June 1995 Asiatic Herpetological Research Vol. 6, pp. 53-61

Ecology and Conservation of *Onychodactylus fischeri* (Caudata, Hynobiidae) in the Russian Far East

PAUL C. GRIFFIN[1] AND VASILI A. SOLKIN[2]

[1]Department of Forestry and Natural Resource Management, University of California at Berkeley, Berkeley, California, 94720, USA

[2]Pacific Institute of Geography, Far East Branch of Russian Academy of Sciences, Vladivostok, 690032, Russia

Abstract. *-Onychodactylus fischeri* (Boulenger, 1886) is a lungless salamander with a larval development time of over four years and lifespan that may extend over 18 years. *O. fischeri* develops and spawns only in cold torrential brooks. In the Russian Primorski Krai of the Russian Far East *O. fischeri* lives in undisturbed Ussuriland montane taiga forest. Adults migrate annually to breed. In homing experiments adults which were ready for breeding migrated over 800m of land to breeding sites. Homing experiments showed that sexually mature adults may demonstrate stream fidelity. Males were more frequently encountered at surface waters than females. There are seasonal peaks to breeding-adult activity. High-impact forest harvesting is now typical in headwater forests and river valleys across the range of *O. fischeri*, causing disturbance and siltation in spawning brooks and surrounding forest habitat. *Pinus koreansis* trees comprised a dominant component of the forest canopy in spawning drainages.

Key Words: Amphibia, Caudata, Hynobiidae, *Onychodactylus fischeri,* Russian Far East, Ussuri taiga, conservation, ecology.

Introduction

This study set out to discover aspects of *Onychodactylus fischeri* biology by collecting standardized morphological and color pattern data during the course of adult and juvenile mark-recapture surveys, by documenting microhabitat location, by determining ages of adults and larvae, by moving marked sets of salamanders and recording their return to home brooks, and by continuing early attempts at inducing captive breeding. and to assess movement of individuals between spawning streams. Ussuri taiga has been heavily harvested from plains and river valleys in this century to the point that headwaters comprise some of the least disturbed examples of this forest type. High-impact, wasteful forest harvesting is now occurring in the elevational range of *O. fischeri* range in an inefficient manner, causing catastrophic disturbance and siltation to its spawning brooks and surrounding forest habitat. *O. fischeri* is an endangered species in the Red Data Book of the USSR but is afforded no protection under current Russian environmental law.

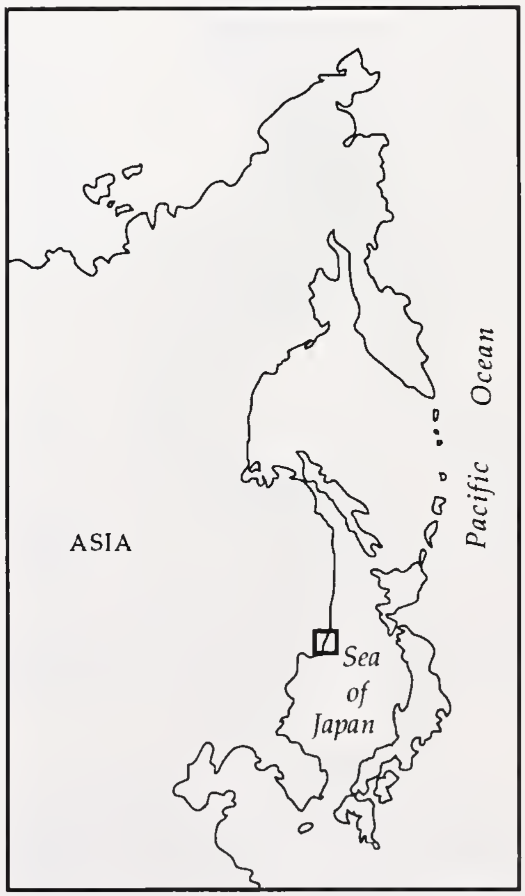

FIG. 1. Map of Asia and the Russian Far East showing study location in boxed area.

