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# ONGOING SHRINKAGE AND FRAGMENTATION IN THE GEOGRAPHIC RANGE OF THE NATTERJACK TOAD, *EPIDALEA CALAMITA*, IN LATVIA AND THE EAST BALTIC REGION

## SHORT COMMUNICATION

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**Abstract**. Historical data indicate the presence of two *Epidalea calamita* population groups in Latvia in the past, one in western Latvia and another connecting populations from Estonia and Lithuania – in central Latvia. Both groups have experienced local extinctions that started after the Second World War in the coastal habitats around developing cities, where there were possible bottlenecks limiting population connectivity. Presently *E. calamita's* range in Latvia has become split into four small- to medium-sized population groups with only two of them having connections with populations in neighbouring states, and this has produced major range gaps in Latvia dividing the once variably connected East Baltic *E. calamita* populations. The process of *E. calamita* range shrinkage continues, and we suggest that the main risk for population sustainability in the region is a combination of adverse local factors or occasional climate events with poor population connectivity and dispersal barriers.

## MAIN FINDINGS:

- ~50% range reduction in Latvia after the Second World War;
- presently isolated populations in Latvia and interruption for the East Baltic part of the species range;
- range fragmentation process is ongoing in XXI century;
- sensitive to dispersion barriers due to its ecological traits;
- observed and suggested causes for local extinctions – extreme climate events, coastal habitat changes, urban development, agriculture intensification; and
- conclude that a combination of dispersion barriers and local extinctions is the main reason for range reductions.

The Natterjack Toad, *Epidalea calamita*, is a medium sized, largely nocturnal toad, which mostly inhabits open lowlands with loose soil, and spawns in shallow, open waterbodies, that may be temporary and (or) brackish. Its geographic range includes large areas of Western and Central Europe eastwards to the Baltic States and Belarus (Arnold and Ovenden 2002). The species is uncommon throughout most of its range, and, while it has been the subject of considerable conservation efforts in North-west Europe (Banks, Beebee, and Cooke 1994; Becart, Aubry, and Emmerson 2007), information from most of the eastern part of its range is extremely sparse (e.g. Franze et al. 2013). The population groups in Latvia are essential for long-term persistence of this species in the East Baltic Region, since it connects with the endangered northernmost *E. calamita* population from the coastal areas and islands of Western Estonia, which has lost two thirds of its previously documented localities between the 1930s and 2000s (Rannap, Lohmus, and Jakobson 2007), and a less studied population in Lithuania which is considered to inhabit the whole territory of that State (Gruodis, Caune, and Vilnītis 1986; Bērziņš 1986; Rašomavičius 2007).

Published information on *E. calamita* in Latvia (Grosse and Transehe 1929; Siliņš and Lamsters 1934; Bērziņš 1984; Andrušaitis 1985; Bērziņš 1986; Gruodis, Caune, and Vilnītis 1986) is outdated; some records are questionable and were never confirmed from other sources. There has been a vast amount of faunistic studies on amphibians in Latvia since 2015, performed by the authors of the present paper, including a state-wide vocalizing anuran survey with additional emphasis on *E. calamita* presence and reproduction success in eight areas. These and past surveys have yielded many species records and provided inventories of large protected areas with historical *E. calamita* records, from surveys carried out during the development of nature protection plans. Reports of these studies are available on the Nature Conservation Agency website (www.daba.gov.lv), although they are written in Latvian and therefore unsuitable for most international readers. Some records are present on the public data portal dabasdati.lv, and data from this portal can also be used as indirect evidence for population extinctions at well-visited and easily accessible locations. For the purpose of the present paper, records from other observers were verified by the authors via site visits, personal communication, and requests for visual or audio evidence whenever possible. Lists of verified and unconfirmed *E. calamita* records for Latvia are given in the Supplement to this paper. Past and recent *E. calamita* records in Estonia were acquired from published sources (Rannap, Lohmus, and Jakobson 2007; Pärimets 2018); whereas published data for the contemporary distribution of *E. calamita* in Lithuania were absent. Locations of recent and past *E. calamita* records in Latvia and Estonia with the latest recorded dates for location groups are depicted in Figure 1.

