



Scymnus ningshanensis Yu et Yao (Coleoptera: Coccinellidae) for Biological Control of *Adelges tsugae* (Homoptera: Adelgidae)

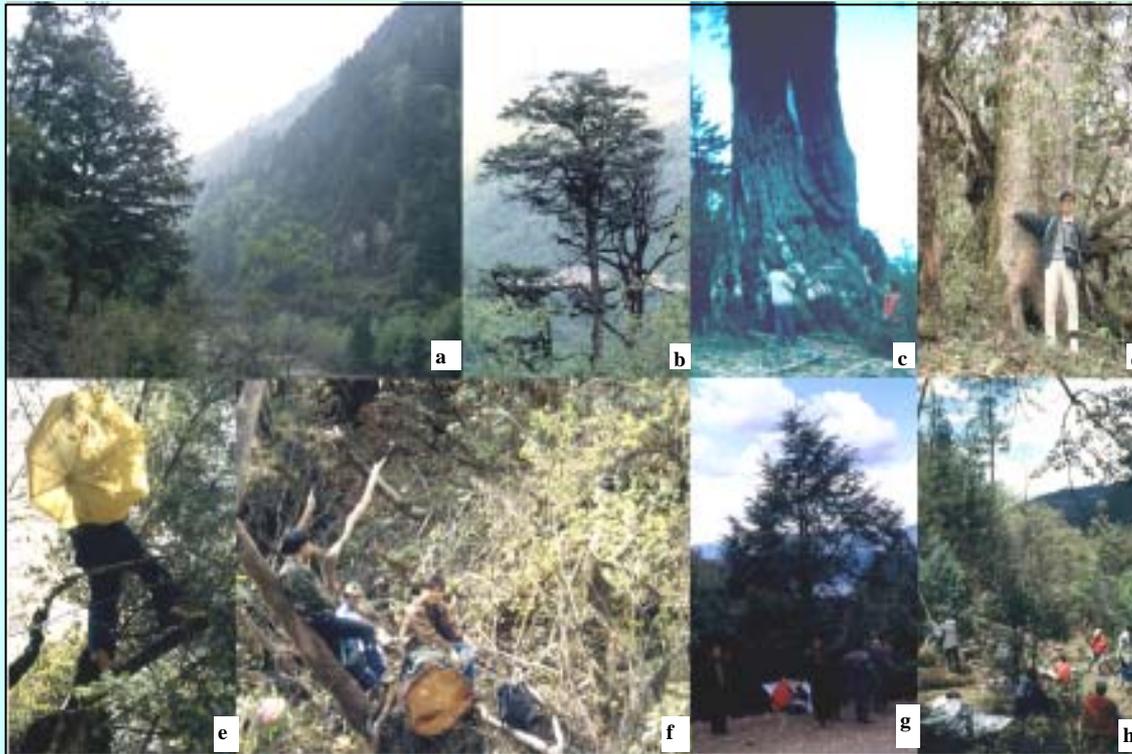


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Native Habitat



Hemlock in China grows in the transition zone between the mixed mesophytic forest and the mountainous, boreal forest (a). Hemlock is usually scattered among hardwoods in steep rugged terrain and occurs in the understory or can rise above the canopy (b). The largest known hemlock in China is a *Tsuga chinensis* in Sichuan (c). Collecting was difficult on prime growth sites where hemlock are large (d); we collected by climbing trees (e) and from trees cut for lumber the previous winter (f). We found that drier sites had smaller, more accessible hemlock from which it was easier to collect lady beetles (g, h).



