Text S1. Definitions of breeding seasons

We defined the breeding season as being that for the population (rather than the individual), so the onset of the breeding season was taken as the date on which the first males started to attain sexual ornamentation. Calculation of non-breeding growth rates (for the analysis of the effects of reproduction – see below) required a definition of the timing of the end of the first breeding season and the start of the second. The dates adopted were again based on changes in male sexual ornamentation within the population (described in more detail in [1]): the date for the end of the first breeding season was taken as 8 October 2008 for the Winter and 16 October 2008 for the Spring experiment (since the fish in the Spring experiment had a slightly delayed 1st breeding season). The start of the second breeding season did not differ between Experiments but was dependent on the photoperiod treatment, being taken as 6 May 2009 for the normal photoperiod group and 1 June 2009 for the delayed photoperiod group.

Text S2. Quantification of male sexual ornamentation

Using a standardized photography protocol described by [2], we measured throat colouration by placing males in a small tank (170 × 70 × 105 mm with 50 mL water) covered by a white board. This acted as a standard background when we photographed the reddish area of the ventral side of the fish from below using a Panasonic DMC-FX12 Digital camera (3072×2304 pixels, shutter speed 1/2000s, f2.8) with greyscale standards (black, grey, and white), using two full spectrum
daylight bulbs angled at 45° to the tank for illumination. The relative position of both lamps and camera was kept constant and the same person photographed all fish on each measurement day. The fish were captured, photographed and returned to their original tank within 60s, a time short enough that it would not have influenced the degree of colouration [3]. When analysing the photographs we obtained the colour score for redness, greenness, and blueness of the red throat colour area based on colour similarities, as described by [4], using the RGB Measure plug-in in the Image J 1.41 software (National Institute of Health, USA). The intensity of red throat colour (R) was calculated as \( R = \frac{r_{\text{STD}}}{r_{\text{STD}} + g_{\text{STD}} + b_{\text{STD}}} \), where \( r_{\text{STD}} \), \( g_{\text{STD}} \) and \( b_{\text{STD}} \) are red, green and blue first standardized by dividing them by the value of the colour levels obtained for the standard in each picture as described by [5] in order to minimize any effect of variation in light or tone between pictures: a high R value indicates a high proportion of the total image brightness being in the red channel [4]. The investment in sexual ornamentation in each breeding season was quantified as the duration (in weeks) that fish sustained the intensity of their red throats above a threshold that was the mean red throat colouration of males in the first breeding season [1].

**Text S3. Relationship between reproduction, growth rate and lifespan**

We categorised the breeding pattern of each female that survived at least as long as the start of the second breeding season as having spawned eggs in both the first and second breeding season (BB), only the first season (1B), only the second season (2B), or not spawned in either season (NB). The analysis considered both breeding pattern and non-breeding growth rate (i.e. growth between the first and second breeding seasons) as explanatory variables of lifespan. The equivalent Cox proportional hazards models for males analysed the relationships between a male’s pattern of red throat investment, his non-breeding growth rate and his lifespan. The
pattern of red throat investment was quantified as the difference between the two breeding seasons in the number of weeks that a male maintained a red throat above the threshold value (taken to be the mean value for the population in the first breeding season) - so that a positive value indicates that the male was redder for longer in the second than the first breeding season, while a negative value indicates he was redder in the first season.

Survival in females was significantly related to breeding pattern: taking only females that lived into their second breeding season, those that failed to produce eggs in either the first or second season died sooner than those that produced eggs, with the greatest lifespan being shown by females that spawned in both seasons (figure S3; significance of breeding pattern in the Cox proportional hazard model, \( R^2 = 0.605 \), Likelihood test = 96.7, df=26.5, \( P<0.001 \)). There was no effect of non-breeding growth rate (= growth rate between the first and second breeding season) on female survival (Cox model, coefficient \( \beta = 1.543 \), Wald = 0.11, \( P = 0.740 \)). The biggest difference in mortality rates occurred during the second breeding season, with 63% of NB females that were alive at the start of that season having died by the end of it, in comparison with 60% of 2B, 35% of 1B, and 25% of BB females.

