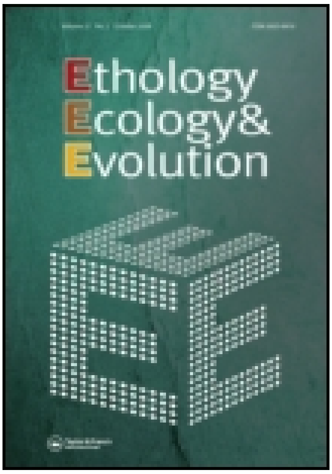

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Worldwide impact of alien parrots (Aves Psittaciformes) on native biodiversity and environment: a review

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Worldwide impact of alien parrots (Aves Psittaciformes) on native biodiversity and environment: a review

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More than 16% of parrot species (Aves Psittaciformes) of the world have currently established at least one breeding population outside their natural distribution ranges. Though including the most introduced bird species all over the world, their interactions with native biodiversity and environments are still poorly known. In this paper, we summarize current knowledge about impacts of introduced Psittaciformes and we identify possible gaps to be filled with future research. Breeding site requirements of alien parrots, e.g. trunk cavities, indicate potential routes of direct and indirect competition with native hole-nesting bird species. Interactions with arboreal rodents, bats and insects are poorly documented, but appear to be limited. Psittaciformes potentially affect economy and human wellness, being responsible for damage to crops and to electrical infrastructures. Association with noise pollution has also been suggested, as many alien populations breed in urban parks or close to human settlements. Psittaciformes are potential reservoirs of *Chlamydophila psittaci*, the etiological agent of human psittacosis, and other diseases transmittable to humans and wildlife. Less is known about impact on native flora as well as on ecosystem functions. Predictive research and information on ecosystem recovery after parrot removal are scarce too, as eradication programs are often hampered by the emotional affiliation linked to these birds.

KEY WORDS: alien species, introduced parakeets, competition, crop damages, diseases.

INTRODUCTION

Climate, land use and atmospheric composition as well as biodiversity have been dramatically altered by human activities during the "era of globalization" (e.g. MCKINNEY & LOCKWOOD 1999; JESCHKE & STRAYER 2005; VANDER ZANDEN 2005). Impacts of non-native species are currently considered the second most influential causes of the current global biodiversity crisis, after habitat loss and fragmentation (WONHAM 2006; GENOVESI & MONACO 2013; SIMBERLOFF et al. 2013), so

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understanding the impacts of non-native species is crucial to preserving indigenous communities (e.g. Barrios-Garcia & Ballari 2012; Gozlan et al. 2013; Waller & Maas 2013). Invasive alien species cover a wide taxonomic spectrum, so their impacts are not easily generalizable, nor predictable (Duncan et al. 2003; Blackburn et al. 2009), as they are expected to be different when densities, invaded communities and interactions with the environment change, both in time and in space (Duncan et al. 2003; Blackburn et al. 2009). In this context, a good preliminary approach to address this problem is to focus on the biological traits of alien species/taxonomic families (Duncan et al. 2003; Barrios-Garcia & Ballari 2012). Psittaciformes represents one of the most readily distinguishable avian taxonomic orders, because of their vividly coloured plumage and popularity as pets (Juniper & Parr 1998). At present, 355 species are recognized in this order (del Hoyo et al. 1997; Juniper & Parr 1998; Clements 2007) and some of them are highly invasive when introduced outside their natural range (Lowe et al. 2000): about 60 parrot species (16.6% of total living species) are currently breeding in at least one country outside their range, with populations mainly deriving from unintentional releases (Fig. 1: e.g. Lever 1987; Runde et al. 2007; Lin Neo 2012; Mori et al. 2013a). Small- to medium-sized, widely distributed species (e.g., *Agapornis* spp., *Amazona* spp., *Aratinga* spp., *Myiopsitta monachus*, *Psittacula* spp.) are the most adept at establishing non-native populations, because they are (i) more traded than others, (ii) commonly sold at relatively low prices, (iii) highly synanthropic and (iv) adapted to live in a variety of environmental conditions, i.e. latitude and habitat types (e.g. Duncan et al. 2003; Cassey et al. 2004). Among them, the rose-ringed parakeet *Psittacula krameri* (hereafter, RRP) and the monk parakeet *Myiopsitta monachus* (hereafter, MP) are considered the most effective parrot species to colonize new territories where historically absent (Cramp & Simmons 1980; del Hoyo et al. 1997).

Introduced parrot populations may experience a "lag period" (i.e. up to some decades) after their release, and then rapidly irrupt in both range and population size (Keiji 2001; Runde et al. 2007; Dangoisse 2009). Currently, in the continental USA, only nine species out of 24 detected have established self-sustaining populations (Runde et al. 2007), while in Hawaii 11 species out of 24 are breeding (Runde et al. 2007), and in Italy five species out of 21 have breeding evidence (Mori et al. 2013a), and only two of them are naturalized (Fracasso et al. 2009). However, possible impacts by non-breeding species cannot be ruled out. Data are reliable, as released/escaped parrots are easily recorded by birdwatchers and ornithologists, being often brightly coloured and frequently vocal. Introduced parrots occur mainly in the surrounding of urban parks, that is in the proximate area of their release sites (e.g. private gardens, airports, ports of entry); few populations are present in rural areas (e.g. Sol et al. 1997; Butler 2003; Chapman 2005). Range expansions of these species could be benefited by their generalist habits (Khan et al. 2004), as well as by food supply provided by suburban households (Polkanov & Greene 2000; Clergeau & Vergnes 2011). Their breeding success is probably due to their ecological traits – all included among those of the "best bird invader" (Cassey et al. 2004; Blackburn et al. 2009) – propagule pressures (i.e. number of released individuals: Lockwood et al. 2009), multiple releases (Cassey et al. 2004) and the absence of native Psittaciformes all over the introduced ranges (Duncan & Blackburn 2002; Butler 2003).