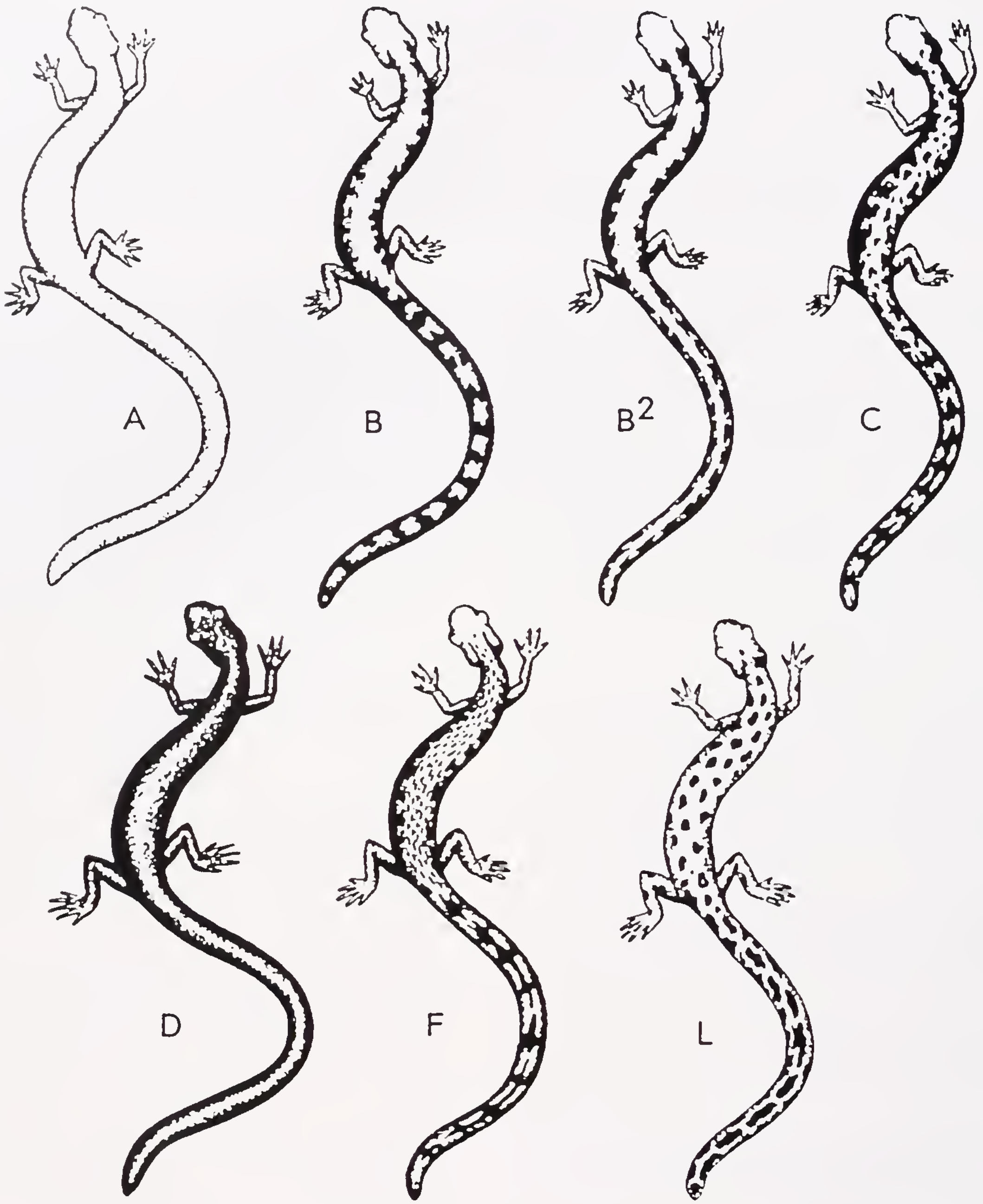

FIG. 2. Dorsal Color Patterns of *O. fischeri*.. Percent frequencies out of 351 salamanders in "Chinese" brook were: A, 1%; B and B2, 36.4%; C, 46.7%;D, 5%; F, 4.8%; L, 0.3%

Methods and Materials

Our studies were within the range of *Onychodactylus fischeri* in the Sixote-Alin Mountain Range of the Primorskii Krai, Russia. These mountains are forested by Usuriland taiga. We conducted our surveys and experiments at elevations between 500 m and 1000 m., at a site 10 km west of the Pacific Ocean in headwater brooks of the Mysovka River (Lat. 135°, Long. 41°). This river flows into the Tinfura River, a tributary of the Ol'ga Bay (Fig. 1). Climate is typical of the maritime Russian Far East, with humid summer days averaging 25° C in July and cold winters down to -30° C. The summer monsoon and winter snows provide approximately 120 cm of annual precipitation (Fullard, 1972).