The lifespan of the 48 males that lived to at least the start of the second breeding season was related to their non-breeding growth rate (= growth rate between the first and second breeding season) (coefficient \( \beta = -0.5066 \), Wald = 11.64, \( P = 0.0007 \)), with males that grew faster between the two breeding seasons living longer (figure S4a). Males tended to maintain their red colouration for a shorter period in the second breeding season compared to the first (so that the difference in red throat duration tended to be negative; figure S4b). There was a significant relationship between this difference in red throat duration and lifespan (coefficient \( \beta = -0.141 \), Wald = 8.23, \( P = 0.004 \)): the bigger the decline from first to second breeding season in the
duration of the red throat, the shorter the male’s lifespan (figure S4b). This effect did not differ between growth treatment groups (catch-up treatment, coefficient ($\beta$) = 0.068, Wald = 0.03, $P$ = 0.870; slow-down treatment, coefficient ($\beta$) = -0.635, Wald = 2.93, $P$ = 0.087).

Given that both non-breeding growth rate and dynamics of breeding ornamentation were predictors of a male’s lifespan, we examined the relationship between these two explanatory variables using a linear mixed effect model (LME) with temperature and photoperiod treatment as fixed effects, tank as a random factor, and red ornamentation and length at the end of first breeding season as covariates, plus all interactions. Males that grew least well over the non-breeding season also showed the biggest reduction in red ornamentation in their second breeding season (LME, $F_{1, 30.55} = 7.76$, $P$ = 0.009; figure S5). While there was no effect of a male’s length at the end of the first breeding season on his subsequent growth rate up to the next breeding season ($F_{1, 30.19} = 2.24$, $P$ = 0.145), males grew fastest when they were already large at the end of the first season and where they were able to maintain their redness in the second breeding season ($F_{1, 30.70} = 7.64$, $P$ = 0.010), indicating that the individual variation in non-breeding growth rate was primarily a consequence of variation in fish quality.

**Supplemental References**


Figure S1. Description of experimental schedule, with illustration of growth trajectories of the three temperature treatment groups (slow-down treatment – red line, catch-up treatment – blue line, control – black line): Period 1 – the 4-week temperature manipulation period, Period 2 – the compensatory period, Period 3 – the first breeding season, Period 4 – non-breeding season, Period 5: the second breeding season, Period 6 – non-breeding season.
Figure S2. Growth trajectories (logarithm of standard length in mm) of three-spined sticklebacks (*Gasterosteus aculeatus*) after the compensation period in the Winter (a) and Spring (b) experiment. Note that the two experiments started on different days, so that day 22 is 23 April 2008 in (a) and day 19 is 3 July 2008 in (b). The symbols indicate the growth manipulation treatment groups (slow-down – open circle and dashed line; control – close circle and solid line; catch-up – triangle and double dashed line). The thick bars in (a) and (b) indicate the two
breeding seasons. Also shown is the compensatory growth rate during Period 2 in relation to length at the end of the temperature manipulation (slow-down – open circle and dashed regression line, catch-up – triangle and double dashed regression line, and control – close circle and solid regression line) in the Winter (c and d) and Spring (e). In the Winter experiment, data are shown separately for the (c) ambient and (d) delayed photoperiod treatment, but in the Spring experiment these are combined since in that experiment there was no effect of photoperiod treatment on growth. See text of main manuscript for statistical analysis.
Figure S3. Survival curves of female sticklebacks that had survived to the start of the second breeding season in relation to their reproductive strategy (spawned in both first and second breeding season, red line; spawned in only first season, blue line; spawned in only second season, orange line; failed to spawn in either season, green line). The point at which each curve crosses the dashed horizontal line indicates the median lifespan, while the two thick horizontal bars indicate the two breeding seasons. See Text S3 for statistical analysis.
Figure S4. Lifespan in male three-spined sticklebacks in relation to (a) growth rate during the non-breeding period (i.e. growth rate between end of first and beginning of second breeding season) and (b) the change in duration of red throat colouration above a threshold (see text) between the first and second breeding season (where positive values indicate the duration of the red throat was longer in the second season than the first). Data are shown separately for Slow-down treatment (red circle), Catch-up treatment (blue) and Control (black) groups. The
horizontal dashed lines indicate the age at the start of the second breeding season. See Text S3 for statistical analysis.
Figure S5. Non-breeding growth rate (= growth between the first and second breeding seasons) in male three-spined sticklebacks in related to difference in duration of red throat ornamentation between the first and second breeding seasons in three temperature treatments (slow-down – red circle, Catch-up – black, Control – blue); there was no effect of temperature treatment and so the regression line is based on the combined data for all treatment groups. See Text S3 for statistical analysis.