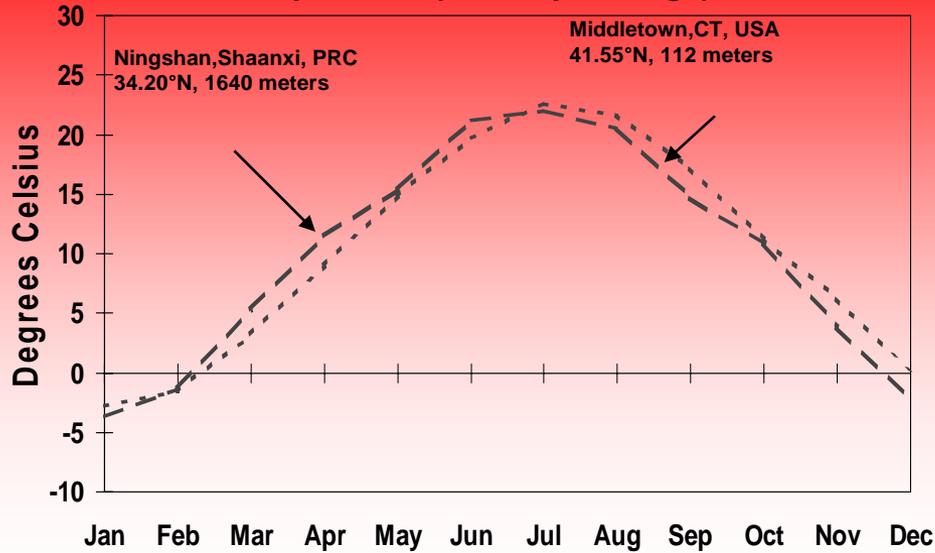
Shaanxi Province, P.R. China



Ningshan

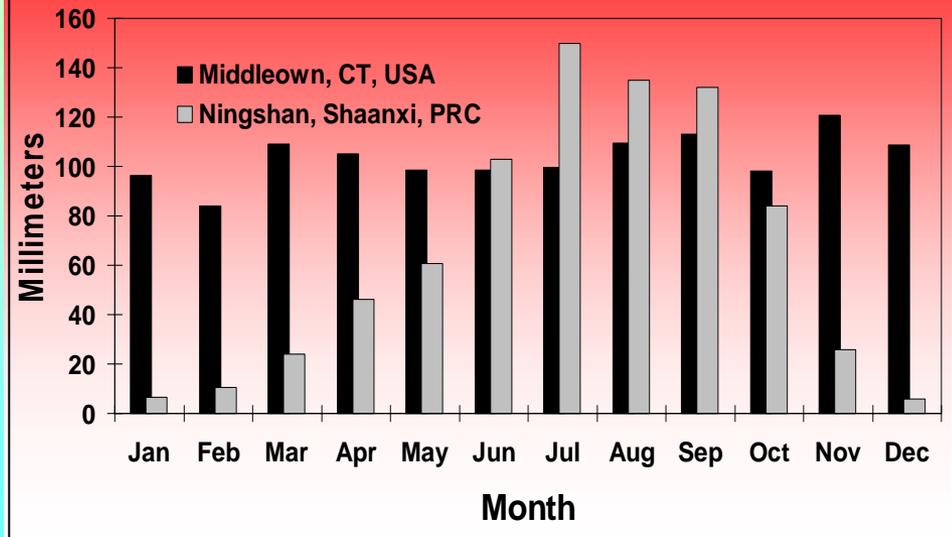
Scymnus ningshanensis is one of three Chinese lady beetles in the subgenus *Neopullus* imported into the USDA Forest Service Quarantine Laboratory, Ansonia, CT, as a biological control agent for the hemlock woolly adelgid (HWA), *Adelges tsugae*. These lady beetles occur separately in three provinces along the eastern edge of the Tibetan Plateau (Yunnan, Sichuan, Shaanxi). *Scymnus ningshanensis* was collected near Ningshan in Shaanxi Province from *Tsuga chinensis*.