We surveyed the brook tributaries at the headwaters of the upper Mysovka watershed and gave them the following arbitrary names: "Chinese," "Zapovednik," "Mutnii," "Himalayan," "Burned," and "Tetkin." We characterized the forest canopy cover in the entire study site in terms of dominant tree species and also inventoried subdominant trees of the forest canopy in "Chinese" drainage. In 1993 we noted changes in soil and forest structure that resulted from forest harvest activity taking place in the Mysovka watershed.

To estimate the sex ratio and age structure in a breeding population we marked and recorded data from all individuals encountered in a one kilometer stream transect of "Chinese" brook, divided into 20 sections, during measurements from 1990 to 1993. Between one and three people with headlamps walked the transect once every night for a two to three hour observation period in June 1990, May and June 1991, September 7-14, 1991, and June 3-13 1993. We began each transect at a downstream gauging station where we measured relative humidity, brook depth and temperature. Each individual yielded data for the following categories: sex, maturity class, biotope, transect section, fat condition, skin pattern, tail wounds, and morphometric lengths for snout-vent, tail, head length and head width. We distinguished adult sex and reproductive stage by the secondary sexual characters discussed in Serbinova and Solkin (1992). We assigned salamanders unique identification numbers by toe-clipping, and reclipped regenerating toes only when we were sure of the original mark. We designated the color pattern for individuals according to our categorization of light-colored spot placement on the neck, back and tail (Fig. 2). To determine exact ages for some individual salamanders we sent a random subset of 118 clipped adult and larval toe bones to Moscow for skeletochronological analysis (Smirina, 1972).

FIG. 3. Timber harvest operations in the Mysovka floodplain downstream from the study site.

To examine stream fidelity we released 20 breeding adults from "Zapovednik" brook into "Chinese" brook in 1991. We released 100 salamanders with a range of secondary sexual characters from "Zapovednik" brook into "Burned" brook. In 1992 we released 31 breeding males, 43 breeding females, and 52 non-breeding adults from "Chinese" brook into "Zapovednik" brook. We searched for marked individuals in "Zapovednik" and "Burned" brooks on nights when we were not surveying the "Chinese" brook transect.

In 1993 we collected three males and females that were ready for breeding from "Chinese" brook. We injected synthetic leutenizing and releasing hormone into them to induce courtship, egg-laying and fertilization. Their aquaria were plastic, with rocks, moss, and 3 to 5 cm of standing water. Air and water temperature in the aquaria were dependent on ambient stream temperature.

Results

Onychodactylus fischeri spawn in “Mutnii”, “Zapovednik”, “Himalayan”, and “Chinese” brooks. “Chinese” brook flows over a substrate of 1.5 meter deep rock cobble which is covered by moss and shallow rooted plant growth. “Zapovednik” brook has much less rock cobble, with smooth

