Recent changes in pair abundance and breeding results in the main French populations of the Common Pochard *Aythya ferina*

JOËL BROYER

ONCFS Direction de la Recherche et de l'Expertise. Station de la Dombes, Montfort, 01330 Birieux, France.
E-mail: joel.broyer@oncfs.gouv.fr

Abstract

This study explored trends in Common Pochard *Aythya ferina* breeding abundance in four of the main breeding areas for the species in France (Dombes, Brenne, Forez, Sologne) since 1992. Systematic declines in the ratios of broods to the total numbers of pairs and in brood sizes of one-week-old families, contrasted with no clear changes in duckling survival between 1–3 weeks of age through the study period. Despite similar trends in reproductive measures, Pochard pair density varied unevenly across regions. In Forez, fish farming ceased at many ponds during the 1990s, where pair density initially increased but then declined. In Dombes and Sologne, pair density has apparently declined, whereas density increased in Brenne where ponds are still regularly stocked with fish for fish farming.

Key words: Common Pochard, France, fishpond, reproductive results, recent trends

Widespread declines in the Common Pochard *Aythya ferina* have been observed in the last 30 years, especially in eastern Europe where breeding numbers are highest (Fox *et al*. 2016). The main causes are probably linked to decreasing productivity (Folliot 2018), although a decrease in female survival rates compared with males may also have occurred in some areas (Brides *et al*. 2017). Changes in fish farming practices and in water quality are among the main hypotheses for explaining these declines. In France, overall breeding numbers are believed to have remained stable over the same period (Fox *et al*. 2016). Here the Pochard breeds mainly in association with fish farming on extensive pond complexes, although these are increasingly being abandoned due to low economic returns (Broyer 2016). Despite the relatively modest breeding numbers in France, it is useful to compare regional trends and to identify the reproductive stages at which changes in Pochard productivity may have occurred there to gain insight into factors affecting the population as a whole. The present study reports the results from a monitoring programme undertaken in four of the

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most important French breeding areas for Pochard (in Dombes, Forez, Brenne and Sologne), where fishpond systems constitute the main breeding habitat for the birds. Changes in Pochard pair density, brood size, brood : pair ratio and duckling survival are presented from ponds sampled in each region over the two last decades, to describe changes in these reproductive measures for Pochard breeding in France.

Methods

Study areas

The study was carried out in Brenne (1999–2017) and Sologne (2004–2017) in central France, and in Dombes (1994–2017) and Forez (1992–2017) in the east of the country (Fig. 1). Carp *Cyprinus carpio* has been the major contributor to fish farming production in all regions, but many ponds in Sologne have now been abandoned for several decades, so only 25% of the 3,000 existing ponds are still regularly stocked with fish and harvested. Aquaculture in Forez

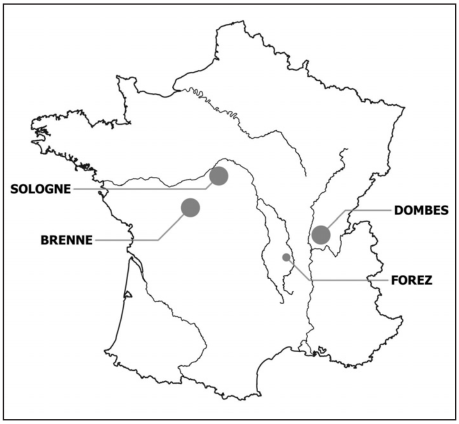

Figure 1. Map of France showing the location of the four main study areas.

(250 ponds) declined mainly during the 1990s. In the two other regions (> 1,000 ponds each), fish farming is more persistent, but there was a major decrease in the level of fertilisation of ponds (nitrogen spreading or cow manure) in Dombes during the 1990s, which also occurred a decade later in Brenne.