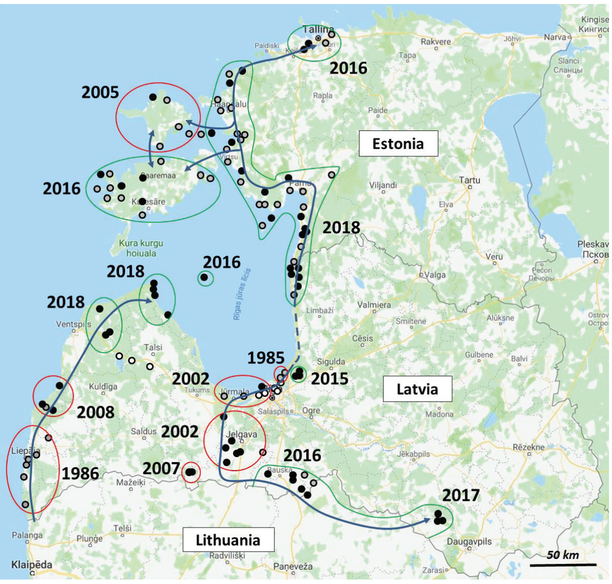


Figure 1. Distribution of the Natterjcak Toad, *Epidalea calamita*, and the latest observation dates for its populations in Latvia and Estonia. Records only before WWII (the Second World War) in Latvia indicated by dots with a white fill, records only before 1990s in Estonia and only after WWII, but before1989 in Latvia – by dots with a grey fill, more recent records indicated by black dots; record groups with the latest observation date less than 10 years ago outlined with green, more than 10 years – with red; suggested population connection routes indicated by blue line.

In the past, there have been two population groups in Latvia – i) Central and ii) Western, whose spatial ranges formed roughly north-south belts. They were separated by the hilly upland habitats of the inland areas of Western Latvia, and both were presumably connected via more southerly Lithuanian populations. The latest observations when compared with historical records indicate a temporally regressive cut-ribbon-like fragmentation and range shrinkage pattern for *E. calamita* in Latvia, beginning with the extinction of populations on relatively narrow land-strips where there are likely to be bottlenecks restricting population connectivity, and then further diminishment of neighbouring populations. There is a large knowledge gap for species records between the 1930s and 1970s, but we suggest that the range fragmentation in Latvia began somewhere after WWII (the Second World War), concurrent with post-war economic recovery. In the central population group this process started in association with an expansion of the City of Riga, where, *E. calamita* inhabited areas with sandy soils, including central parts of the modern-day city in the 1920s and 1930s. In the second half of the 20th century the species was recorded only in the coastal area of the City of Riga, and most populations within Riga's administrative borders disappeared in the late 1980s. The exception was an isolated population in a wildlife area on Daugavgrīva Island, where the last record was in 2002. Southerly range shrinkage continued with localised extinction in the mainly agricultural western part of the Zemgale lowland in the beginning of the 21st C. In the eastern part of the lowland *E. calamita* is still present; the population here is presumably connected with a small population in south-eastern Latvia via northern Lithuania.

North from the City of Riga, *E. calamita* have survived in the protected landscapes area of Ādaži, which encompasses the largest military training area in the Baltic States with a large heathland protected from strong disturbances due to restricted access. Presently this population is not only isolated from other *E. calamita* populations, but also cut off from previously inhabited coastal areas by a busy highway that lacks any wildlife passes. The remainder of the central population group is located some 70 km further to the north, in coastal habitats and inland sand pits near the Estonian border. This population group probably had poor connectivity with the southern populations in the past due to a lack of sand accumulation along considerable stretches of sea-coast, necessary for the formation of shallow temporary breeding pools. Essentially it is part of a larger population inhabiting Estonian coastal areas.