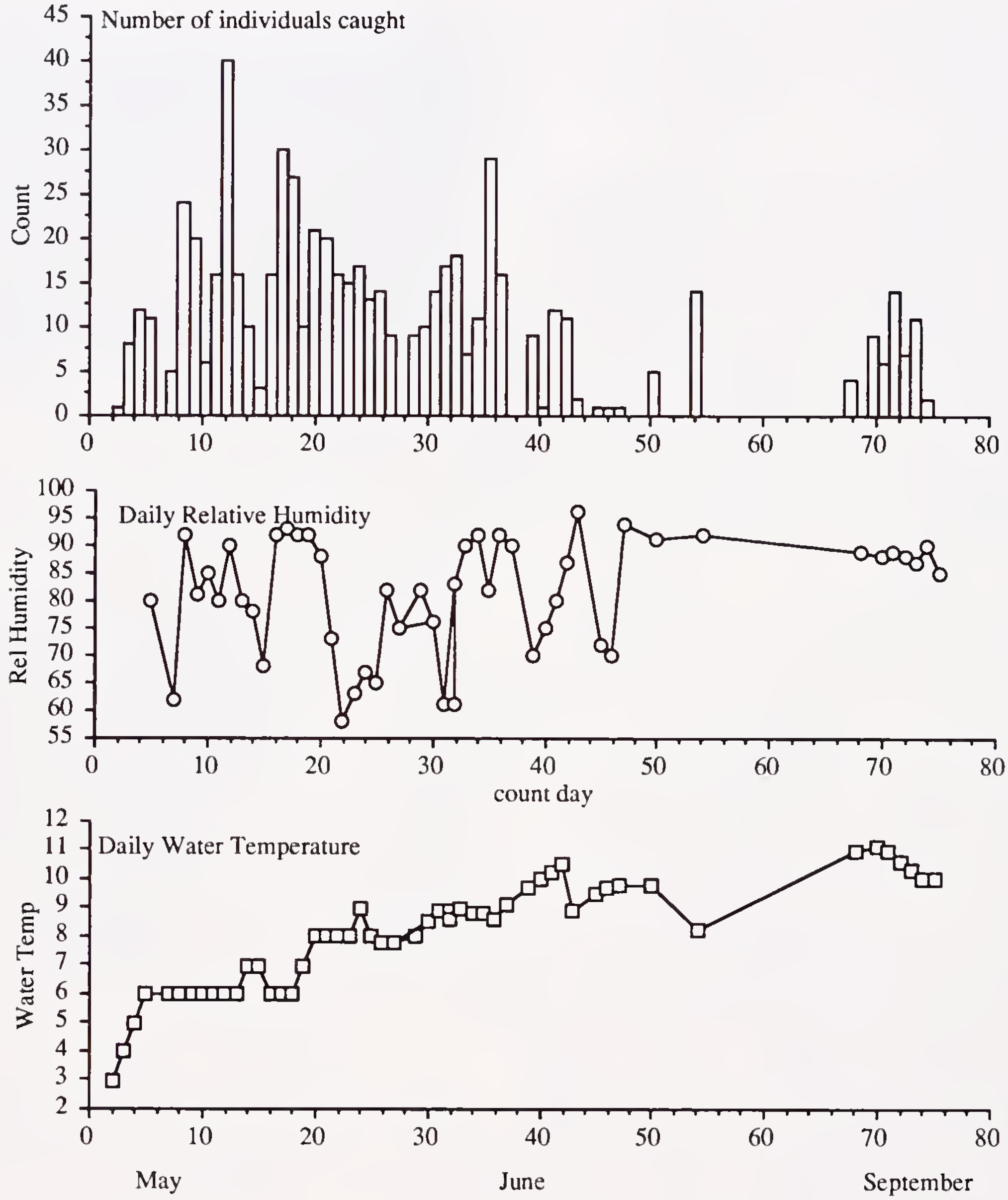

FIG. 4. Daily number of salamanders captured, relative humidity and stream temperature in "Chinese" brook during May, June and September 1991.

bedrock as the substrate for some sections. In the study area predaceous fish only occurred in "Burned" and "Tetkin" drainages, which were both affected by a forest canopy-removing wildfire 40 years ago and by ensuing landslides.

Pinus koreansis accounts for a significant portion of the dominant canopy cover in the brook drainages where *O. fischeri* does occur. Dominant forest trees in the drainage of "Chinese" brook reflects a strong slope effect; Manchurian oak (*Quercus mongolica*) and *P. koreansis* dominate the southeast-facing slope while *P. koreansis*, fir (*Abies* sp.), birches (*Betula* spp.), maples (*Acer* spp.), elms (*Ulmus* spp.), and linden (*Tilia* spp.) comprised much of the canopy of the north-facing slope.