Except in densely wooded Sologne, the land around the fishponds is put mainly to arable crops or to pasture. Agriculture in the pond watersheds is more intensive in Dombes, where a massive conversion of grassland to cereal crops since the 1970s has had a major effect on duck breeding conditions (Tournier 1990; Broyer 2000), leading for example to increased clutch predation resulting from nest concentration along pond edges (Broyer 2009). The harvesting of ducks at the start of the hunting season probably also impinges on local populations. No precise statistics are available, but a national survey of duck bags in winter 2013/14 found a relatively stable hunting bag in comparison with 15 years earlier (although numbers shot declined for Pochard; Guillemain *et al.* 2017), and hunting pressure in the study regions may be considered as stable or slightly decreasing. A striking change for the pond ecosystem in each region, however, was the rapid expansion of Coypu *Myocastor coypus* during the 1990s, which had dramatic consequences because of its suppression of emergent aquatic vegetation at these sites (Curtet *et al.* 2008).

Ponds sampled in each region

Breeding ducks were surveyed at 80 ponds in Dombes (mean ± s.d. surface area S = 13.9 ha ± 13.3), 57 in Brenne (S = 10.9 ha ± 9.1), 60 in Sologne (S = 8.9 ha ± 8.1) and 60 in Forez (S = 7.4 ha ± 7.6). The ponds sampled were consistent from year to year, except in Dombes where each pond is left empty and ploughed for cereal cultivation every fourth year. Roads or tracks providing motor vehicle access were used to contribute routes to five transects established for each region, each of which could be covered within a day, so that all ponds were visited within the same week. Routes were planned to ensure that the most representative parts of the study regions were traversed, and that typically managed fishponds were included in the surveys. The distances to reach all studied ponds of each transect were 5–8 km, covered by car. Distances between neighbouring transects were usually 3–5 km.

Duck censuses

Pochard adults and broods were counted every week from mid-April to the end of July, by making one unique comprehensive, very slow, scan of the whole area of the pond on each occasion using a ×40 telescope. Observations were limited to mornings and late afternoons to avoid the hottest part of the day when birds may seek shelter within vegetation cover. Time spent on each pond was proportional to the surface area to be surveyed and to the abundance of aquatic vegetation likely to constitute visual obstacles. Pairs, isolated adults and groups were recorded separately during the scan, and brood size and age (in weeks) were also systematically recorded. Brood age was determined by comparing body lengths of ducklings to the body length of the female (following Fournier & Cordonnier 1982). The contemporaneous fieldwork had to rely on different observers across regions, and usually also from year to year, which may potentially introduce an observer effect in detection of the birds. The same well-trained observer, however, did all weekly counts in each region for a given year while the frequency of visits would also help to reduce any bias in the results.

Data analysis

Pair density

Duck pair densities estimated from direct ground counts can only be considered as approximations of absolute numbers of breeding pairs per pond. However, Rotella *et al.* (1995) concluded that, for many research and monitoring applications, the level of error may be inconsequential, because breeding pairs restrict their activity during the pre-nesting, laying and early incubation periods. The numbers of Pochard pairs per pond were estimated during the pre-nesting and early incubation periods, *i.e.* between April 15 and May 25 (at least 5 visits). Pairs and isolated adults were recorded separately in each of the weekly counts and large groups of males, females or both sexes were normally not considered for assessing pair numbers per pond. For each weekly count in each pond, we added to the observed number of pairs, either lone females (considered to be on a short recess from incubation), or males alone or in small groups (< 5) thought to be paired birds where the female had started incubation, and retained the highest of these two additions. As a rule, the number of pairs per pond used in the analyses corresponded to the highest number recorded at least three times during the study period (April 15–May 25) that year.

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Of course, we cannot with certainty know that pairs assigned by this method to a given pond eventually nested there.

Each year for each site, Pochard pair abundance was measured as the mean numbers recorded at the ponds. Defining standardised indices was however complicated by variation in pond sizes and by the strong interactions between the pond's surface area and Pochard abundance or density. In this study, the number of pairs per pond therefore was divided by the square root of the pond's surface area to offset this effect (as in Broyer *et al.* 2015).

