colour and swollen were counted, while already hatched mummies were excluded from the counts. In the case of heavy infestation of aphids, tillers were clipped and put in paper bags, which were then preserved in ice chest boxes for later counting in the laboratory (Klueken, et al.,2008). The armyworm population was also observed if appear. The table of predators and parasitoids are shown as below.

Predators		Parasitoids	
Species	No. of records	Species	No. of records
All predators	9[a]	All parasitoids	1
Acari		**Aphelinidae**	
Amblyseius californicus	1	*Encarsia formosa*	2
Amblyseius fallacis	3	**Braconidae**	
Phytoseiulus persimilis	4	*Aphidius colemani*	4
Typhlodromus pyri	6	*Aphidius rhopalosiphi*	3
Zetzellia mali	1	*Bracon* sp.	1
Coleoptera		*Bracon mellitor*	2
Predatory *Coleoptera*	2	*Cardiochiles nigriceps*	2
Coccinellidae	5	*Cotesia marginiventris*	4
Aleochara bilineata	5	*Cotesia plutella*	1
Coccinella septempunctata	1	*Macrocentrus ancylivorus*	1
Coleomegilla maculata	2	*Microplitis mediator*	4
Cycloneda sanguinea	3	*Psyttalia concolor*	7
Harmonia axyridis	3	**Chalcididae**	
Hippodamia convergens	5	*Haltichella rhyacioniae*	1
Scymnus spp.	1	**Encrytidae**	
Stethorus punctum	4	*Leptomastix dactylopii*	3
Tachyporus sp.	2	**Eulophidae**	
Dermaptera		*Pnigalio flavipes*	2
Doru taeniatum	8	*Diglyphus isaea*	1
Hemiptera		**Eurytomidae**	
Geocoris spp.	2	*Eurytoma pini*	1
Geocoris punctipes	10	**Ichneumonidae**	
Macrolophus caliginosius	3	*Hyposoter didymator*	4
Nabis spp.	3	*Diadegma insulare*	1
Nabis capsiformis	1	**Pteromalidae**	
Orius spp.	8	*Cactolaccus grandis*	2
Orius insidiosus	16	**Trichogrammatidae**	
Podisus nigrispinus	4	*Trichogramma* spp.	1
Tytthus chinenis	3	*Trichogramma bacterae*	1
Zelus spp.[b]	1	*Trichogramma chilonis*	1
Neuroptera		*Trichogramma exiguum*	2
Chrysoperla carnea	28	*Trichogramma galloi*	4
Chrysoperla rufilabris	2	*Trichogramma inyoense*	4
Others		*Trichogramma pretiosum*	6
Spiders	10		
Other predators	6		
Totals:	162		66

[a]Includes two records reported as all natural enemies, but in both cases, most of these species were insect predators.
[b]*Sinea* spp. also present and included in evaluation.

Results and Discussion

The aphid population was observed more in numbers during 2020 as compared with year 2021. The population of aphid was observed starting from 15th February to end of March during both years. As the temperature rises the population of aphid becomes less. More number of aphids observed during the 1st and 2nd week of March. Armyworm was observed during both years but not in much numbers and that was controlled by hornets which parasitoids the larvae in great numbers and controlled its population. The number of aphids and armyworms was controlled by natural enemies during both years. Usually natural enemy populations don't appear in significant numbers until aphids begin to be numerous. Many predators also feed on aphids. The most well-known are lady beetle adults and larvae, parasitic wasps, lacewing larvae, and syrphid fly larvae. The list of natural enemies which observed during both years are listed below.

1. Lady Beetles

Several species of lady beetles can be found in wheat, including the convergent lady beetle (*Hippodamia convergens*), the seven-spotted lady beetle or C-7 (*Coccinella septempunctata*) and the much smaller species *Scymnus loewii*.