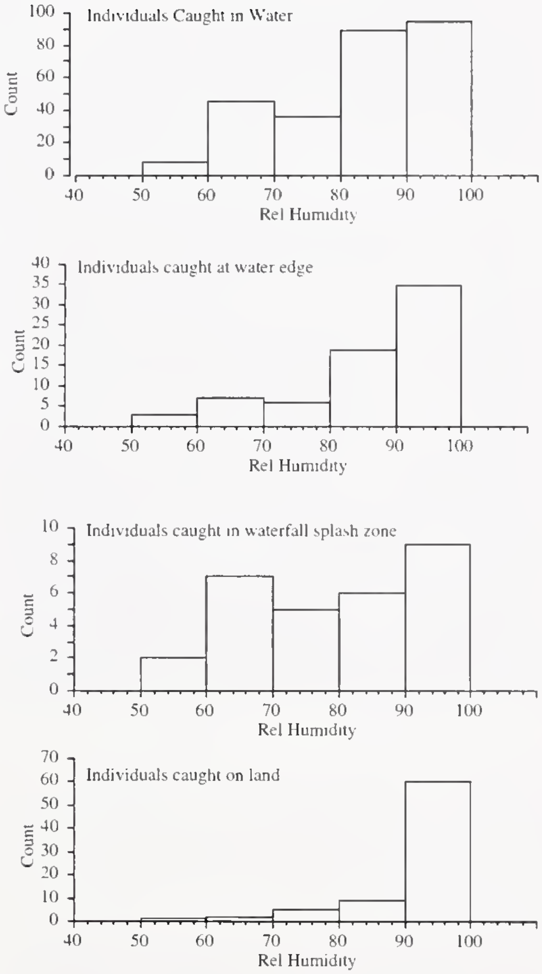

FIG. 5. Histograms divided according to ten-percent atmospheric relative humidity classes showing number of salamander captures in water, water edge, splash zone and land biotopes. Note that few salamanders were active on land when relative humidity was below 90%.

A six man work team from the local forest production ministry harvested timber downstream in 1993 with one tank-treaded bulldozer and one rubber-tired loader servicing a logging truck (Fig. 3). Their road building often crossed the small river in the floodplain. The bulldozer skidded logs down slopes of greater than 35 degrees. There was severe disturbance to soil structure caused by these activities. Soils were brown podbels with an illuvial B horizons ending less than 50 cm below the litter surface (Ivanov, 1976). *Pinus koreansis* was being harvested from the river plain and hills despite current regulations outlawing harvest of that species. Other harvested species included *Abies sp., Tilia sp.* and *Populus tremula.* The river channel was widened in 1992, apparently as a subsequent outcome of harvest activities.

We first encountered breeding adults at spawning brooks during snowmelt in late April and early May. Adult males captured in surface waters outnumbered adult females in all seasons. Breeding adult activity was highest in May and June, when stream temperatures were low (Serbinova and Solkin, 1992). In September 1991 the breeding population rose during a small peak composed of adults aged 6 to 9 years; at that time 11 out of 20 males and 5 out of 9 females exhibited secondary sexual characters and juveniles represented 45.3 % of all captures.

Around spawning brooks we found *O. fischeri* in pools and riffles, on dry and wet rocks in the watercourse, on rocks in the misty zone near waterfalls, and on the shore. Salamanders were most active at the surface during evenings of high relative humidity (Fig. 4). 535 captures provided data for biotope location. We found salamanders most often in the water (54.0 % of total) and on the streambank (16.4 % of total). On nights of low relative humidity salamanders were often located on rocks in the misty splash zone near waterfalls (6.0 % of total). On land salamanders were most often within 50 cm of the water (11.3 % of total). Salamanders were rarely active on land if relative humidity was lower than 90 percent (Fig. 5). Juveniles were active on land markedly less than adults. In the brook channel we uncovered 1 gravid female when we dismantled a 0.5 cubic meter rock matrix where brook water seeped through moss-covered rocks. We occasionally observed *O. fischeri* on land between streams and on ridges during times of rainfall and high relative humidity.

We found abundant larvae in surface waters during nocturnal transect surveys. Larvae were also active diurnally. During two one-hour periods in June 1993 we observed *Onychodactylus fischeri* larvae

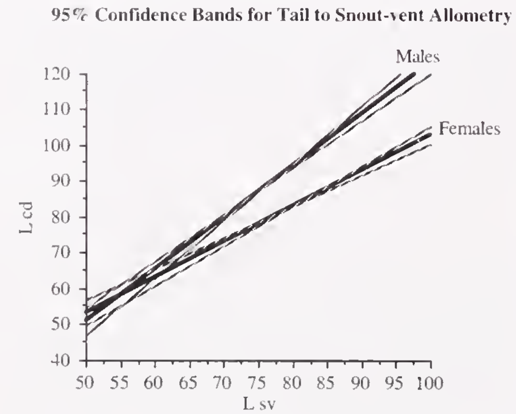

FIG. 6. Allometric relationship showing relatively longer tail size (L cd) in adult males at given snout-vent length (L sv). The difference in the slopes is significant (ANCOVA; F = 18.21; df = 1; p < 0.0001).