Brood:pair ratio

The ratio of the number of broods to the number of pairs was calculated to generate an overall annual index for each study region, based on the sum of the number of pairs and broods recorded at each pond in the region. Because broods may move between neighbouring ponds, only ≤ 2-week-old broods were considered in determining the number of broods, in order to limit the risk of double counting. Brood number was the sum of all ≤ 1-week-old broods recorded at different dates throughout the sample and of 2-week-old broods provided that no ≤ 1-week-old broods of same or bigger size were observed in the same pond or a nearby pond during the preceding weekly count.

Brood size and duckling loss in early stages of growth

Duckling numbers were used for assessing mean brood size shortly after hatch (at ≤ 1 week old) and losses during the duckling growth period, because Pochard brood sizes decrease at French fishponds mainly during the first 3 weeks after hatching (Broyer 2002). Duckling losses at the ponds included in the study therefore were estimated as the percentage difference between ducklings counted at 1-week-old stage and those at 3 weeks old. To limit the possible error introduced by broods being present but undetected, the 1-week-old brood number was considered as being equal to 1-week-old + 2-week-old broods observed for the first time, and the 3-week-old brood number was equal to 3-week-old + 4-week-old broods where the latter were not observed at 3 weeks of age. This method assumed that any ingress of broods into the ponds being monitored was counterbalanced by a similar egress of the same number to water bodies away from the study sites.

Statistical analysis

Generalized linear mixed models (GLMMs) in Program R (R 64 3.0.3, with package lme4) were used to analyse trends in the demographic variables (using annual regional means recorded at the sample ponds), with "year" included as an explanatory variable and "region" as a random effect in the model. The distribution of all dependent variables permitted the use of a Gaussian error term. AIC scores for each of the models were compared to the scores of the respective null models and confirmed by a graphical analysis. In cases with AIC ≤ 2, or where the AIC was higher than the score of the null model, each regional trend was described individually by the best fitting curve (highest R^2) from a linear, quadratic or cubic regression. Where statistically significant trends were detected, the mean values of the variable in the first five years and the last five

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years of the study were described to illustrate the magnitude of the change over time.

Results

The GLMMs failed to identify clear global trends across the four study regions over time in pair density or duckling losses (t_{72} = 0.31 and t_{76} = 0.47, respectively, P > 0.05, n.s.) with AIC higher than the scores of the respective null models in each case; Table 1). Specific regional variation with time was nevertheless recorded in pair density: a linear decrease in Dombes (R^2 = 0.183, d.f. = 22, P = 0.04), a linear increase in Brenne (R^2 = 0.393, d.f. = 15, P < 0.01), a quadratic regression in Forez (R^2 = 0.548, d.f. = 22, P < 0.01; *i.e.* a decrease following a temporary increase), and a cubic regression with a late decrease in pair densities in Sologne (R^2 = 0.619, d.f. = 8, P = 0.05) (Fig. 2). No clear trend was observed in duckling losses in any region (R^2 < 0.09, n.s. in each case, except in Brenne where R^2 = 0.103, d.f. = 18, P = 0.18, n.s.). This variable however showed an increase in annual variation from the mid-2000s onward (Fig. 3).

There was evidence for a trend in brood size and also in the brood : pair ratio over time (t_{76} = –3.59 and t_{70} = –4.60 respectively, P < 0.05; AIC > 3 in comparison with the null model; Table 1), and graphical analysis indicated a common declining trend across the study regions (R^2 > 0.11 for brood size; R^2 > 0.15 for the brood : pair ratio; Figs. 4, 5). Comparing the mean values for these parameters in the first five years and last five years of the study in each region (Table 2) provides some indication of the magnitude of recent changes in Pochard productivity in France.

Discussion

Recent declines in the numbers of breeding pairs of Pochard have been reported in many breeding areas in northeast Europe, for instance in Russia, Belarus, Ukraine, Latvia and Lituania (Viksne *et al.* 2010). Such trends have been attributed to large-scale drainage schemes, overgrowing of nesting areas with shrubs and dense reed stands, and the disappearance of stoneworts *Chara* sp. or pondweeds *Potamogeton* sp. at the breeding sites (Viksne 1997; Viksne *et al.* 2005;

Table 1. Results of GLMMs explaining the variation with time of Pochard pair density, brood size, brood : pair ratio, and duckling loss, with "region" included as a random effect in the models. AIC comparisons are with the respective null models.