Lady beetles provide some control of aphids in small grains every season. No one lady beetle species can completely reduce an aphid population. The most significant action a farmer can take to help lady beetles control aphids is conservation. Lady beetle population consists of egg or pupal stages rather than young larvae. Convergent lady beetles alone or in combination with parasitic wasps often suppress green bug and bird cherry-oat aphids in wheat. The number of lady beetles that develop in a field depends on environmental conditions and the size of the aphid population. Lady beetles have the greatest effect on green bugs before temperatures become extremely cold and when temperatures warm up. The C-7 lady beetle is larger than the convergent and is bright red with seven black spots. Adult females live for about 4 to 6 weeks and produce about 1,000 eggs. C-7 larvae feed for about 2 weeks, consuming about 20 green bugs per day. Scymnus is a small, dull brown beetle with a V-shaped black area down the centers of the wing covers. Larvae are covered with long, waxy filaments and feed on aphids and mites. Heavy, rapidly increasing greenbug infestations can cause excessive damage; however, lady beetles and parasitic wasps, under favorable weather conditions, can reduce greenbug populations to below treatment levels. Convergent lady beetle with six small black dots on the wing covers. The black plate (pronotum) just behind the head has two diagonal white lines which appear to converge. The bright yellow eggs are laid in groups on leaves. Larvae are alligator-shaped and black with rows of orange spots. Convergent lady beetle adults and larvae feed primarily on aphids but also eat other insect eggs and larvae. Under laboratory conditions, convergent lady beetle larvae consume about 20 greenbugs per day.

Fig.1 seven spotted lady bird beetle

2. Syrphid flies

Adult flies can be found hovering around flowers, feeding on nectar and pollen. They are often attracted to honeydew covered leaves characteristic of infestations of sucking insects such as aphids.

Ischiodon scutellaris (Fabricius) and *Episyrphus balteatus* (DeGeer), are among the most common aphidophagous species in wheat growing areas of Pakistan. The shortest egg and pupal durations were observed at 33 °C, followed by 27 and 23 °C. Females of both species had longer life span (20.4 and 22.4 days) compared to the respective males (17.2 and 16.2 days). The pupal stage for I. scutellaris was significantly shorter than for E. balteatus at different temperatures; but statistically insignificant differences were found for any other life stage. The larvae of I. scutellaris consumed significantly more aphids than E. balteatus during their larval life span, and this difference was significant during the 1st and 3rd instars. However, the average daily prey intake of both species was found similar until the 10th day after hatching, and thereafter, I. scutellaris consumed significantly higher numbers of aphids/day. Aphidophagous flies belonging to family Syrphidae are efficient predators of wheat aphids (Gilbert, 2005)

3. Yellow Jackets

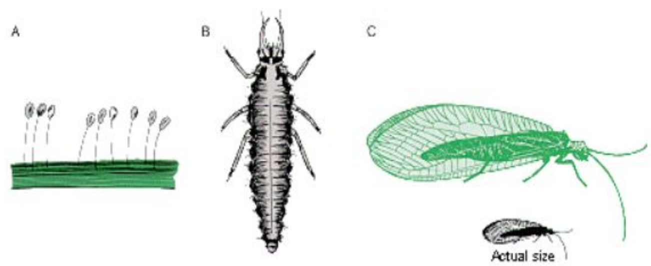
Yellow jackets are beneficial around home gardens and commercial crops because they feed on caterpillars and harmful flies. The yellow jacket worker is about ½ inch in length with alternating yellow and black bands on the abdomen. Yellow jackets are social insects that have a division of labor between workers and sexually developed queens (both females) and males. The queen builds a small paper nest and lays several eggs that hatch and mature to adult workers. The workers assume all tasks of nest expansion including foraging for food, defending the colony entrance, and feeding the queen and larvae. The colony rapidly increases in size and may reach several hundred workers. Yellow jacket adults feed on foods rich in sugars and carbohydrates such as plant nectar and fruit. They also search for foods high in protein such as insects and fish. These are chewed and conditioned in preparation for larval consumption. The larvae secrete a sugary substance that is eaten by the adults. This exchange of food between the adults and larvae is known as trophallaxis. Among the most important natural enemies are various species of parasitic wasps that lay their eggs inside aphids. The skin of the parasitized aphid turns crusty and golden brown, a form called a mummy. The generation time of most parasites is quite short when the weather is warm, so once you begin to see mummies on your plants, the aphid population is likely to be reduced substantially within a week or two.