hunting on flat rocks under 3 cm of water in the late afternoon. By means of their limbs the larvae locomoted to approach aquatic Gammarid casings and lunged when the invertebrates exposed their legs and head. It appeared that larvae used their forelimbs in conjunction with a gape-and-suck feeding technique to apprehend the prey.

The number of transect captures was an index of active adult population size, generally decreasing over the course of the summer except for a small increase in early fall. Analysis of our mark-recapture data by the Jolly-Seber stochastic method (Donnely and Guyer, 1994) yielded standard errors too large for individual population estimates of males, females, and juveniles.

Males had significantly longer tails than did females once the effect of snout to vent length was accounted for (ANCOVA; F = 8.99; df = 1; P = 0.003). Also, tail length increased more rapidly with body size in males than in females (ANCOVA; F = 18.21; df = 1; p < 0.0001) (Fig. 6). We observed tail wounds on 23 out of 350 males and 19 out of 166 females. It appeared that females in "Chinese" brook had a thinner fat layer than females in “Mutnii” brook, where the brook substrate includes more bedrock. According to our

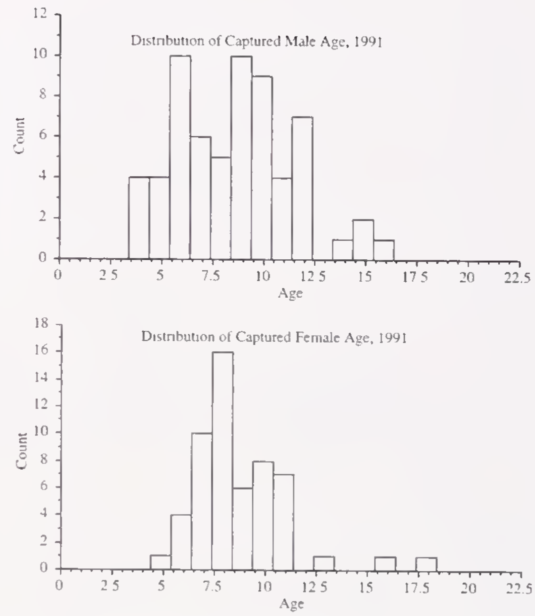

FIG. 7. Histogram showing relative abundance of ages in a subset of captured males and females.

designation of color pattern 351 individuals in "Chinese" brook, the dominant patterns of bright flecking on grey to brown backgrounds were C (46.7 % of total) and B (36.4% of total).

Our data on age and development times support the hypothesis that *Onychodactylus fischeri* is a slow developing, long-lived salamander. Cross sections of larval bones indicate that larvae may develop up to four years before metamorphosis to terrestrial juveniles. The mean age of breeding males in 1991 was 8.65 years (Std Dev. 2.87); mean breeding female age was 8.75 years (Std. Dev. 2.34) . Maximum ages were at least 16 years for males, and 18 years for females (Fig. 7). Ages approximated by counting winter rings may underestimate true age because of endosteal resorption (Leclair 1990).

In 1991 at “Zapovednik” brook we recaptured one of the 20 salamanders that we had taken from there for release into “Chinese” brook; we recaptured none of these in “Chinese” brook. In 1991 we recaptured none of the 100 salamanders which we had released into "Burned" brook from “Zapovednik” brook. We also

FIG. 8. *Onychodactylus fischeri* female lays eggs in two gelatinous sacs.

FIG. 9. *Onychodactylus fischeri* male grasps and fertilizes egg sacs with hind limbs.

recaptured none of these in their original stream. In 1992 at "Chinese" brook we recaptured 8 of 31 breeding males, 15 of 43 breeding females and none of the 52 non-breeding adults out of the total 126 salamanders which we moved in 1991 from "Chinese" brook to "Zapovednik" brook. The breeding adults which we caught had returned within a month to "Chinese" brook over 1 km of land or by a longer route along the Mysovka river.