	Estimate	s.e.	*t* value	d.f.	AIC	AIC (null)	ΔAIC
Pair density	0.0014	0.0046	0.307	72	36.45	25.61	10.86
Brood size	–0.0471	0.0131	–3.594	76	199.69	202.91	–3.22
Brood : pair ratio	–0.0116	0.0025	–4.603	70	–51.39	–45.06	–6.33
Duckling loss	0.0012	0.0026	0.469	76	–46.43	–58.30	11.87

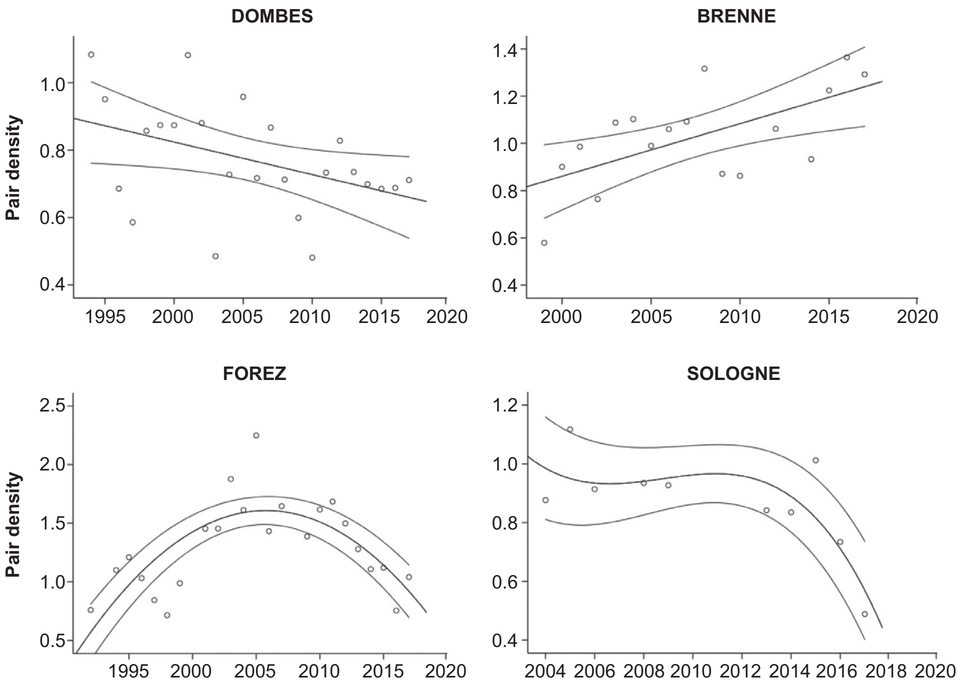

Figure 2. Regional trends of Pochard pair density (regression curves with 95% confidence intervals), in: Dombes (linear regression: $R^2 = 0.183$, d.f. = 22, $P = 0.04$), Brenne (linear regression: $R^2 = 0.393$, d.f. = 15, $P < 0.01$), Forez (quadratic regression: $R^2 = 0.548$, d.f. = 22, $P < 0.01$), and in Sologne (cubic regression: $R^2 = 0.619$, d.f. = 8, $P = 0.05$).

Stanevicius 1999; Švazăs & Kozulin 2002). Change in fishpond management was also one of the possible causes most frequently given by experts (Fox *et al.* 2016). Eutrophication may be detrimental to waterbird populations (Lehikoinen *et al.* 2016), and too high fish stock density may also lead to conditions unsuitable for duck breeding (Musil 2006), in particular if macrophyte beds are destroyed (Maceda-Veiga *et al.* 2017). In fact, intensification of fish farming (leading to eutrophication, high carp biomass density, *etc.*) seems to be detrimental to Pochard habitat, especially through its negative impacts on aquatic vegetation. Conversely, the cessation of pond management following the abandonment of fish farming may also reduce Pochard breeding numbers (Broyer *et al.* 2015, 2018).