Temperature (monthly average)

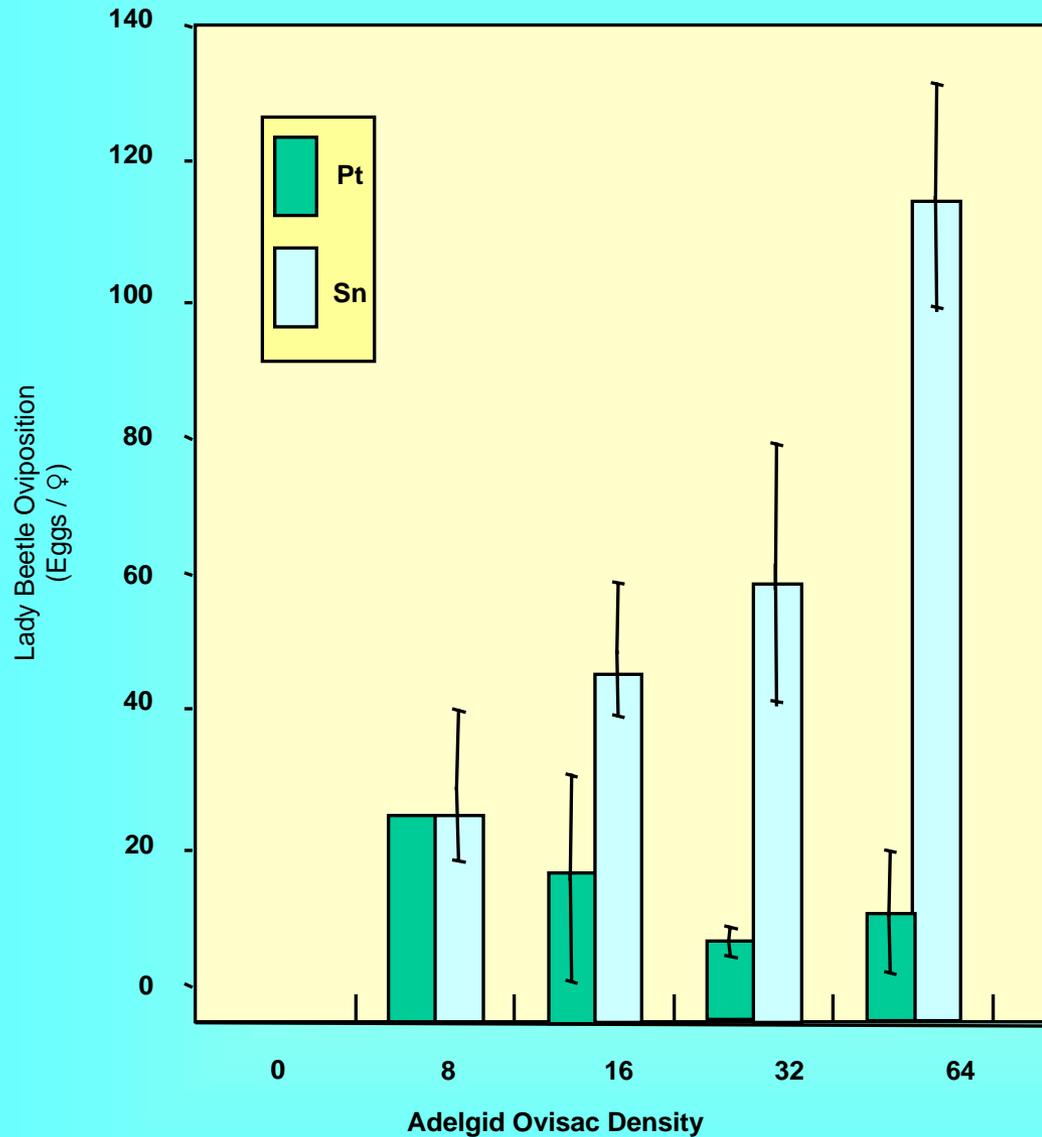


The temperature at Ningshan is similar to Middletown, CT. Ningshan is about 1000 kilometers more south in latitude and 1500 meters higher in elevation than Middletown. The two locations differ considerably in the amount and distribution of rainfall. Ningshan is at the northwest edge of the influence of tropical typhoons and has rainy summers and dry winters, which is unlike the more evenly distributed monthly rainfall of Middletown.