Deep gaps still remain in understanding how much introduced parrots affect native biodiversity and ecosystem functions. Interactions with native birds have been described in roosting (e.g. Runde et al. 2007), breeding (e.g. Strubbe et al. 2010; MacGregor-Fors et al. 2011) and feeding sites (e.g. Dubois 2007; Dangoisse 2009; Lin Neo 2012).

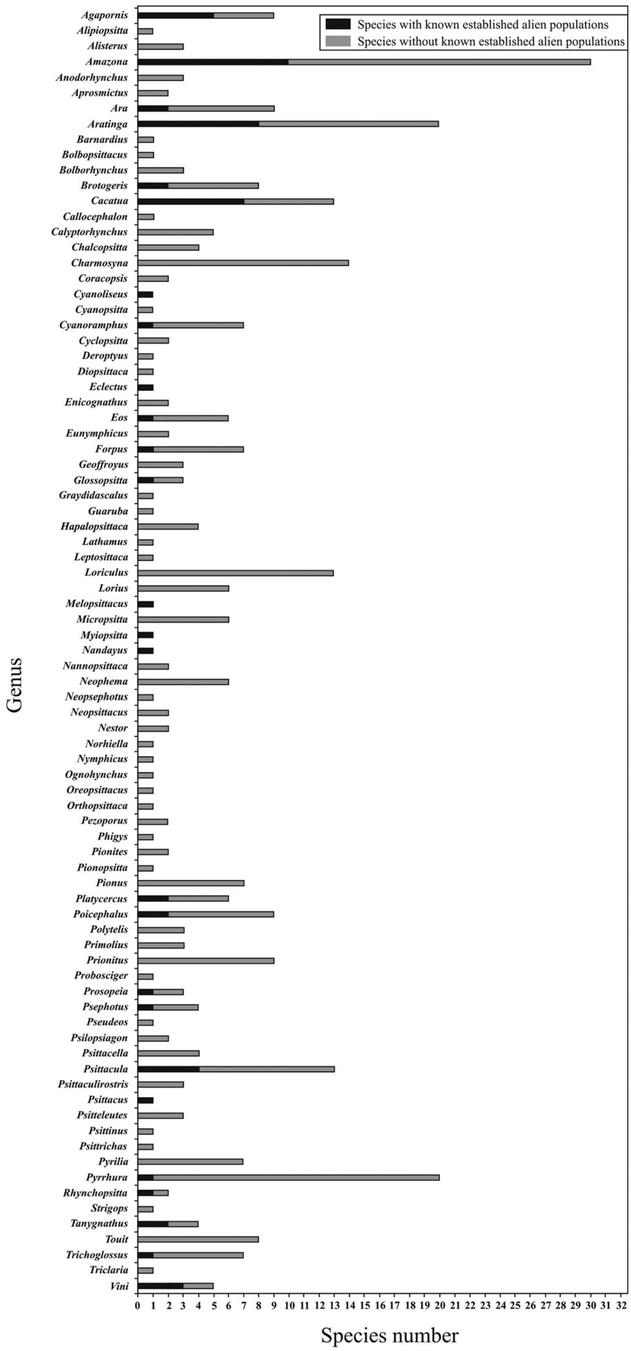

Fig. 1. — Global number of Psittaciformes species and number of breeding introduced species in the world, ordered by genus.

Negative effects on human activities and facilities have also been reported (e.g. Avery et al. 2002; Dubois 2007; Fletcher & Askew 2007). Parrots are possible reservoirs of many viral and bacterial diseases, which may pose risks to humans, poultry industries and wildlife (Runde et al. 2007). Native species rarely prey on introduced parrots: few predation events exerted by corvids (del Hoyo et al. 1997; Mabb 1997; Weiserbs & Jacob 1999; Chapman 2005), diurnal raptors (Lever 1987; Mabb 1997; Chapman 2005), rats (Scortecci 1953), squirrels (Gebhardt 1996; Shwartz et al. 2009; Mori et al. 2013b) and stray cats (Lever 1987) have been reported.

Psittaciformes represent an ideal focus of a review to collate available evidence regarding the actual/assumed impacts of non-native populations. In this review, we summarize the literature on parrots' impacts in their introduced range, and we identify knowledge gaps and research needs at the end of each subheading, following the structure of Barrios-Garcia & Ballari (2012).

NEGATIVE EFFECTS

Competition with native birds

Most parrot species are gregarious and, when released in new territories, may group together with native birds (e.g. Batllori & Nos 1985; Weiserbs & Jacob 1999; Zocchi et al. 2009). Parrots show a territorial behaviour during the breeding season: active, aggressive displays are mainly limited to the nest/cavity which houses the eggs (e.g. Cramp & Simmons 1980; Spanò & Truffi 1986). Introduced MPs were observed showing aggressive behaviours (i.e. mobbings and direct killings) against native species (USA: Long 1981; MacGregor-Fors et al. 2011). Noisy and physical intimidations against raptors (e.g. *Falco tinnunculus*, *Athene noctua*) and corvids (e.g. *Corvus cornix*) have been reported in the surrounding of the nests of MPs (Belgium: Dangoisse 2009) and RRPs (UK: Cramp 1985; France: Dubois 2007; Italy: authors' pers. obs.); a lethal attack by RRP on *Athene noctua* was suggested in Algeria (A. Fellous pers. comm. 2012). Attacks on native species by introduced parrots have been recorded in feeding sites in Europe (Cramp & Simmons 1980; Batllori & Nos 1985; Weiserb & Jacob 1999; Dangoisse 2009), Southeast Asia (Peh 2010; Lin Neo 2012), North America (Lever 1994) and Hawaii (Loope et al. 2001). Flocks of RRPs may show aggressive behaviours also against large-sized species (seagulls, herons: Dubois 2007). In Western Australia and Queensland, introduced *Trichoglossus haematodus* show aggressive behaviour against native Passeriformes and doves in feeding areas (Chapman 2005). Feeding mostly on unripe fruits and seeds, RRPs may take food before other species consume it, thus enhancing competition with native birds (Fletcher & Askew 2007; Lin Neo 2012).