In France, Pochard nest survival is correlated with female body condition and with predation risk (Folliot *et al.* 2017). The present study found that breeding outcome may have been negatively affected at the four main breeding areas in the country over the last 20 years by a decrease in the brood : pair ratio. This could reflect either a lower proportion of females actually nesting or a lower hatching rate. Simultaneously, brood sizes recorded for one-week-old broods

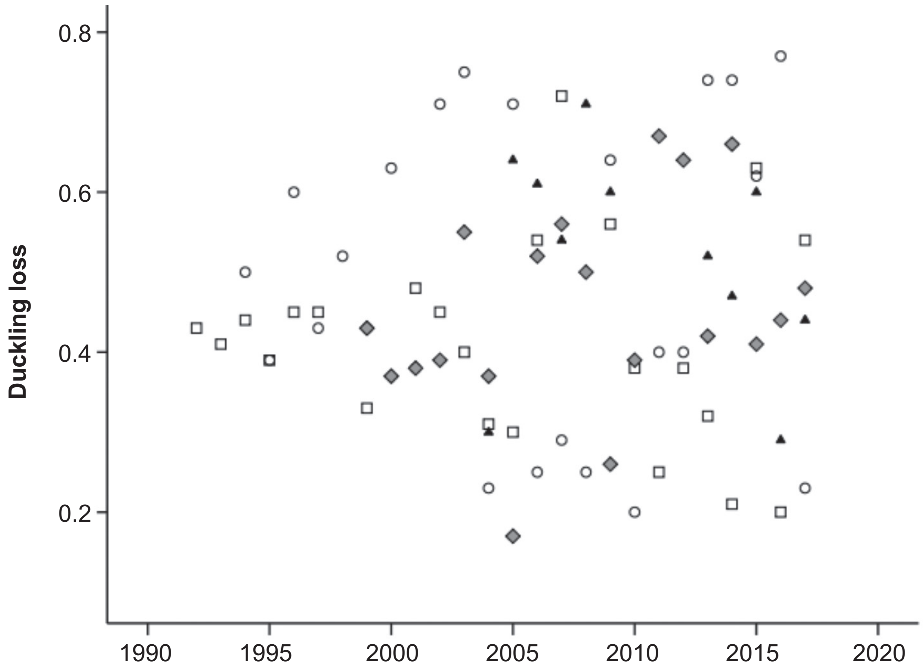

Figure 3. Trend in Pochard duckling losses between the ages of one and three weeks, in Dombes (circles), Brenne (diamonds), Sologne (triangles) and Forez (squares). $R^2 < 0.09$, n.s. in each case, except in Brenne where $R^2 = 0.103$, d.f. = 18, $P = 0.18$, n.s.

were also decreasing. Although there was no significant trend in duckling losses between 1 and 3 weeks, between-year variance increased, perhaps as a consequence of between-year weather extremes that either caused drought (as in 2011 or 2017) or flooding (as in 2013 or 2016) in ponds. These results clearly indicate a deterioration of Pochard breeding conditions in the nesting phase. In Dombes, this phenomenon is a long-term process (Tournier 1990), which began in the 1980s with the conversion of grassland habitats in pond surroundings into cereal cultivation (Broyer 2000). Several decades later, habitat deterioration seems to affect Sologne and Forez, where the observed changes in breeding Pochard numbers may be chronologically related to the massive abandonment of fish farming (Broyer *et al.* 2016a, b). In Brenne where no such decline in fish farming has occurred, a possible explanation to the negative trend in Pochard nesting success could relate to reduction in fishpond fertilisation by many fish farmers between 2002 and 2013 which likely reduced primary productivity associated with these ponds (Broyer *et al.* 2015). Mean brood sizes of Pochard in Brenne were lower than in the other nesting areas in France even before recent declines (Broyer 2002), possibly indicating the relatively lower carrying