The western population group in Latvia has a similar pattern of range shrinkage, starting with extinction from the area within and south from the City of Liepāja in southwestern Latvia in mid 1980s, where *E. calamita* inhabited less than a one kilometre-wide coastal strip extending between the Baltic Sea and the Liepāja Lake. Over the following 30 years the species range has retreated about 100 km northwards. The northern part of that population group has survived in a forest-dominated area on glacial sands, where they inhabit sand pits and disturbed habitats. In the extreme northwest *E. calamita* inhabits an area only several tens to hundreds of meters wide, but several tens of kilometres long in a very sparsely populated coastal stretch along the Gulf of Riga, where it breeds in shallow beach waterbodies at sites with freshwater influx, created by accumulating sand and periodically washed away during winter storms. Presently the western population group is separated by ~150 km from other mainland populations, but the closest population is across the 27 km wide Irbe Strait on the Estonian island of Saaremaa.

Eight *E. calamita* populations in Latvia were surveyed during the 2015–2018 amphibian state monitoring programme; local population sizes in all cases were estimated to be small, 50–100 breeding adults, with the exception for the Ādaži population whose numbers were estimated to be several hundreds of adults in early 2010, but now are considered to be in decline (from a monitoring report available at Nature Conservation Agency home page).

Among reported causes of *E. calamita* population declines are heathland and dune habitat overgrowth (Beebee 1977; Denton et al. 1997), loss of coastal meadow habitat (Rannap, Lohmus, and Jakobson 2007), acidification of breeding ponds (Beebee et al. 1990), and inferior competition with other anurans (Griffiths 1991; Bradsley and Beebee 1998). Nevertheless, *E. calamita* can persist in isolated populations with low genetic diversity without inbreeding (Hitchings and Beebee 1996) and can maintain sustainable populations in intensively managed agricultural landscapes (Frei et al. 2016). The species may breed once in several years in periodic waterbodies to quickly restore population abundance after several years of unfavourable climatic conditions (Drobenkov 2015); however, several studies have indicated high annual adult mortalities, with most of the breeding population being aged 3–4 years with a maximum life expectancy of about seven years (Sinsch and Seidel 1995; Stevens, Wesselingh, and Baguette 2003; Drobenkov 2015). This kind of demographic pattern may cause local extinctions if unfavourable conditions continue for more than 5–6 years. Average reproductive success is often low, and the sustainability of several local populations may depend on immigration of juvenile recruits from a single successful site (Sinsch 1992). Hence, despite innate resistance against the genetic consequences of isolation, *E. calamita* populations are sensitive to connectivity issues and the presence of dispersal barriers.

Anthropogenic pressures may have caused the interruption of population connections and local extinctions in Latvia. Initial range reductions coincided with urban development of coastal cities after WWII, and subsequently continued with the development of cottage villages, vehicular traffic increases and associated development of road infrastructure, and increased overall pressure from recreational activities in seacoast habitats during the late 1980s – early 1990s. For instance, between 1980 and 1993 the number of registered cars in Latvia more than doubled, and by 2008 it had increased six-fold (data from Central Statistical Bureau of Latvia) escalating the impacts from traffic and visitation. In addition, 1985 and 1987 had exceptionally harsh winters with minimum monthly temperatures 10–15 $^{o}$C below average, although overall temperature trends in the Baltics have been increasing (Jaagus et al. 2013). Such extremely cold weather could undermine the persistence of *E. calamita* populations because low winter temperatures are a limiting factor for the species range in Latvia (Bērziņš 1995). Further extinctions in the early 2000s can be attributed to several local factors, such as coastal habitat change – overgrowth with the reed *Phragmites australis*, causing disappearance of a breeding habitat in the Daugavgrīva Island, and intensification of agriculture in the western part of the Zemgale Lowland (unpublished). Triggers of more recent population extinctions in Western Latvia are not clear, but one of them could also be the exceptionally cold winter of 2010.