Cavities represent limited resources in urban/suburban areas where decaying trees are uprooted (Wesołowski 2007), and this elicits competition between hole-nester birds. Competition between parrots and woodpeckers for nesting sites has been suggested (Cramp 1985; Hockey et al. Ryan 2005; Fletcher & Askew 2007), but experimental studies did not support this hypothesis (Strubbe et al. 2010; Newson et al. 2011; Orchan et al. 2012). Woodpeckers are primary cavity nesters, i.e. they excavate new holes at each reproduction event, while parrots rely upon already existing cavities, and they seem to nest at lower altitudes on the trunks with respect to parrots (Strubbe et al. 2010; Newson et al. 2011; Orchan et al. 2012). Antagonistic behaviours are displayed against secondary hole-nesters which select cavities as larger as those used by parakeets (Fletcher & Askew 2007; Orchan et al. 2012). Some parrot species (e.g. RRP) are advantaged in competition, as they begin breeding earlier than native birds (Cramp 1985). Displacement and/or nest destructions by introduced RRPs have been observed in Europe (Batllori & Nos 1985; Cramp 1985; Dubois 2007; Strubbe & Matthysen 2007; Czajka et al. 2011), South America (Nebot 1999) and in the Middle East (Shwartz et al. 2009). Despite differences in body size necessarily reflecting different cavity preferences (Martin et al. 2004; Fletcher & Askew 2007; Orchan et al. 2012), different diameters of hole-nests do not rule out possible competition with native species (e.g. European starlings: Braun et al. 2009). An experimental study showed that RRPs may also compete with nuthatch *Sitta europaea* (Strubbe et al. 2010), as the native species may choose large cavities – thus idoneous for breeding parakeets – and then apply mud to reduce their size (Cramp & Simmons 1980). Newson et al. (2011) claimed that this competition phenomenon disappears when the degree of urbanization is taken into account. Despite being secondary cavity nesters, Psittaciformes can enlarge smaller tree holes with their strong beaks to better satisfy their needs for nesting purposes. This behaviour is uncommon, being time- and energy-consuming (Butler 2003), thus performed only in soft-wooded trees (e.g. *Salix* spp.) and when suitable nesting sites are scarce (Czajka et al. 2011). In Israel, cavity enlargement by alien parrots improves the breeding success of the alien invasive common myna *Acridotheres tristis* (Orchan et al. 2012). In its introduced range (Western Australia), *Trichoglossus haematodus* chases indigenous *Strepera graculina* from breeding sites and competes with native parrots (Chapman 2005). Similarly, released RRPs as well as *Platycercus elegans*, *Cacatua sanguinea* and *Cacatua tenuirostris* compete with indigenous Psittaciformes in Oceania (Lever 1994; Wright & Clout 2001; Latitude42 2011).

Competition between *Agapornis fischeri* and *Passer domesticus* for breeding sites in France has been suggested (Dubois 2007); the same parrot species, as well as the congeneric *A. personatus*, can displace native *Cypsiurus parvus* for breeding purposes in Kenya (Lever 1994). In Southeast Asia, alien *Cacatua goffiniana* has been observed usurping cavities of native *Cacatua sulphurea* (Lin Neo 2012) and *Anthracoceros albirostris* (Peh 2010; Lin Neo 2012). *Aratinga mitrata* may displace native marine birds from breeding colonies in Hawaii (Runde et al. 2007). Displacement behaviour by introduced RRP is particularly noteworthy if exerted against native, threatened species, such as the endemic *Psittacula eques* in Mauritius (Jones 1980), *Coracopsis nigra* in Mahé Island (Fanchette 2012), *Calyptorhynchus latirostris* in Oceania (Chapman 2005), and *Cyanoramphus cooki* in Norfolk Island (Lever 2005).

Quantitative studies on displacement/aggressive behaviours through standardized direct observations (e.g. linear transects), both in nesting and in feeding sites, would be crucial all over the introduced ranges of parrots. Impacts on threatened, endemic species should be rapidly assessed and quantified, by testing competition hypotheses with methods borrowed from other similar works (e.g. Strubbe et al. 2010; Orchan et al. 2012).

Competition with other animal species

Start (1998) and Gebhardt (1996) claimed that RRP may displace dormice and bats from tree-holes and nest-boxes, without providing any further detail. Parrots may harass and push away European squirrels, only rarely touching them (P. Clergeau pers. comm. 2012). In France, groups of 3–4 RRPs were observed attacking and killing an adult *Sciurus vulgaris* (Japiot 2005; park of l'Hay les Roses: P. Clergeau pers. comm. 2012); more recently (December 2013), in a park of the village "Marnes la Coquette" (Department of Hauts de Seine, 92430), six RRP individuals attacked and pursued a red squirrel with numerous pecks, for 20 min (P. Clergeau pers. comm. 2013). A female *Polytelis swainsonii* killed an *S. vulgaris* in Central Italy, by hurting the head and back of the rodent with the beak (Mori et al. 2013b). In Germany, a swarm of *Apis mellifera* tried to enter a nest-box occupied by RRPs, actively defended by the female parakeet (M. Braun pers. comm. 2012); a similar situation involved introduced *Trichoglossus haematodus* and feral honeybees in Western Australia (Chapman 2005).