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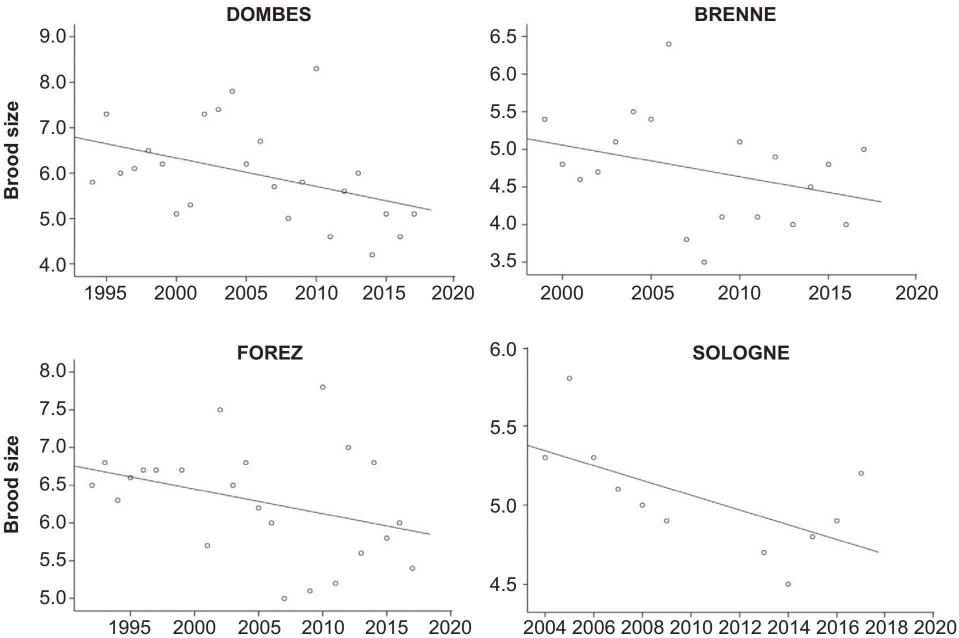

Figure 4. Trends in the size of one-week-old broods for Pochard in Dombes (R^2 = 0.173, P = 0.056, n.s.), Brenne (R^2 = 0.111, P = 0.16, n.s.), Forez (R^2 = 0.122, P = 0.10, n.s.) and Sologne (R^2 = 0.392, P = 0.039).

capacity of waterbodies in this region. In Brenne, high carp biomass density (*c.* 400 kg/ha) was not obtained at the expense of macrophyte beds (Broyer & Curtet 2011). This could explain the positive trend for Pochard pair density, in ponds still managed for fish farming. A more detailed analysis of the consequences on Pochard breeding of spatio-temporal variations in pond management practices by fish farmers and by waterfowl hunters in Brenne is underway for a separate publication.

Decreases in overall abundance were evident in Dombes and Sologne, where agriculture intensification (Dombes) or the demise of fish farming (Sologne) have affected the aquatic environment of most ponds in these regions over many years. The decline in fish farming at the Forez ponds is more recent, mainly from the 1990s onwards. There, Pochard pair density initially increased until 2005, and subsequently decreased. This effect could perhaps be explained by a short-term positive effect of reduced competition for food between Pochard and fish after the cessation of fish stocking, followed by longer-term adverse effects from the absence of pond management. This could be manifest as a result of the lack of Cyprinid influence on the nutrient cycle of the aquatic ecosystem, as a result of their excretions and feeding effects on sediment resuspension (Lamarra 1975; Breukelaar *et al.* 1994; Chumchal *et al.*

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Table 2. Mean (± s.d.) brood sizes and brood : pair ratios for Pochard in different study areas during the first years and the last five years of the study in each region.

Variable	Region	First 5 years (mean ± s.d.)	Last 5 years (mean ± s.d.)
Brood Size	Dombes	6.34 ± 0.59	5.00 ± 0.67
	Forez	6.58 ± 0.19	5.83 ± 0.53
	Brenne	4.92 ± 0.33	4.46 ± 0.46
	Sologne	5.30 ± 0.31	4.82 ± 0.26
Brood : pair ratio	Dombes	0.45 ± 0.71	0.26 ± 0.05
	Forez	0.81 ± 0.10	0.54 ± 0.22
	Brenne	0.68 ± 0.02	0.45 ± 0.15
	Sologne	0.64 ± 0.06	0.41 ± 0.13