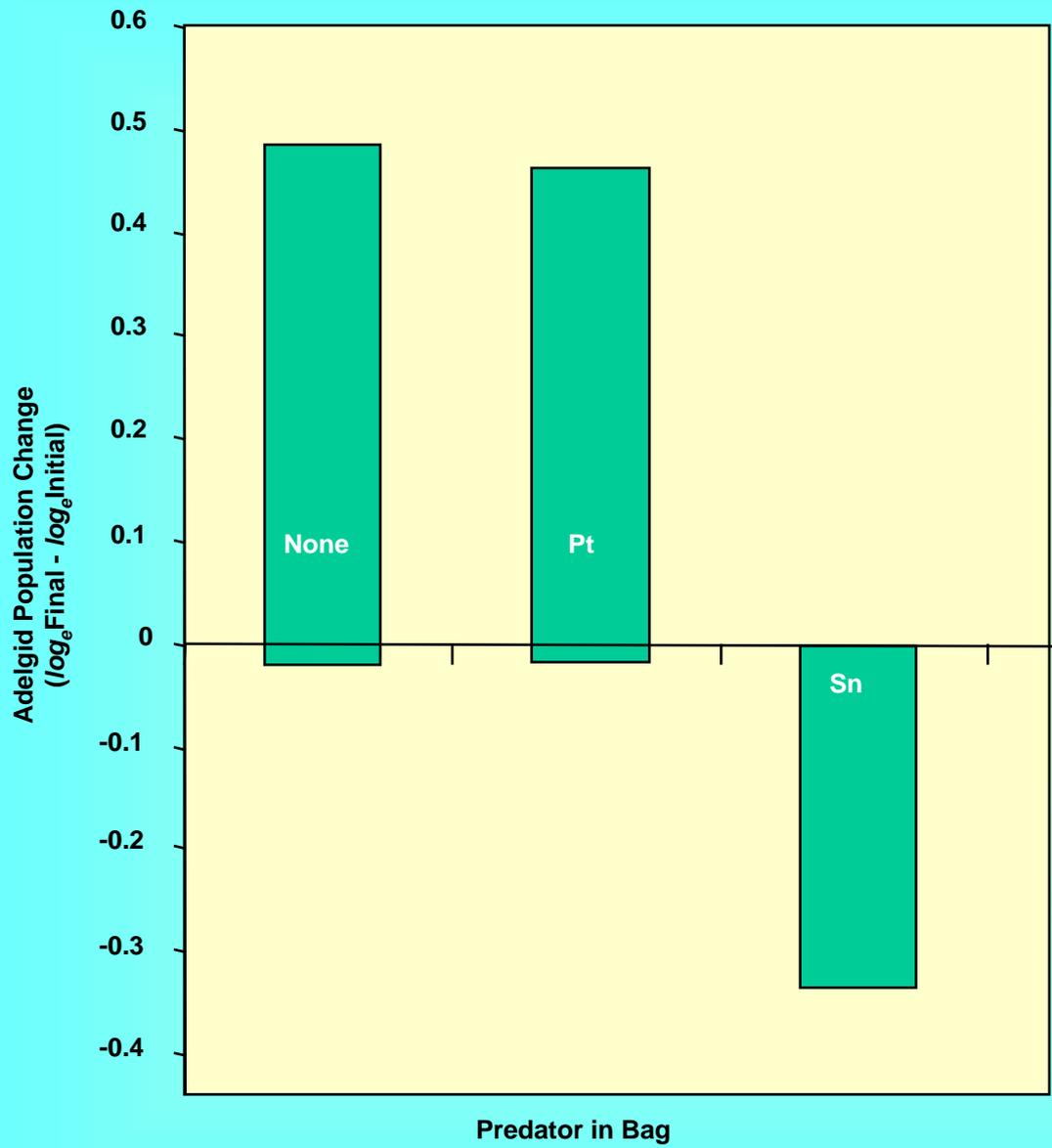
Precipitation (monthly mean)



Tests of Effectiveness



Laboratory study of oviposition of *S. ningshanensis* (Sn) and another lady beetle, *Pseudoscymnus tsugae* (Pt), at different prey densities. *S. ningshanensis* responded to increasing prey densities by laying more eggs. This positive numerical response to prey density is desirable in a biological control program.