Up to now, no experimental study has ever analyzed impacts of parrots on communities of bats and arboreal rodents: the few available data are merely descriptive and not statistically supported. A possibility to fill this gap may consist in implementing experimental designs, which take into account bats'/arboreal rodents' densities in areas occupied by introduced parrots. Data should be compared to control parrot-free areas characterized by the same suitability level for both taxa, and following the methodologies of Gotelli & McCabe (2002). A summary of the negative impacts on native species is shown in Table 2.

Effects on natural plant communities

The role of parrots as seed dispersers is debated (Wunderle 1997; Norconk et al. 1998; Loope et al. 2001). In Hawaii, the non-native *Aratinga mitrata* feeds essentially on exotic plants and may be responsible for the spread of the alien invasive *Miconia calvescens* (Runde et al. 2007). Rubbing the surface of the seed accelerates germination, but a complete removal of the coat exposes seeds to predation by invertebrates and terrestrial microbes (Norconk et al. 1998). Howe (1977, 1984) and Galetti (1993) stated that parrots contribute to inhibit the reproduction and the germination of native plants, because fruits they strip are dropped immediately under the forest canopies. Thus, parrots may represent a hindrance to the reproduction of native plant species and become a serious threat for plants of economic concern or endemic to a certain area (Runde et al. 2007; Lin Neo 2012). In their natural distribution ranges, frugivorous species disperse only those seeds able to sprout which survive undestroyed by the beak and by the passage through the gut (Norconk et al. 1998).

Breeding MPs exert damages on trees and plantations in Europe and in Australia (Campbell 2000; Butler 2003; Fletcher & Askew 2007). In UK, droppings under the roosts may have altered the herbaceous vegetation composition; a direct cause-effect relationship cannot be assessed because no detailed data are available about floral composition before parakeets' invasion (Fletcher & Askew 2007). Defoliation of native trees and epiphytes by introduced *Cacatua galerita* in New Zealand was detrimental for forest dynamics, as it caused both increases of understorey vegetation and declining of rare plant species (Styche 2008).

Qualitative and quantitative studies on seed-dispersal abilities of parrots would be beneficial. This gap could be filled in captive-breeding conditions, with parrots fed with seeds of native and alien plants. Droppings would then collected and put to germinate. On the other hand, a real quantification of the damage caused by droppings under the roosts is difficult to assess; spatial distribution models may be helpful in identifying future invasion areas (e.g. Di Febbraro et al. 2013), where the herbaceous vegetation composition should be analyzed before and after the invasion.

Economic consequences: damages to crops/orchards and human facilities

Damages by parrots are complained about on crops/orchards, greenhouses as well as on human facilities.

About 70% of introduced parrots are considered agricultural pests in their natural extent of occurrences (Lever 1987, 2005), targeting a variety of fruits and crops (losses up to 45%: for MP: Stafford 2003), such as corn and apples (Mott 1973). RRP is one of the worst pest species of the Indian subcontinent (Dhindsa & Saina 1994); corn (losses up to 81%: Reddy 1998a), sorghum (losses up to 74%: Reddy 1998b) and sunflowers constitute the staple of its diet in summer, fruits in winter (Rao & Shivanarayan 1981; Luft 1994; Ahmad et al. 2012a). As for the introduced ranges, records are locally significant and increasing in the grey literature (e.g. agriculture bulletins, unpublished technical reports), but damages are rarely quantified (Butler 2003; Chapman 2005; Bauer & Woog 2008). Introduced MPs in the USA feed on corn, orchards and ornamental gardens (crop losses up to 28% for *Euphoria longana*; up to 64% on *Litchi chinensis*: Tillman et al. 2001; Stafford 2003). Orchard damages by RRPs in the UK have been recorded since the 1950s (Yealland 1958), and the cost of vineyard damage in Surrey (UK) is estimated at about £ 5,000 per year (Fletcher & Askew 2007). On the countrary, crop damages exerted by MP and RRP are reported in many European countries, but without any quantification (Spanò & Truffi 1986; Andreotti et al. 2001; AFV 2004; Vidal Rodriguez 2004; Dubois 2007). A preference by these species for orchards (Batllori & Nos 1985; Caruso & Scelsi 1994; Dangoisse 2009; Zocchi et al. 2009) and cultivated fields (corn, vine, *Hordeum* spp., *Pisum sativum*, *Pistacia vera*: Borgo et al. 2005; Latsoudis 2007; Tayleur 2010) – as feeding sites – was observed also when other plants were present within a study area (e.g. Fraissinet et al. 2000; Fletcher & Askew 2007; Martens et al. 2013). Barns may also be invaded, grain bags torn (Andreotti et al. 2001) and vine branches used to coat nests (e.g. MP in Northern Italy: Caldonazzi et al. 2003). Introduced *Trichoglossus haematodus* cause losses in fruit production both in Western Australia and in East Timor (Polkanov & Greene 2000; Bomford & Sinclair 2002; Chapman 2005). First crop damage's records (i.e. haystacks pulled apart at the seed heads) by introduced *Cacatua roseicapilla*, *C. galerita* and *Platycercus elegans* have been documented in New Zealand since the first 2000s (Lever 2005); a probable range expansion seems to depend on cultivated resource availability, so that it could be concerning for human economy (Lever 2005; Styche 2008). In some islands (e.g. Rodrigues, Puerto Rico and Virgin Islands), number of alien parrots are kept under control, to prevent crop damages (Lever 1987; del Hoyo et al. 1997). A possible range expansion of *Nandayus nenday* in USA as well as in suburban Buenos Aires is thought to trigger similar problems (del Hoyo et al. 1997). *Agapornis personatus* introduced in Kenya is responsible for damages to millet crops (Lever 2005). In the USA, crop damages exerted by *Melopsittacus undulatus* are complained about by local farmers (Lever 2005), while *Brotogeris versicolurus* and *B. chiriri* seem to select cultivated blossoms and fruits (Lever 1987; del Hoyo et al. 1997). A similar feeding behaviour has been described for *Forpus passerines*, introduced in Jamaica, and for *Amazona viridigenalis*, released in North America, Puerto Rico and Oahu (Lever 2005), with no available quantitative determinations of crop losses. Dubois (2007) speculated that a possible expansion of the small colonies of *Agapornis fischeri* in France may increase damages to orchards and greenhouses. The diet of *Psittacula eupatria* introduced in Iran includes a large part of cultivated plants of economic interest (Khaleghizadeh 2004). *Cacatua goffiniana* and *Psittacula alexandri*, both exotic in Southeast Asia, pose a threat to plant vivaria, feeding on tropical flowers and ornamental fruits (Lin Neo 2012). From a general perspective, data about damages to cultivated plants within the introduced ranges are still scanty, because current breeding populations are concentrated near cities, rather than in rural areas (Butler 2003; Stafford 2003), or constituted by a small number of individuals (e.g. Nebot 1999; Anderson & Baldock 2001; Eguchi & Amano 2004). Only 2% of respondent Hawaiian farmers complained about parrot damages to fruits (e.g. bananas and papayas) and corn (Runde et al. 2007). Undocumented cases are not to be excluded, as it is difficult to distinguish between damages exerted by these species and those caused by native birds traditionally recorded in agroecosystems and often gregariously coexisting with parrots (Pruett-Jones & Tarvin 1998).