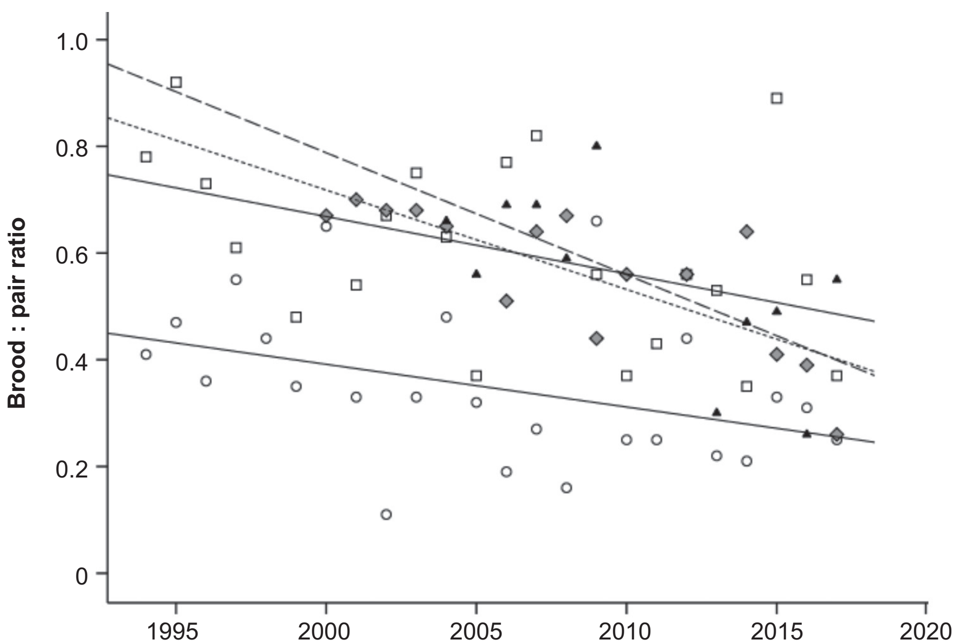

Figure 5. Trend in Pochard brood : pair ratio in Dombes (circles and solid line: $R^2 = 0.156$, $P = 0.056$, n.s.), Brenne (diamonds and dashed line: $R^2 = 0.613$, $P = 0.001$), Sologne (triangles and dotted line: $R^2 = 0.431$, $P = 0.028$) and Forez (squares and solid line: $R^2 = 0.196$, $P = 0.044$).

2005; Driver *et al.* 2005). In Brenne however, neither the interruption of fertilisation (which reduced nutrient concentrations), nor the decrease in brood : pair ratio, prevented Pochard pair density from increasing. The persistence of fish farming in this region seems to correlate with a strong attractiveness to Pochard pairs there, despite declining nesting success.

In conclusion, the apparently stable numbers of Pochard breeding in France (Fox *et al.* 2016) masks contrasting regional trends at four of the most important countrywide breeding areas for this species. However, the systematic decline in reproductive output was common to all areas suggesting factors operating during the nesting phase. This common conclusion across four separate breeding areas under different habitat conditions and fish farming management regimes strongly suggests a common cause. This could potentially be the result of the adverse effects of the arrival of the invasive alien Coypu on the quality of Pochard nesting sites (Broyer & Curtet 2002), which has caused the loss of dense aquatic vegetation along pond edges, which provides the species with opportunities for nest concealment to counteract nest predation. It should also be noted that other factors not considered here (*e.g.* carp and Red Swamp Crayfish *Procambarus clarkii*) have been found to influence Pochard habitat elsewhere in Europe (Geiger *et al.* 2005; Souty-Grosset *et al.* 2016; Maceda-Veiga *et al.* 2017) and may also contribute to Pochard declines in France. Pond attractiveness for Pochard breeding adults seems nevertheless to be positively influenced by the persistence of extensive fish farming, as shown in Brenne (this study) and in Sologne (Broyer *et al.* 2018).

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Photograph: Female Pochard with duckling, by Maurice Benmergui.

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