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The role of regulatory decision-making on non-indigenous species introductions

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Abstract Introduction is a critical stage in vertebrates' invasion process; once imported, they have a high probability of establishment and spread. While there is a consensus that trade is a primary conduit for non-indigenous species (NIS) introductions, and a key locus for preventive regulation, few policies have been evaluated by scientists for effectiveness. A science-based quantitative assessment of regulatory performance could significantly decrease invasion risk. We carried out a quantitative analysis of data on importation permits of terrestrial vertebrates and the reporting system, using the Israeli regulatory system as a model. This regulatory system is based on long-established wildlife protection legislation, now being used to control NIS vertebrates, much as is the case in many other countries. Ecological risk assessment for NIS was sometimes carried out, but it is not mandatory within the regulatory process, and no legally-binding criteria for assessment exist. We found a significant decrease in number of permits issued over the years, but this decrease does not reflect perception of ecological risk. We found permit quotas of much wider volumes than those actually used, indicating that trade volumes are dictated by retailers rather than by regulators. Actual imports are frequently not reported, hindering efforts to assess propagule pressure and to monitor and analyze effects of introductions. We conclude that the regulatory system should be more science-based, that the import database should be formulated to allow future ecological research and mitigation, and that legally-binding ecological risk assessment would contribute significantly to the strength of NIS regulation.

Keywords Nonindigenous species · Regulatory performance · Science-based decision-making · Terrestrial vertebrates · Import permits system

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Introduction

While many invasive species have arrived as stowaways in agricultural products (Cowie and Robinson 2003), in ballast waters (Drake et al. 2005), or have otherwise arrived uninvited to their new ranges, other species, in particular vertebrates, have invaded after undergoing legal proceedings of importation (Kraus 2003; Semmens et al. 2004). Control of the former is complex and often costly; control of the latter could be fairly straightforward with proper regulatory

measures. Therefore, conservation biologists often demand that decision-makers reconsider permissive trade regulations in light of their ecological costs (Reichard 2005; Simberloff 2005). Most debates on this topic, however, remain theoretical and are rarely translated into practice (Bossenbroek et al. 2005). While there is a consensus that trade is a primary conduit for non-indigenous species (NIS) introductions, and a key locus for preventive regulation (Levine and D'Antonio 2003; Shine et al. 2005; GISP 2008), few policies have been evaluated by scientists for effectiveness.

Ecologists usually ignore the role of the regulatory process unless they are dealing with specific problematic species; this is in spite of the fact that the seemingly banal operational bureaucracy involved in implementing importation policies is a critical component of an effective strategy to address the NIS problem successfully. It has been argued that the stricter the regulatory process, the greater the probability of successful control of trade volumes of NIS (Shine 2000; Miller 2004), but this assertion remains largely untested. Although scientists have indicated that the risks from lack of proper regulation are expected to be high (Simberloff 2005) and several studies have indeed identified loose regulation and importation policies as facilitating introduction (Semmens et al. 2004; Křivánek et al. 2006; Miller and Fabian 2004), none carried out a systematic quantitative analysis of the regulatory process.

We studied the performance of regulatory decision-making on NIS in Israel by carrying out a quantitative analysis of the governmental authority's import permit database. Although such databases have previously been used in other conservation contexts (Kentula 1992; Schlaepfer et al. 2005), permit systems' capacity to serve as a conservation tool has been underestimated and is generally unexplored in the context of NIS. This paper focuses on the permits system because of the key role that it plays in controlling the introduction of exotic species. Of course there are other regulatory measures such as quarantine measures, fines, licensing, rules for possessing or owning animals and others, but these are not explored in the current paper.

The import permits system is a critical stage in regulating trade volumes of NIS (Lodge et al. 2006); it is the first and often last screening of NIS before their release into the market. Trade volumes were identified in previous studies as strong predictors of propagule pressure, a significant factor in invasion success (Williamson and Fitter 1996; Cassey et al. 2004; Lockwood et al. 2005). Consequently trade volumes can serve as an efficient tool for assessing the performance of regulatory decision-making in minimizing risky NIS introductions. Organizing permits data and analyzing them has several benefits: it provides accessible factual records in terms of trade volumes; it allows us to test the need for regulatory reform; it may assist in predicting invasion risks, particularly of species that are imported repeatedly; and it can serve as a conservation tool when employed by relevant authorities in the daily management of wildlife trade.

Our study focuses on terrestrial vertebrates, since many known cases of ecological damage were caused by their deliberate introduction (Long 1981; Lever 2003). Specifically in Israel many established and invasive non-indigenous terrestrial vertebrate species have been deliberately brought into the country, many if not all with legal permits, and were subsequently released from or escaped captivity. The rose-ringed parakeet (*Psittacula krameri*), Indian palm squirrel (*Funambulus pennati*), red-eared slider (*Trachemys scripta elegans*), and nutria (*Myocastor coypus*) are only a few examples (Roll et al. 2008).