Parrots may also damage human facilities. Some parakeet species maintain nests throughout the year: preference of MPs for electrical utility structures (transmission lines, distribution lines and substations) as nesting substrate is one of the main and less known problems caused by this parakeet in the southern USA (e.g. Florida: Avery et al. 2002). Wet sticks and branches may trigger short circuits and electrical fires, resulting in power outages. It has been estimated that more than 1000 power failures were caused by MPs in 2001, at a cost of ca $ 585,000 (restoration and equipment damages included: Avery et al. 2006). Similarly, in France, *Agapornis fischeri* dissects the wires of lamps to use them for nesting purposes: though never quantified, economic damage may be currently limited, as the population of this alien species is still small (Dubois 2007). Airports are often used by birds as roosting areas (Allan 2000; Mallord et al. 2007; Soldatini et al. 2010); birdstrikes (bird-aircraft collisions) may cause high economic losses (Soldatini et al. 2010). Most parrot colonies located in the surroundings of airports never cause problems (e.g. Montemaggiori 1998; Chapman 2005), although three birdstrikes involved RRPs in Heathrow Airport (UK, in 2004 and 2005), with an average cost of ca £ 20,000 each (Fletcher & Askew 2007). An involvement of parrot calls in generating noise pollution has been suggested for MPs (Stafford 2003; Parrot et al. 2008) and for *Trichoglossus haematodus* (Chapman 2005). Both these species are rowdy and continuously vocal when in flight, thus causing a constant nuisance in the surroundings of resting and breeding sites (e.g. residential areas, urban parks: Stafford 2003; Chapman 2005).

Many knowledge gaps still remain also in this context and future research is necessarily urgent. Camera trap projects and closed-circuit television systems in the surroundings of the fields may show which species mainly cause crop damages, thus providing a quantification of the economic loss. Spatial distribution models could be used to assess where a population may increase and where damages to human activities and facilities may thus occur, following the methods proposed by Di Febbraro et al. (2013). Prevention strategies would represent the most cost-effective technique to limit economic losses (cf. Genovesi & Shine 2004).