Fig.2 yellow wasp making hole in field

Fig.3 yellow wasp grab armyworm inside the hole to parasitized

4. Lacewings

Green lacewings are found in many crops, including wheat. Lacewings are used in the biological control of greenbugs. The larval stages of all lacewings are predators which feed primarily on aphids but also on insect eggs and small caterpillars. The adults of some lacewing species, such as *Chrysoperla carnea*, feed only on honeydew or pollen. Lacewing larvae are not common in wheat but compliment other predators. Adult green lacewings are delicate, slender insects 1/2 to 3/4 inch long with large wings held roof-like over their bodies. The green wings have a fine, net-like pattern of veins. Their eyes are a bright gold color. Larvae are alligator-shaped, grayish-brown and have long sickle-shaped mandibles protruding from their heads. Newly hatched larvae are very small (less than 1/8 inch long), while mature larvae are ¼ to 3/8 inch long. Eggs are laid singly on top of a fine thread attached to leaves or stems and are easily seen and recognized. Lacewing larvae feed primarily on aphids in wheat but also attack small caterpillars, insect eggs and mites. They are most common in wheat in the spring. Although the adults of some species are predators, adult feed only on honeydew, nectar and pollen. Eggs hatch in 3 to 6 days. Larvae are voracious predators and will eat other lacewing eggs and larvae. Larvae feed for about 2 weeks and then spin a spherical white cocoons of tough silk. The larvae pupates inside the cocoon and the adult lacewing emerges in about 10 days. Upon emergence, adult lacewings make long dispersal flights regardless of the presence of food. Lacewings fly at night and may travel several miles. Females must feed on nectar, pollen or aphid honeydew to produce eggs. Females lay their first eggs 4 to 6 days after emergence. Adults live several weeks, during which they lay 200 or more eggs.



The common green lacewing. *Chrysoperla carnea*. A) Eggs. B) Larva, commonly known as an "aphid lion." C) Adult.

Armyworms

The true armyworm and the fall armyworm are parasitized by several species of wasps and flies. However, these natural enemies are apparently less effective during cool, rainy weather, and armyworm moths can fly long distances and escape them. A parasitic wasp which commonly parasitizes the fall armyworm is Chelonus. The female deposits her eggs inside the armyworm egg. Upon hatching, the parasite larva consumes the armyworm. The parasite then spins a tough, white cocoon in which it develops to the adult stage. Groups of 10 or more of these white cocoons can be seen where an armyworm was consumed by these parasite.

References

1. Aheer G, Ali A & Ahmad M (2008). Abiotic factors effect on population fluctuation of alate aphids in wheat. J Agric Res 46 (4): 367–371.
2. Ahmad R & Shaikh A (2003). Common weeds of wheat and their control. Pak J of Water Resou 7(1): 73-76.
3. Berry and Money (1998), "Relationship Marketing of Services: Growing Interest, Emerging Perspectives," Journal of the Academy of Marketing Science, 23 (4), 236–45.
4. Bhambhro S (2002). Threat of aphids to wheat crop. DAWN–Business, The Internet Edition.https://www.dawn.com/.
5. Biondi A, Zappalà L, Stark JD & Desneux N (2013). Do biopesticides affect the demographic traits of a parasitoid wasp and its biocontrol services through sublethal effects? PLoS ONE 8(9): e76548.
6. Brault V, Herrbach É & Reinbold C (2007). Electron microscopy studies on luteovirid transmission by aphids. Micron 38(3): 302-312.
7. Carter N. 1987. Management of cereal aphid (Hemiptera: Aphididae) populations and their natural enemies in winter wheat by alternate strip spraying with a selective insecticide. Bull Entomol Res. 77:677–682.
8. Dixon AFG. 1987. Cereal aphids as an applied problem. Agric Zool Rev. 2:1–57.
9. De-Deus G, Reis C, Fidel S, Fidel R, Paciornik S (2007) Dentin demineralization when subjected to BioPure MTAD: a longitudinal and quantitative assessment. *Journal of Endodontics* 33, 1364– 1368.
10. El-Gizawy NKB (2009). Effect of planting date and fertilizer application on yield of wheat under no till system. World J of Agri Sci 5(6): 777-783.
11. El-Wakeil NE, Gaafar N, Vidal S. 2006. Side effect of some Neem products on natural enemiesof Helicoverpa, Trichogramma spp. and Chrysoperla carnea. Arch Phytopathol Plant Prot. 39:445–455.
12. Fogel MN, Schneider MI, Desneux N, González B & Ronco AE (2013). Impact of the neonicotinoid acetamiprid on immature stages of the predator Eriopis connexa (Coleoptera: Coccinellidae). Ecotoxicol 22(6): 1063-1071.