In Israel, demand for terrestrial vertebrates usually comes from retailers, zoos, and research institutions. Although ecological research on biological invasions in Israel has recently expanded (e.g., Roll et al. 2007a, b, 2008, 2009) with some focus on terrestrial vertebrates (Shwartz et al. 2008, 2009), there is still a lack of coherent policy on deliberate introductions of NIS. The legal framework suffers from weaknesses common to other countries, i.e. its current scope does not specifically address NIS that could be harmful to native biodiversity but are not known to present risks to commercial and agricultural production systems (see also Miller and Fabian 2004). One governmental agency—the Israel Nature and Parks Authority (INPA)—regulates terrestrial vertebrate NIS using existing statutes that govern wildlife protection in general. In other words, currently, there are no specific requirements for NIS (unlike other concerns such as endangered species). Consequently, their importation is subjected to INPA full discretion. The same situation prevails in many countries where there is no specific legislation to address invasive species.

In the US, for example, there is a further effort to address the importation of potential invaders at the federal level in the proposed legislation "To prevent the introduction and establishment of nonnative wildlife species that negatively impact the economy, environment, or other animal species' or human health, and for other purposes" (H.R. 669: "Nonnative Wildlife Invasion Prevention Act").

Hence, the Israeli import system on terrestrial vertebrates offers a useful and apparently typical case-study for assessing the current ability of regulatory systems to meet conservation needs. Trade volumes are dictated worldwide to a great extent by consumer demands, so that much of what is discussed in the Israeli context is relevant elsewhere.

Our goal was to test whether the current vertebrate permits system is adequate to meet the challenges of the invasive species arena, and whether stronger legally binding measures are required. We also evaluated the potential use of permits and retailers' reports as a conservation tool.

Methods

We analyzed the INPA computer database records of import permits issued in Israel between 2001 and 2006 for the four terrestrial vertebrate classes: amphibians, reptiles, birds, and mammals. Earlier data were not considered owing to insufficient documentation. Import of terrestrial vertebrates in Israel is managed exclusively by the INPA under the Wildlife Protection Law, 1955. Data were obtained under Israel's Freedom of Information Act 1998.

The INPA database contains 1,771 records for the years 2001–2006 (the database was accessed on March 2007). The database included four records of fish species, and what we considered an innocuous import—a stuffed animal! These were promptly removed. Each record refers to the total number of permits issued for one species for one year. Both indigenous and non-indigenous species are included in this count, with no indication of their status. We considered a species indigenous if it has a native occurrence in Israel, according to Israeli faunal checklists (Amitai and Bouskila 2001; Svensson 2003; Mendelssohn and Yom-Tov 1999). Accidental and introduced bird species were not considered native.

Each record in the INPA database is comprised of the following: (1) binomial scientific name (in three cases, the record was identified only by genus); (2) common name; (3) class affiliation; (4) ecological-risk code, i.e. True (perceived ecological risk) or False (no perceived ecological risk) (5) number of permits issued for this species per year; (6) reference to Ecological Risk Assessment (ERA), if any; (7) "Requested" refers to the number of individuals permitted for each species; (8) "Imported" refers to the number of individuals reported by retailers as actually imported for each species. The latter information did not exist for all records.

For our quantitative analyses we took the INPA risk classification (True/False) as a given, as we were primarily interested in examining regulatory decision-making according to established criteria. Nevertheless, we also searched the Web of Science database (1965–2009) using common and scientific species name and using the keywords invasion, invasive, alien, exotic, non indigenous, introduced, introduction, foreign, non-native, and invasiveness to get a better sense of the species pool that appears in either risk category.

First, we examined the process of granting permits through several basic questions: (1) how many species of those permitted were NIS? (2) how many of the permit-issued species and individuals were considered by INPA as posing a 'true' ecological risk? (3) are there any trends in the number of permits issued per year over the years? And if so, can this trend be linked to ecological considerations? Then, in order to gain a better picture of the presence of NIS terrestrial vertebrates in Israel, we studied trade levels using two further questions referring to the import reporting process: (4) how many individuals of those permitted from each taxon were actually imported? (5) Which of the taxa were reported by retailers to the INPA more frequently than others? These questions were specifically chosen to investigate shortcomings of the regulatory decision-making process and possible lack of control over NIS introductions.

Data were analyzed using SPSS 14.0 statistical software. It should be noted that the INPA database does not state whether the importation was permitted for commerce, scientific research, education etc. Nonetheless, about 52% of our database was specified as CITES-2 species (species used for commercial purposes) so we speculate that the requests were

permitted for the pet trade, zoos, and various other commercial or recreational purposes.