Transmission of diseases and zoonoses

Parrots are reservoirs of a plethora of bacterial and viral diseases (Gismondi 1991; Fletcher & Askew 2007; Runde et al. 2007). Thus, free-ranging alien populations may threaten the fitness of native wild species, as well as aviculture and human health. Pathologies are transmitted by direct contact with infected birds (handling of plumage and tissues), contaminated equipment, droppings and aerosols of the secretions (through nostrils, mouth and eyes: Gismondi 1991). Other possible sources of exposure are mouth-to-beak contact and bites from infected birds (GISMONDI 1991). Newcastle Disease (NCD, caused by a *Paramyxovirus*), presents with acute performances and a high mortality, and may affect wild bird communities, avian pet trade and poultry industries (NELSON et al. 1952; FITZWATER 1988). Movements of people, animals and vehicles help the spread of the infection from farm to farm. MP has a great potential for the dissemination of this pathology (NELSON et al. 1952; FITZWATER 1988; BUTLER 2003). Other diseases transmitted by parrots to other birds include avian malaria, avian pox, erysipelas and pasteurellosis (GISMONDI 1991; RUNDE et al. 2007). Psittacine beak and feather disease (PBFD) is a potentially fatal, infectious viral disease caused by the "Beak and Feather Disease Virus" (BFDV): this pathology, native to Australia (DE KLOET & DE KLOET 2004; CHAPMAN 2005), is of great concern in countries where introduced parrots come into contact with autochthonous Psittaciformes (HA et al. 2007). Diseases provoked by RRPs may harm the indigenous Vasa parrot *Coracopsis nigra* in Mahé Island (Seychelles: FANCHETTE 2012). In New Zealand, this virus was first detected after the introduction of *Platycercus exymius* and *Cacatua galerita,* and may affect the native populations of *Cyanoramphus novaezelandiae* (ORTIZ-CATEDRAL et al. 2009). Introduced parrots live mainly in close associations with humans, thus representing a possible sanitary hazard. Zoonoses include psittacosis (also known as ornithosis or avian chlamydiosis), avian influenza, salmonellosis, pseudotuberculosis and tuberculosis. Both psittacosis and avian influenza are currently of great worry for human health (RUNDE et al. 2007). Psittacosis is a lung infection caused by *Chlamydophila psittaci* and could affect both birds and their owners (GISMONDI 1991; GREGORY & SCHAFFNER 1997; FLETCHER & ASKEW 2007). When bacteria avoid the defense mechanisms of the lungs, an infection process, variable in severity from mild flu-like illness to severe pneumonia, is triggered (GREGORY & SCHAFFNER 1997). *Chlamydophila*-positive parrots may belong to a higher number of species than those in which this pathology has been detected (e.g. HIRAI et al. 1984; MAGNINO & SAMBRI 2005; ECCO et al. 2009; GUZMAN et al. 2010; MADANI et al. 2011: cf. Table 1). Avian influenza, harmful to birds and humans – so greatly concerning worldwide – has been detected in a parrot introduced in the UK from Suriname (FLETCHER & ASKEW 2007). To finish, the first record of nocardiosis, a bilateral necrotizing pectenitis that causes blindness in humans, has been detected in an introduced *Trichoglossus haematodus* in Western Australia (RAIDAL 1997). A global consciousness about disease transmission risks associated with wildlife migration and international trade is currently growing (FEVRE et al. 2006); highly pathogenic avian influenza (subtype H5N1) is globally spreading, thus cross-species transmissions cannot be ruled out (RUNDE et al. 2007). Released parrots can also contract endemic diseases within their introduced ranges and increase their spread (LATITUDE42 2011).

POSITIVE EFFECTS

A few positive aspects linked to the introduction of parrots can be acknowledged. *Amazona oratrix* and *Vini ultramarina* are classified as "Endangered" within their natural distribution ranges (BIRDLIFE INTERNATIONAL 2013), so that breeding populations are to be conserved also outside their natural ranges (e.g. *Amazona oratrix* in Stuttgart: MARTENS et al. 2013). Thus, hybridization between *Amazona oratrix* and the congeneric *A. aestiva* introduced in Southern Germany is a conservation concern: backcrosses with fertile offspring pollute the genetic pool of the Endangered species (MARTENS et al. 2013). Experimental qualitative and quantitative evidence is required

Table 1.

Summary of alien Psittaciformes documented impacts on native ecosystems (– negative effect; + positive effect; 0 neutral effect; † extinct in the introduced range; * not-naturalized species; [1] reservoir of pathologies; [2] noise pollution). For species whose impact is not mentioned in the manuscript, see Lever (1987, 2005) (*Amazona aestiva*, *A. ochrocephala*, *Ara ararauna*, *Cyanoliseus patagonus*); for impacts on native fauna, Hirai et al. (1984) (*Psittacula alexandri*, *Psittacula cyanocephala*); Magnino & Sambri (2005) (*Amazona aestiva*, *Ara* spp., *Aratinga mitrata*, *Cacatua* spp., *Melopsittacus undulatus*, *Nymphicus hollandicus*, *Platycercus elegans*, *Poicephalus senegalus*, *Psittacus erythacus*); Ecco et al. (2009) (*Amazona aestiva*); Guzman et al. (2010) (*Nymphicus hollandicus*); Madani et al. (2011) (*Psittacus erythacus*) for impacts on human life.

Species	Impacts on native fauna		Impacts on native flora	Impacts on human life	
	Birds	Other species		Economy	Health
Agapornis canus				–	
Agapornis fischeri	–/0			–	
Agapornis personatus	–/0			–	
Amazona aestiva	0 [1]	[1]		–	[1]
Amazona ochrocephala	0				
Amazona oratrix	0/+				
Amazona viridigenalis	0			–	
*Ara ararauna**	–	–			[1]
Aratinga mitrata	– [1]		–	–	[1]
Brotogeris chiriri				–	
Brotogeris versicolurus				–	
Cacatua galerita	[1]		–	–	[1]
Cacatua goffiniana	–/0 [1]			–	[1]
Cacatua moluccensis	[1]				[1]
Cacatua sanguinea	– [1]				[1]
Cacatua sulphurea	[1]				[1]
Cacatua tenuirostris	– [1]				[1]
Cacatua roseicapilla	[1]			–	[1]
Cyanoliseus patagonus	0	–			
Forpus passerinus				–	
Melopsittacus undulatus	–/0/+ [1]			–	[1]
Myiopsitta monachus	–/0/+ [1]	+	–	– [2]	– [1]
Nandayus nenday				–	
*Nymphicus hollandicus**	+ [1]				[1]
Platycercus elegans	–/0/+ [1]			–	[1]
Platycercus exymius	–/0/+ [1]				[1]
Poicephalus senegalus	[1]				[1]
*Polytelis swainsonii**		–			

(*Continued*)

Table 1.