Hormone injection in captives successfully induced courtship, egg-laying (Fig. 8) and fertilization (Fig. 9). One female produced a clutch of two egg sacs in 1993. Eggs were 6 to 8 mm in diameter, with 5-10 eggs in each sac. We observed deflation of female cloacal labia in the six days after egg-laying. Egg death probably resulted from a severe rise in pH of available water.

Discussion

Onychodactylus fischeri is limited by the availability of suitable torrential streams for reproduction and development. The seasonal activity pattern which we observed in adults seems limited by water temperatures over 10° C. The burst of breeding activity observable in late spring may signify the most strategic time for egg-laying in view of the short warm season in the Russian Far East; it is logical that eggs laid in the late spring develop faster than eggs laid in early fall because water temperatures drop below 5° C in the winter. The higher proportion of males caught in our surveys suggests that males may wait on the surface rocks and waters to seek females. Egg sacs and larvae seem to be located most often in intersticial rock habitat, sheltered from surface predators in areas of continuous water flow (Regel and Epshtein, 1975). Iwasawa and Kira observed that *O. japonicus* eggs developed slowly for 143 days in water of 10° C (1980). Longer winters may cause the larval stage in *O. fischeri* occasionally to extend longer than the three years observed in *O. japonicus* (Hayase and Yamane 1982).

Lunglessness is a synapomorphy of salamanders in the *Onychodactylus* clade, which have a long larval period in torrential streams as a requisite portion of their ontology. Bruce et al. (1992) supported the hypothesis that lunglessness in amphibians is a larval adaptation to torrential streams by showing that experimentally lungless salamander larvae were displaced downstream less when released in fast-flowing water than were control larvae with lungs.

The reproductive potential of an individual *Onychodactylus fischeri* seems low, despite their long lifespan, considering that a female living 12 years may only produce 140 eggs. Additionally, many of the adults we found did not have secondary sexual traits indicative of reproduction. Akita (1989) notes that not all adult *O. japonicus* breed every year. The low clutch size and large egg mass suggest that each egg is a significant reproductive investment relative to other hynobiids. Kuzmin showed that the sympatric hynobiid *Salamandrella keyserlingii* is more general in its feeding and breeding habitat preferences (1990).

Our 1992 experiments suggest that successful homing was only by adults which were ready for breeding, indicating that adults may have a preference for particular spawning brooks. It is also possible that non-breeding adults may also have returned to their original brooks and not been recaptured, or that the breeding adults that did not return may have spawned in a different stream. *Onychodactylus fischeri* may migrate over land through forested corridors. We speculate that the connectedness of suitable habitat between large watersheds is important for dispersal after landscape level disturbances.

The pressure to harvest trees in the fragile taiga is promoted by an international wood and fiber market that devalues natural capital by not factoring in negative externalities such as anthropogenic fire, landslides and species loss. Repeated highgrading is the most widespread harvest method in the Russian Far East and has lasting effects on forest ecology. Forested slopes and floodplains are exposed to catastrophic erosion for years after tractors are used to skid out widely spaced trees. Reduction of canopy cover to levels to below 40% alters the evapotranspiration regime in a way which allows catastrophic wildfire. The hard currency that goes to the Primorskii krai in return for the Ussuri taiga logs does not compensate for the permanent loss of seasonal employment in fur, mushroom, honey, berry, ginseng, and game meat gathering and preparation (Schumacher, 1973). The best conservation strategy for *Onychodactylus fischeri* appears to be exclusion of high-impact timber harvest activity from key spawning watersheds, given that regional timber harvesters, Hyundai and other multinational timber interests generally ignore existing rules of the Russian Federation's Ministry of Forests. It would be informative to delineate metapopulation boundaries in order to assess the adequacy of existing preserves.