Raw data are available upon request from the first author.

Results

Unless otherwise stated, our results refer first to all data accumulated and then we analyze data stratified according to ecological risk.

NIS constituted a large fraction (98.75%) of all terrestrial vertebrates permitted: our database of 1,766 records included 1,744 records on NIS (626 species in all), whereas only 22 records (16 species) existed for indigenous species (Table 1). The majority of NIS records belong to birds (58.4%), while mammals are dominant among the indigenous species (72.7%) (Pearson Chi-Square test; $\chi^2 = 64.89$, $df = 3$, $P < 0.001$) (e.g., wolves [*Canis lupus*], sand cats [*Felis margarita*], honey badger [*Mellivora capensis*]).

Of a total of 626 NIS, most NIS permitted were birds and reptiles, at a total of 540 NIS (358 and 182, respectively). 562 NIS were categorized as 'False'—non risk potential, while 64 NIS were categorized as 'True'—risk potential. Of the latter group, about 45% of the species were reptiles (29), and about 23% were amphibians (15). In all classes except for amphibians, species that do not pose ecological risk according to INPA classification (False) dominated the number of NIS permitted (Fig. 1).

A higher rate of 'True' risk code permit records belonged to amphibians and reptiles (about 70% of total risk-code records) than to mammals and birds (about 30%) (Pearson Chi-Square test; $\chi^2 = 232.9$, $df = 3$, $P < 0.001$).

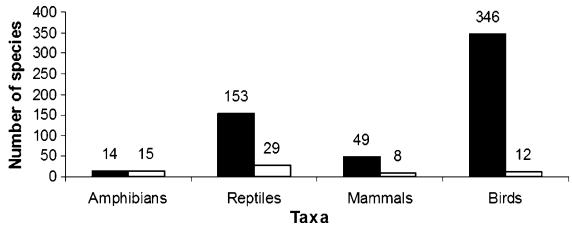


Fig. 1 Numbers of permitted ecological risk ('True', marked white) and non-ecological risk ('False', marked black) NIS by Taxa (2001–2006)

We found significant differences in the proportions of 'True' ecological risk NIS permitted within different taxa and the proportion of 'True' ecological risk permitted within the entire NIS group ($\chi^2 = 80.2$, $P = 2.78\text{E-}17$). Three classes showed significant differences when the two ecological risk categories were compared to each other within taxa (Yates corrected χ^2 goodness of fit test). A higher proportion of NIS from the amphibians and reptiles permitted were classified as 'True', compared to the percentage of 'True' cases from all taxa taken together ($\chi^2 = 52.42$, $P = 4.49\text{E-}13$; $\chi^2 = 8.26$, $P = 0.004$). Within birds, the proportion of 'True' classified NIS was lower than that of 'True' NIS when all taxa were aggregated ($\chi^2 = 41.29$, $P = 1.31\text{E-}10$).

We found that about 32% of our database (576 records; 96 species) are of permits issued in high frequencies, meaning permits issued for the same species each year (2001–2006) (henceforth category VI). Permits issued in five out of the six years (2001–2005) contributed an additional 15% to the database (270 records; 54 species) (henceforth category V). These records (846 in total; 47%) refer to NIS only. Two NIS categorized as posing 'True' ecological risk were issued permits at categories V and VI,

Table 1 Records on non-indigenous species (NIS) and indigenous species permitted per taxon by the Israeli Nature and Parks Authority during 2001–2006

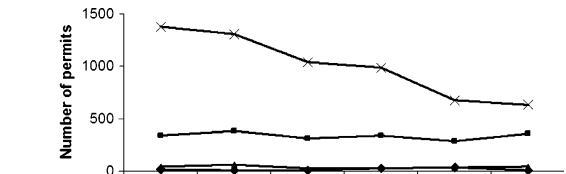
		Amphibians	Reptiles	Mammals	Birds	Total
NIS	Number	65	558	103	1,018	1,744
	% within NIS	3.7	32	5.9	58.4	100
	% within class	100	99.8	86.6	99.5	98.8
Indigenous	Number	0	1	16	5	22
	% within indigenous	0	4.5	72.7	22.7	100
	% within class	0	0.2	13.4	0.5	1.2
Total	Number	65	559	119	1,023	1,766
	% within total	3.7	31.7	6.7	57.9	100
	% within class	100	100	100	100	100

respectively: Aldabra giant tortoise (*Geochelone gigantean*) (reptiles) and African clawed toad (*Xenopus laevis*) (amphibians). However, an additional 31 NIS currently categorized as posing no ecological risk ('False') but recommended for status adjustment following ERAs (see below) were also imported frequently.