Hence, the combination of occasional extreme climatic events or local adverse factors with dispersal barriers created by traffic and infrastructure development may have caused the overall species decline in Latvia. Among further risks for this species is the presence of *Batrachochytrium dendrobatidis*, recently found in green frogs from *E. calamita* breeding sites in Southeastern Latvia (LEPFA project Nr. 1-08/153/2017 "Data acquiring and development of guidance for limitation measures for three invasive, lethal for amphibians, species in south-eastern Latvia"). Replacement by *Bufo bufo* has been observed by the authors in shallow bare breeding ponds in former *E. calamita* sites in Western Latvia, although it is not clear whether *B. bufo* outcompeted *E. calamita* here or took up occupancy of an already vacant site.

On-going range shrinkage in the East Baltic Region indicates an urgent need for further *E. calamita* conservation efforts like the kind of habitat restoration performed in Estonia in 2001–2004 (LIFE-Nature project "Boreal Baltic Coastal Meadow Preservation in Estonia" LIFE00NAT/EE/7083) and Latvia in 2018–2019 (LEPFA project Nr. 1-08/263/2018 "Endangered amphibian and reptile habitat management measures in Nature Reserves "Karateri" and "Ilgas"), involving the creation of ecological corridors for species dispersal, and population enhancement from the release of individuals raised in captivity (22154 juveniles released in 2014–2017 in Estonia (Pärimets 2018), 2 742 in 2018 in Latvia (Pupiņa and Pupiņš 2018). In addition, several tens to hundreds of juveniles have been released occasionally since 2003 from a captive population bred at the Riga Zoo to compensate for poor recruitment in situations where there is a lack of sufficient numbers of *E. calamita* or insufficient waterbodies of suitable quality for successful breeding.

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## SUPPLEMENT

**List of *Epidalea calamita* records after WWII (the Second World War) in Latvia (older records placed close to more recent records omitted)**