(*Continued*)

Species	Impacts on native fauna		Impacts on native flora	Impacts on human life	
	Birds	Other species		Economy	Health
Psittacula alexandri	–/0 [1]	0	–	–	[1]
Psittacula cyanocephala	[1]				[1]
Psittacus erythacus	[1]				[1]
Psittacula eupatria	0			–	
Psittacula krameri	–/0/+ [1]	–/+	–	–	[1]
Pyrrhura leucotis†					
Trichoglossus haematodus	–/0/+	–		– [2]	–
Vini ultramarina	+				

to support the hypothesis that parrots reduce the impact of some invasive predators on native fauna (e.g. predation on RRPs by grey squirrel in the UK: Shwartz et al. 2009; on MPs by rats in Italy: Scortecci 1953; on *Melopsittacus undulatus* by domestic cats in Florida: Lever 1987). Conversely, the fact that some invasive predators may prey on alien parrots may supply invasive predator populations with another means of sustenance, thus contributing to maintain them. The chasing behaviour of *Trichoglossus haematodus* is suggested to reduce the breeding success of the invasive *Acridotheres tristis* in Western Australia (Chapman 2005). *Platycercus exymius* and *P. elegans* introduced in New Zealand are considered efficient predators of a destructive fly species, *Calliphora laemica*, perpetrator of flystrike on sheeps (Lever 1994). To finish, enlargement of cavities by parakeets is suggested to increase breeding chances of native species, e.g. *Columba oenas* (Czajka et al. 2011).

ERADICATION

Eradication, as well as numerical control of alien/invasive species, is an expensive procedure; preventing introductions and early detection of new invasions are preferable strategies (Genovesi & Shine 2004). Lethal control against feral/escaped pets is unpopular and may result in public protests (Avery & Tillman 2005): common people enjoy the sight of bright parrots flying in courtyards or urban parks (Lever 1987; Spreyer 1994; Polkanov & Greene 2000). For this reason, some eradication programs against alien Psittaciformes have been started and interrupted several times in North America and Oceanic islands, thus allowing populations to rapidly grow up (Lever 1987; Van Bael & Pruett-Jones 1996; Avery & Tillman 2005). Strategies to prevent new escapes and establishments of self-maintaining populations in New Zealand included public education and breeding controls in aviaries (Chapman 2005). Modifications addressed to infrastructures as well as nest removals, as possible mechanisms to reduce damages to electric facilities (e.g. by MP in Florida Tillman et al. 2004; Avery et al. 2006) are expensive operations ($ 1.3 to 4.7 million between

2003 and 2007). Removing nest substrates is ineffective in the long term, as parrots may change preferred breeding sites according to their availability within a territory (Lever 1994; Van Bael & Pruett-Jones 1996). Application of chemosterilants to reduce fitness has been considered, but no data on the effectiveness of this technique are available yet (Avery et al. 2008).

Eradication of small populations is still possible, but requires logistically and economically intense efforts. Strict controls are necessary to prevent future invasions; monitoring population increases within adaptive management programs (Elzinga et al. 2001) is highly recommended (Genovesi & Shine 2004).

DISCUSSION

At least 62 of 355 Psittaciformes species of the world have established one or more breeding populations outside their natural distribution ranges: three of them (i.e. *Glossopsitta concinna*, *Pyrrhura leucotis* and *Vini peruviana*) went extinct after being naturalized (Lever 1987, 2005).

The success of Psittaciformes as invaders may be due to their high synanthropy, to the low predation risk within introduced ranges and/or to their ability to exploit many anthropogenic resources (Butler 2003). Poaching is poorly documented, with few exceptions (e.g. MP in Central Italy: Mori et al. 2013a; RRP in Syria and Iraq: Cramp & Simmons 1980; Cramp 1985). The greatest part of the recorded impacts on native biodiversity and human wellness (79.20%) are exerted by the most widely introduced species, RRP and MP: a higher propagule pressure may reflect a more detailed knowledge of possible impacts, with respect to other introduced Psittaciformes. Negative impacts represent the majority of documented data (71.20%), 18.33% reporting a neutral coexistence with indigenous species, and only 10.47% describing positive effects. Despite the high number of native species breeding in natural or artificial cavities, exploitation of this resource by introduced parakeets seems to affect only one European bird, the nuthatch *Sitta europaea* (Strubbe et al. 2010). Aggressions against indigenous species may be limited by the fact that parrots are more distributed in urban parks, where nest-boxes may be supplied by man and wild species richness is low, rather than in rural/forested areas. Impacts on other animal species (e.g. arboreal mammals, insects) are haphazardly described (e.g. Mori et al. 2013b), and not statistically supported. Parrots are indicted to possibly inhibit native flora seed dispersal and alter the floral herbaceous component under roosting sites with droppings (Fletcher & Askew 2007), as well as to favour the spread of invasive weeds in native environments (Runde et al. 2007).

Detrimental effects on electrical infrastructures by breeding MPs have affected the US economy since the start of the 2000s (Avery et al. 2002). Furthermore, birdstrikes result in high costs in terms of both human and economic losses, although rarely involving parrots (e.g. Fletcher & Askew 2007). Parrots are not yet included among the species causing the heaviest agriculture damages in Europe (Cramp & Simmons 1980), but cross-border monitoring programs (Elzinga et al. 2001) are highly recommended, to prevent economic losses (cf. Mott 1973; Stafford 2003). Prevention of crop damages by birds covers a variety of strategies (e.g. Conover 2002; Gorreri et al. 2008): repellents (e.g. reflecting ribbons, gas exploders) have proven to be the optimum in limiting depredation by RRP in orchards, as well as in maize/sunflower cultivations within the native range (Khan et al. 2011; Ahmad et al. 2012b). Given that parrots are mainly released in proximity to human settlements, possible range expansions of

Table 2.

Synthesis of the negative interactions (*S* = speculative, *D* = descriptive and *E* = experimental) between introduced parrots and native species.