13. Freier B, Triltsch H, Möwes M, Moll E. 2007. The potential of predators in natural control of aphids in wheat: Results of a ten-year field study in two German landscapes. Biocontrol. 52:775–788.
14. French W, Elliott N, Kindler D, Arnold D. 2001. Seasonal occurrence of aphids and natural enemies in wheat and associated crops. Southwest Entomol. 26:49–61.
15. Gilbert F (2005) Syrphid aphidophagous predators in a food-web context. Eur JEntomol 102:325–333.
16. Hunt, J. H., and Toth, A. L. (2017). "Sociality in Wasps," in Comparative Social Evolution, eds D. R. Rubenstein and P. Abbot (Cambridge: Cambridge University Press), 84–123.
17. Husti I (2006). The main elements of sustainable food chain management. Cereal Res Communications 34(1): 793-796.
18. Khan SA, Ullah F, Hussain N, Saljoqi A, Hayat Y & Sattar S (2006). Distribution pattern of the cereal aphids in the wheat growing areas of the North West Frontier Province (NWFP) of Pakistan. Sarhad J of Agric 22(4): 655.
19. Khaliq A (2003). Impact of plant phenology and coccinellid predators on the population dynamic of rose aphid *Macrosiphum rosaeiformis* Das (Aphididae: Homoptera) on rose. Asian J of Plant Sci 2(1): 119-122
20. Khattak MK, Riazuddin & Anayatullah M (2007). Population dynamics of aphids (Aphididae: Homoptera) on different wheat cultivars and response of cultivars to aphids in respect of yield and yield related parameters. Pak J of Zoo 39(2): 109-115.
21. Khan SA & Ullah F. (2005). Studies on the aphids distribution pattern and their natural enemies in wheat and maize crop. Ph. D. thesis, NWFP Agricultural University, Peshawar.
22. Klueken AM, Hau B, Koepke I, Poehling HM. Comparison of techniques to survey populations of cereal aphids (Homoptera: Aphididae) in winter cereals during autumn and spring with special consideration of sample size. J Plant Dis Prot. 2008; 115: 279–287.
23. Landolt, P. J. and A. L. Antonelli. 2003. Yellow jackets and paper wasps. Wash. State Univ. Coop. Ext. Bull. EB0643. 7 pp
24. Lee, M. R. F.; Parkinson, S.; Fleming, H. R.; Theobald, V. J.; Leemans, D. K.; Burgess, T., 2016. The potential of blue lupins as a protein source, in the diets of laying hens. Vet. Anim. Sci., 1-2: 29-35
25. Matsuura, E.T., Niki, Y., Chigusa, S.I. (1991). Selective transmission of mitochondrial DNA in heteroplasmic lines for intra- and interspecific combinations in Drosophila melanogaster. Jpn J. Genet. 66(2): 197--207.
26. Meena BL, Dadhich SR, Kumawat RL. 2002. Efficacy of some insecticides against ladybird beetle, *Coccinella septumpunctata* L. feeding on fenugreek aphid, *Acyrthosiphon pisum* (Harris.). Ann Biol. 18:171–173
27. Oerke E-C (2006). Crop losses to pests. The J of Agric Sci 144(1): 31-43.
28. Ono, S., J.L. Eigenbrode, A.A. Pavlov, P. Kharecha, D. Rumble, III, J.F. Kasting, and K.H. Freeman, 2003: New insights into Archean sulfur cycle from mass-independent sulfur isotope records from the Hamersley Basin, Australia. Earth Planet. Sci. Lett., 213, 15-30.
29. Palmer D. FAO–Food and Agriculture Organization of the United Nations.
30. Redfearn A & Pimm SL (1988). Population variability and polyphagy in herbivorous insect communities. Ecolog Monographs 58(1): 39-55.
31. Sigsgaard L. 2002. A survey of aphids and aphid parasitoids in cereal fields in Denmark, and the parasitoids'role in biological control. J Appl Entomol. 126:101–107.
32. Stark JD & Banks JE (2003). Population-level effects of pesticides and other toxicants on arthropods. Annu Rev Entomol 48(1): 505-519.
33. Steffy, B.D. & Grimes, A.J., 1986, 'A critical theory of organization science', Academy of Management Review 11(2), 322–336
34. Swaran D. 1999. Effect of some important insecticides on the adults of *Coccinella septempunctata* L. Predating on different aphid species. J Entomol Res. 23:127–131.
35. TaheRi S, RazmJou J & RaSTegaRi N (2010). Fecundity and development rate of the bird cherry-oat. Plant Protection Sci 46(2): 72-78.
36. Wetzel, M.J. 2004. In memoriam: Michael Robert Milligan (1951-2005). Pp. 18-20, In: Wang, H.-Z. et al. (eds.). Aquatic Oligochaete Biology X. Proceedings of the 10th International Symposium on Aquatic Oligochaeta. *Acta Hydrobiologica Sinica* 31 (suppl.).