The population of adelgids in the bags containing Sn lady beetles decreased, whereas adelgids increased in the bags with no beetles or with Pt.



Bags were placed on hemlock branches in early spring when the initial (sistens) generation was counted. Bags enclosed either a male or female of Sn, Pt, or no beetle (control). The adelgids of the next generation (progreiens) were counted 3 months later.

Quarantine Laboratory Study of Biology



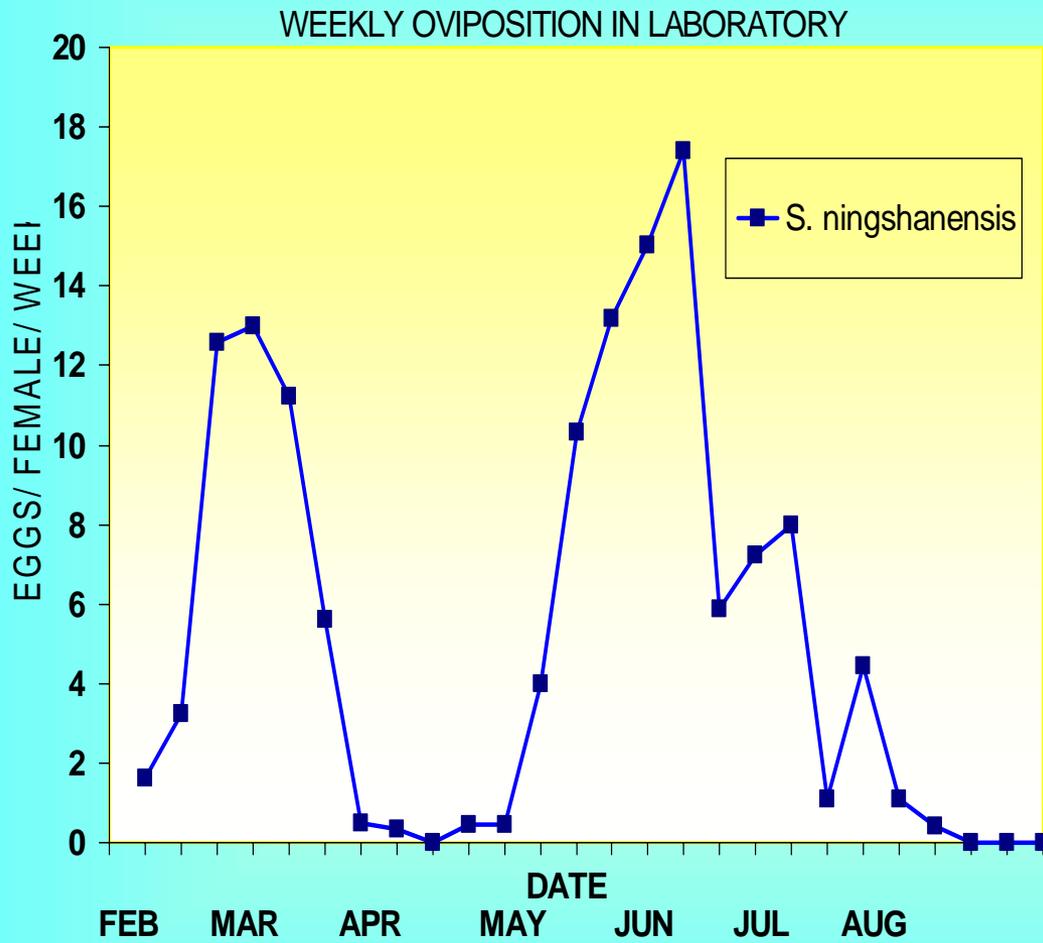
Developmental Time (Days) at 20° C
of *Scymnus sinuanodulus* (Ss) and
S. ningshanensis (Sn)