Affected native species	Introduced parrot species												References
	Agapornis fischeri	*Agapornis personatus*	*Aratinga mitrata*	*Cacatua goffiniana*	*Cacatua sanguinea*	*Cacatua tenuirostris*	*Melopsittacus undulatus*	*Myiopsitta monachus*	*Polytelis swainsonii*	*Platycercus elegans*	*Psittacula krameri*	*Trichoglossus haematodus*	
Birds													
Acridotheres tristis												D	Chapman (2005)
Anous minutus			D										Runde et al. (2007)
Anthochaera carunculata												D	Chapman (2005)
Anthochaera chrysoptera												D	Chapman (2005)
Anthracoceros albirostris				D									Peh (2010); Lin Neo (2012)
Athene noctua											D		Dubois (2007)
Columba livia								D			D		Cramp & Simmons (1980); Batllori & Nos (1985); Dangoisse (2009)
Columba oenas											D		Dubois (2007)
Corvus cornix											D		Cramp (1985)
Cyanocitta cristata								D					Long (1981)
Cypsiurus parvus	D	D											Lever (1994)
Falco tinnunculus								D			D		Cramp (1985); Dubois (2007); Dangoisse (2009)

Manorina spp.							D	Chapman (2005)
Parus major						D		Cramp (1985)
Passer domesticus	D			D	D	D		Long (1981); Lever (1994); Dubois (2007); Shwartz et al. (2009)
Phylidonyris novaehollandiae							D	Chapman (2005)
Progne subis				D				Lever (1994)
Pterodroma spp.		D						Runde et al. (2007)
Puffinus spp.		D						Runde et al. (2007)
Sitta europaea						E		Strubbe et al. (2010)
Strepera graculina							D	Chapman (2005)
Sturnus vulgaris						E		Czajka et al. (2011)
Treron vernans			D					Lin Neo (2012)
Turdus merula					D			Weiserb & Jacob (1999); Batllori & Nos (1985)
Turdus migratorius					D			Long (1981)
Zenaida macroura				D				Lever (1994)

(*Continued*)

Table 2.

(*Continued*)

Affected native species	Introduced parrot species												References
	Agapornis fischeri	*Agapornis personatus*	*Aratinga mitrata*	*Cacatua goffiniana*	*Cacatua sanguinea*	*Cacatua tenuirostris*	*Melopsittacus undulatus*	*Myiopsitta monachus*	*Polytelis swainsonii*	*Platycercus elegans*	*Psittacula krameri*	*Trichoglossus haematodus*	
Unidentified heron											S		Dubois (2007)
Unidentified seagull											S		Dubois (2007)
Other indigenous parrots				D	D	D				D	D/S	D	Jones (1980); Lever (1994); Nebot (1999); Chapman (2005); Hockey et al. (2005); Lever (2005); Latitude42 (2011); Fanchette (2012); Lin Neo (2012)
Mammals													
Chalinolobus gouldii												S	Start (1998)
Elyiomis quercinus												S	Gebhardt (1996)
Glis glis												S	Gebhardt (1996)
Myotis spp.												S	Gebhardt (1996)
Sciurus vulgaris									D		D/S		Japiot (2005); Mori et al. (2013b)
Insects													
Apis mellifera											D	D	Chapman (2005); M. Braun pers. comm. (2012)

species characterized by limited dispersal abilities (e.g. MP) would result in an increase of damages to electrical facilities, while those with a high dispersal attitude (e.g. RRP) may become crop pests (DEL HOYO et al. 1997).

Currently, available data about impacts of introduced Psittaciformes on native biocoenoses are scanty and related to half the breeding species (and to two non-breeding species; cf. Table 1). Useful information for this review has been taken from only 78 out of 149 (52.4%) analysed papers about alien parrots. It may be due to the low number of individuals of each population (e.g. NEBOT 1999; ANDERSON & BALDOCK 2001; EGUCHI & AMANO 2004), to the short time passed since first releases and, possibly, to the emotional affiliation that links mankind to these bright birds. Evidence that non-native psittacids are causing massive ecological or economic damage is not yet compelling, although competition with individuals of native species is documented. However, no proof linking this competition with declines of native species has ever been shown: parrot populations may not yet be large enough to cause noticeable declines. Given that parrots have belonged to national fauna for only a few years in many countries, misidentifications of species responsible for crop damages may occur. The majority of the information available on the impact of introduced Psittaciformes on native species results from descriptive and speculative, sometimes haphazard, data (cf. Table 2), while a very few quantitative and experimental studies have been carried out (e.g. STRUBBE et al. 2010; ORCHAN et al. 2012). This prevented us from performing further statistical analyses, currently used to assess potential impacts of invasive alien species (cf. MCCARTHY et al. 2006; WARD & RICCIARDI 2007; VILÀ et al. 2011; NAGAKAWA & SANTOS 2012), to avoid misinterpretations or misleading outputs. Further quantitative research is needed and strongly recommended to better understand this issue and to address suitable management actions.

The conception of wildlife as a contentious issue between biologists (e.g. ecologists, conservation biologists, zoologists) and stakeholders (e.g. citizens residing in urban/rural areas, hunters, environmentalists) is increasing worldwide. We propose to model the potential distribution of both breeding and non-breeding introduced parrot species, projecting outputs throughout the world for medium and long periods (e.g. NORI et al. 2011; DI FEBBRARO et al. 2013), to forecast future invasion sites as well as to prevent possible impacts. Statewide controls, permanent individual markings or importation bans of invasive parrots as pets would be important measures to control population increases of these alien species, as well as to limit disease spread (SHELGREN et al. 1975; CAMPBELL 2000; STAFFORD 2003).

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