Onychodactylus fischeri is an indicator species of high-quality old growth forest habitat in upper slopes of Ussuri taiga. Because eggs and larvae develop in cold running water year round under the cover of rocks, undisturbed stream substrate and a specific hydrological regime are critical for quality spawning habitat. Long-term stability of stream hydrology, which is needed to support *O. fischeri* breeding and development, is dependent on undisturbed complex forest structure. Shade and large woody debris affect stream temperature and riffle-pool ratio. Extensive root systems retain soil structure and decaying logs on the forest floor regulate soil moisture. The deep roots of conifers provide more soil stability on slopes than shallow-rooted deciduous trees. Acid soils locally associated with *Pinus koreansis* litter may regulate stream pH and nutrient availability. We observed that catastrophic disturbance to spawning brooks occurred through natural processes of wildfire and landslides and through anthropogenic road building and logging in the watercourse, upslope, and downstream. Tree harvest on slopes above watercourses causes stream sedimentation of fine materials and organics. Such increased sediment loads associated with logging have negative effects on aquatic amphibians (Corn and Bury, 1989). As is the case on "Burned" creek, siltation eliminates the spaces between rocks which are critical for egg deposition and larval development. Disturbed brooks may be suitable to *O. fischeri* spawning only after adequate forest structure regenerates and interstitial spaces filled with silt and sand are cleared.

Acknowledgments

The authors would like to thank Vladimir Aramilev for his invaluable assistance in Vladivostok and in the field; Dmitri Pikunov for support from the Laboratory of Wild Animals of the Pacific Institute of Geography; Irina Olenicheva for her assistance with the skeletochronological work; and David Wake and Mario Garcia-Paris for their constructive criticism of the manuscript.

Literature Cited

AKITA, Y. 1989. Breeding Cycle of *Onychodactylus japonicus* on Mt. Hodatsu, with Special Reference to Biannual Spawning. P. 305. *In* M. Matsui, T. Hikida and R. C. Goris (Eds), Current Herpetology in East Asia. Herpetological Society of Japan, Kyoto.

BRUCE, R. C., C. K. BEACHY, P. G. LENZO, S. P. PRONYCH AND R. J. WASSERZUG. 1994. Effects of Lung Reduction on Rheotactic Performance in Amphibian Larvae. The Journal of Experimental Zoology 268:377-380.

CORN, P. S. AND R. B. BURY. 1989. Logging in Western Oregon: Responses of Headwater Habitats and Stream Amphibians. Forest Ecology and Management 29:39-57.

DONNELLEY, M. A. AND C. GUYER. 1994. Estimating Population Size: Mark Recapture. *In* Heyer, W.R. et al. (Eds.), Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonion Institution Press, Washington and London.

FULLARD, H. (ED.). 1972. Soviet Union In Maps. George Philip and Son, Ltd., London.

HAYASE, N. AND S. YAMANE. 1982. [Life History During the Aquatic Life Period of a Salamander, *Onychodactylus japonicus* (Houttuyn), at Mts. Tsukuba, Ibaraki, Japan]. Japanese Journal of Ecology 32(3):395-403. (In Japanese).

IVANOV, G. I. 1976. [Soil Formations in the south of the Far East]. Moscow. Science. 200 pages. (In Russian).

IWASAWA, I. AND Y. KIRA. 1980. [Normal Stages of Development of he Japanese Lungless Salamander, *Onychodactylus japonicus* (Houttuyn)]. Japanese Journal of Herpetology 8(3):73-89. (In Japanese).

KUZMIN, S. L. 1990. [Feeding of Sympatric Species of Hynobiidae in the Primorye]. Zoological Journal 69(5):71-75. (In Russian).

LECLAIR, R. 1990. Relationships between relative mass of the skeleton, endosteal resorption, habitat and precision of age determination in ranid Amphibians. Annales des Sciences Naturelles Zoologie et Biologie Animale 11:205-208.

REGEL, E. D., AND S. M. EPSHTEIN. 1975. [Some Patterns of Biology in *Onychodayctulus fischeri*]. Zoological Journal 63(7):1515-1524. (In Russian).

SCHUMACHER, E. F. 1975. Small is Beautiful: Economics as if People Mattered. Harper and Row. New York. 305 pages.

SERBINOVA, I. A. AND SOLKIN V. A. 1992. Reproduction of the Ussuri Lungless Triton *(Onychodactylus fischeri)]*. Zoological Journal 71(7):68-74. (In Russian).

SMIRINA, E. M. 1972. [Annual Layers in bones of *Rana temporaria*]. Zoological Journal 51:1529-1534. (In Russian).