1. 57°6'33.79"N, 24°23'58.81"E. Ādažu novads. 26 04 2011. D. Jurciņš observation, 1 adult.
2. 57°6'25.63"N, 24°24'55.06"E. Ādažu novads. May 2013. A. Čeirāns observation, 1 adult.
3. ~57°6'41.03"N, ~24°26'27.13"E. Ādažu novads. 13 05 2013. I. Mārdega observation, 10+ males call record.
4. 57°7'8.86"N, 24°26'9.42"E. Ādažu novads. 22 05 2015. dabasdati.lv (E. Račinskis observation); male call record.
5. ~57°7'42.42"N, 24°26'52.09"E. Ādažu novads. 2008. I. Mārdega observation, male call record.
6. 57°9'50.04"N, 24°27'33.90"E. Ādažu novads. 2008. I. Mārdega observation, male call record.
7. 56°26'52.91"N, 23°6'9.27"E. Auces novads. 25 05 2007. Protected area "Garākalna smilšu krupja atradne" Nature Protection Plan for 2008–2023 (SIA ELLE, 2007) available at www.daba.lv; male call record.
8. 56°26'51.99"N, 23°6'59.28"E. Auces novads. 25 05 2007. Protected Area "Garākalna smilšu krupja atradne" Nature Protection Plan for 2008–2023 (SIA ELLE, 2007) available at www.daba.lv; male call record.
9. 56°24'23.45"N, 24°20'44.76"E. Bauskas novads. 19 06 2008. A. Čeirāns observation; juveniles.
10. ~56°21'36.55"N, 24°21'33.08"E. Bauskas novads. 1995. G. Pētersons observation; several individuals.
11. ~56°20'21.55"N, ~24°26'47.00"E. Bauskas novads. 2011. V. Vintulis observation; male call record.
12. ~ 56°17'24.17"N, ~ 24°32'32.92"E. Bauskas novads. 27 04 2016. E. Račinskis observation; 3 males call record.
13. ~ 56°25'53.70"N, ~ 24°27'59.53"E. Bauskas novads August 1983; 1 individual (Bērziņš 1984).
14. ~57°5'59.13"N, ~24°12'9.27"E. Carnikavas novads. 06 10 1985. I. Caune observation.
15. ~ 57°7'56.82"N, ~24°17'9.29"E. Carnikavas novads. 1983. Bērziņš, 1986 (J. Roks observation).
16. ~ 57°45'15.71"N, ~22°33'35.84"E. Dundagas novads. 2005. K. Vilks observation.
17. 57°44'59.96"N, 22°35'52.99"E. Dundagas novads. 1991. A. Čeirāns observation; 1 adult.
18. 57°44'14.24"N, 22°35'23.75"E. Dundagas novads. 1992. A. Čeirāns observation; juveniles.
19. 57°42'39.84"N, 22°34'35.55"E. Dundagas novads. 12 06 2016. dabasdati.lv (V. Skuja observation); tadpoles.
20. ~57°41'8.06"N, ~22°34'24.82"E. Dundagas novads. 14 06 2018. V. Skuja observation; tadpoles.
21. ~56°38'37.60"N, ~21°18'23.09"E. Durbes novads. 09 07 1979. Bērziņš, 1986 (I. Caune observation).
22. ~ 56°57'7.44"N, ~23°26'21.54"E. Engures novads. 1980. A. Poikāns observation; several subadults from this site brought by pupils.
23. ~56°31'4.84"N, ~21°10'40.50"E. Grobiņas novads. 28 04 1986. M. Roze observation.
24. 56° 4'14.72"N, 26°13'26.84"E. Ilūkstes novads. 22 05 2017. A.Čeirāns observation, 3 males call record, juveniles later that year.
25. 56° 4'6.78"N, 26°10'13.55"E. Ilūkstes novads. 22 05 2009. E. Račinskis observation; male call record.
26. ~56°5'56.90"N, 26°8'39.13"E. Ilūkstes novads. 02 09 2012. dabasdati.lv (L. Strazda observation); juveniles (photo).
27. ~56°30'35.22"N, ~23°31'12.60"E. Jelgavas novads. 1998. G. Pētersons observation; 2 individuals.
28. 56°36'20.40"N, 23°29'59.23"E. Jelgavas novads. 1998. G. Pētersons observation; 3 individuals.