<u>Stage</u>	<u>Ss</u>	<u>Sn</u>
Eggs	10.2	8.6
L1	3.1	2.8
L2	2.5	2.5
L3	2.9	3.7
L4	11.4	5.9
Pupa	10.6	11.1
Total	40.1	34.2

- ⊗ Egg hatch rate was 88%; decreases if eggs were held at 5° C
- ⊗ Larval wax covering increases through the four instars, including a prepupal stage
- ⊗ Pupae have setae with droplets of defense chemicals
- ⊗ Adults began mating 3 weeks after emergence and continued intermittently
- ⊗ Total development from egg to adult was 6 days faster than *S. sinuanodulus*



Oviposition occurs singly in concealed locations such as bud scales and under the edge of ovisacs. If oviposition sites are not abundant, 2 or 3 eggs may be placed together on backside of needles, cotton gauze, etc.



In the lab, oviposition by *S. ningshanensis* began within a week after removal from cold storage and continued for 5 weeks. When provided abundant HWA eggs on healthy foliage, a second period of oviposition lasted for two months.

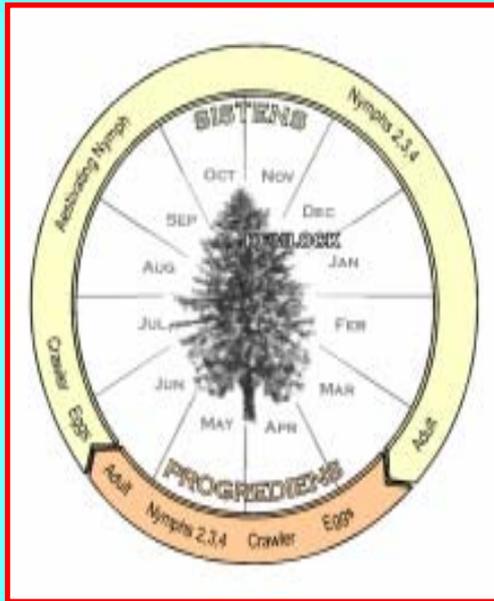


- ⚙️ Sn prefers HWA more than aphids
- ⚙️ Larvae consumed a total 23 ovisacs in China (avg. 35 eggs/sac)
- ⚙️ Response to odor from HWA infested foliage was not observed in olfactometer tests, visual and tactile cues seemed more important

Feeding Preferences	
<u>Prey</u>	<u>No. Eaten</u>
Hemlock woolly adelgid	8.6
Woolly alder aphid	2.1
Alder leaf aphid	2.6
Basswood aphid	1.0
Greenhouse aphid	1.1
Hemlock psocid	0.0

Conclusions

Scymnus ningshanensis appears to have good potential as a biological control. The climate of its native habitat in China is similar in many respects to that of New England. Its larval development is faster than other lady beetles. It is specific to adelgids and closely associated with active stages of HWA. It has a positive numerical response to prey density. A caged field study indicates that it is effective in reducing populations of hemlock woolly adelgid.



HWA life cycle on hemlock is similar in China and North America. Sexual reproduction on spruce may occur in China.



North America does not have a suitable species of spruce, the primary host on which HWA can complete sexual development. In China, we found adelgids and galls in the spring and in the fall on *Picea likiangensis*. *Scymnus* beetles were found feeding on adelgids on spruce in the fall.

In China, *S. ningshanensis* adults became active in early April when the 10-day average temperature reached 7°C. Adults are numerous on the foliage until mid-June, then are difficult to find on the foliage until early September. Adults are found on the foliage throughout September and October until the 10-day average temperature is below 7°C. Egg laying is from April to June, when eggs of the progrediens generation of HWA are present. *Scymnus ningshanensis* was found only on hemlock; it was not on nearby *Pinus armandii* that was infested with another adelgid species.