29. ~56°37’38.56”N, ~23°34’17.07”E. Jelgavas novads. 2002. G. Pētersons observation; ~20 individuals.
30. 56°34’29.02”N, 23°36’51.97”E. Jelgavas novads. 2002. G. Pētersons observation; 2 adults.
31. ~56°35’42.45”N, ~23°40’51.22”E. Jelgavas novads. 2001. G. Pētersons observation; 2 adults.
32. ~56°57’54.12”N, ~23°42’43.17”E. Jūrmala City. 1979. A. Poikans observation; 1 individual on beach.
33. ~56°57’34.39”N, ~23°44’13.17”E. Jūrmala City. 1980. A. Poikans observation; 1 individual.
34. ~56°29’4.62”N, ~20°59’57.45”E. Liepāja City. 28 04 1986. M. Roze observation.
35. ~56°27’32.99”N, ~21°0’21.35”E. Nīcas novads. Andrušaitis 1985 (J. Lipsbergs observation after A. Bērziņš)
36. ~56°22’44.99”N, ~20°59’13.67”E. Nīcas novads. Andrušaitis 1985 (J. Lipsbergs observation after A. Bērziņš)
37. ~56°33’44.08” N, ~23°59’22.29”E. Ozolnieku novads 1984 (Gruodis et al 1986).
38. 56°50’29.50”N, 21°22’3.44”E. Pāvilostas novads. 23 07 2008. A. Čeirāns observation; juveniles 2–3 ind/m$^2$.
39. ~56°53’47.26”N, ~21°11’48.33”E. Pāvilostas novads. 2008. Protected Area „Pāvilostas pelēkā kāpa” Nature Protection plan for 2009–2019 (Latvijas Dabas Fonds, 2009); 1 individual.
40. ~56°52’4.86”N, ~21°13’40.32”E. Pāvilostas novads. 1983. Gruodis et al. 1986.
41. ~57°2’39.99”N, ~24° 0’24.78”E. Rīga City. 21 06 2002. EMERALD project (L. Diedišķe, A. Skuja observation), 1 individual.
42. ~57°38’53.61”N, ~22°35’0.38”E. Rojas novads. 2014. E. Perekrests observation; several subadults.
43. ~57°31’34.10”N, ~22°45’21.40”E. Rojas novads. 1994. V. Vintulis observation; 1 adult.
44. 56°9’58.68”N, 21°1’3.59”E. Rucavas novads. 1978–1979. Bērziņš, 1986 (J. Baumanis observation).
45. 56°24’47.03”N, 24°1’27.67”E. Rundāles novads. 27 04 2014. dabasdati.lv (V. Ērmane observation); 1 adult (photo).
46. 57°48’34.98”N, 24°26’45.37”E. Salacgrīvas novads. 06 09 2018. A. Čeirāns observation; 1 adult.
47. ~57°44’48.70”N, ~24°26’21.63”. Salacgrīvas novads. 1995. A. Urtāns observation.
48. ~57°38’12.25”N, ~24°22’25.33”E. Salacgrīvas novads. 1985. Bērziņš, 1986 (A. Bērziņš observation).
49. ~ 57°40’25.30”N, ~24°21’53.36”E. Salacgrīvas novads. 1985. Bērziņš, 1986 (A. Bērziņš observation).
50. 57°51’18.74”N, 24°27’22.52”E. Salacgrīvas novads. 2012. I. Mukāne observation; juveniles.
51. ~57°51’24.63”N, ~24°20’46.80”E. Salacgrīvas novads. 1994. V. Vilnītis observation; several adults.
52. ~56°49’10.55”N, ~23°28’34.81”E. Tukuma novads. 12 06 1999. V. Vintulis observation; male call record.
53. ~56°23’1.38”N, ~24°38’4.37”E. Vecumnieku novads. 1984. Gruodis et al. 1986.
54. 57°1’4.02”N, 21°23’25.37” E. Ventspils novads. 24 07 2008. A. Čeirāns observation; several juveniles.
55. 57°22’24.95”N, 21°56’22.22”E. Ventspils novads. 23 07 2000. A. Čeirāns observation; 1 adult, a road-kill.
56. 57°23’22.20”N, 22°0’28.74”E. Ventspils novads. 19 05 2016. A. Čeirāns observation; 3 subadults.
57. ~57°33’21.79”N, ~21°53’3.02”E. Ventspils novads. 2018. 05 06 2018. V. Skuja observation; 4 adults, tadpoles.

**The list of plausible *Epidalea calamita* site names in Latvia, where it was found only before WWII**

1. Stirnurags, Jūrmala City (Siliņš, Lamsters 1934).
2. Meža kapi, Riga City (Siliņš, Lamsters 1934)
3. Mīlmanis (Jaunciems), Riga City (Siliņš, Lamsters 1934)
4. Sarkandaugava, Riga City (Siliņš, Lamsters 1934)
5. Iļģuciems, Riga City (Siliņš, Lamsters 1934)
6. Stende, Talsu novads (Grosse, Transehe 1929)
7. Spāre, Talsu novads (Grose, Transehe 1929)
8. Usma, Ventspils novads (Grose, Transehe 1929)

**List of erroneous *Epidalea calamita* sites in Latvia**

1. Valmiera (Grosse, Transehe 1929)
2. Ķūļciems (Bērziņš 1984)
3. Silene (Bērziņš 1984)
4. Atašiene (Bērziņš 1984)
5. Pļaviņas (Bērziņš 1986)
6. Ranka (Bērziņš 1986)
7. Ikšķile (Gruodis et al 1986)