We calculated the number of individuals permitted from each taxon, considering ecological-risk ('True') and non-ecological risk ('False') species separately. Of all 'True' individuals permitted, 27,601 in total, 85% were birds and 12.5% amphibians. Except for 77 individuals (of 5 species), all 'True' individuals were NIS. The number of permitted 'False' individuals was much higher: of all 1,500,597 individuals permitted (both NIS and indigenous), 91% were birds, 5.6% reptiles, 3.3% mammals, and the remainder amphibians (<1%). Of all individuals, only 192 (of 11 species) were of species indigenous to Israel.

While the regression between number of permits and year in which they were issued was significant and negative for birds ($r = -0.98$; $r^2 = 0.96$; $P < 0.001$), regressions for other taxa were all insignificant (mammals: $r = -0.31$; $r^2 = 0.1$; $P = 0.53$. reptiles: $r = -0.23$; $r^2 = 0.05$; $P = 0.65$. amphibians: $r = 0.11$; $r^2 = 0.01$; $P = 0.83$) (Fig. 2).

Pooling all classes together we found a significant negative regression between the fraction of permits issued (for both risk categories, True/False) and the period examined ($r = -0.95$; $r^2 = 0.92$; $P = 0.002$), suggesting that INPA issues decreasing numbers of permits for NIS (Fig. 3). For each year we divided the number of permits issued for 'True' risk species, by the sum total number of permits issued for the risk species for the entire duration of our study (6 years). We conducted the same analysis for non risk species



Year	2001	2002	2003	2004	2005	2006
Amphibians	21	12	10	27	38	7
Reptiles	335	385	313	341	285	359
Mammals	40	64	31	30	32	44
Birds	1373	1302	1040	984	677	632

Fig. 2 Total number of permits issued for each taxon during the years 2001–2006

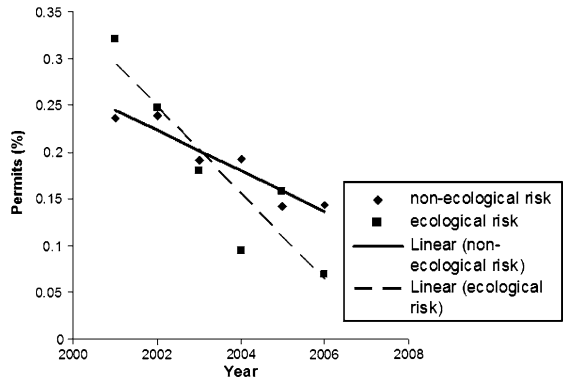


Fig. 3 Percentage of permits (of total number of permits for each risk category) for ecological risk ('True') and non-ecological risk ('False') species by year (2001–2006)

(False). We found: (a) non-risk NIS were also permitted in decreasing numbers throughout the years. The fraction of permits granted to this group was significantly and negatively correlated with the year in which they were issued ($r = -0.96$; $r^2 = 0.92$; $P = 0.003$); (b) similarly, the fraction of permits granted to risk NIS was significantly negatively correlated with the period examined ($r = -0.92$; $r^2 = 0.85$; $P = 0.009$).

A test of homogeneity of slopes, indicated no significant differences between the regression slopes of the two different ecological risk groups ($F_{1,6} = 0.01$; $P = 0.999$). This result suggests that no relationship exists between ecological risk and the number of permits issued over the years.

105 ERAs were conducted by INPA (birds—67; reptiles—33; amphibian—1; mammals—4). Of a total of 64 NIS categorized by INPA as posing ecological risk (True), 13 NIS underwent a procedure of ERA. Results of these ERAs confirmed their status as posing a potential threat to native species and ecosystems.

However, 65% (58) of ERAs carried out on NIS formerly categorized as non-ecological risk (False) (49 bird species, 9 reptiles) revealed their potential ecological risk. We assume that the re-assessed species were not chosen randomly. Nevertheless, it is of concern that the status of these NIS as 'non-ecological risk' has not yet been changed in the INPA database. Among these NIS were two avian species already known to be invasive in Israel: *Psittacula k. krameri* and *Agapornis personata* (Hatzofe and Nemzov 2004; Svensson 2003), as well as species

known as naturalized/invaders worldwide, for example, masked lovebird (*Agapornis personata*) (5,990 individuals permitted) corn snake (*Elaphe guttata guttata*) (*3,405*), brown anole (*Anolis sagrei*) (*2,000*), *and* pine snake (*Pituophis melanoleucus*) (*1,132*),

Previous results refer to the number of NIS permitted but do not disclose data on actual importation of NIS. Several tests were used to examine this aspect of NIS introduction, evaluating the efficiency of the reporting system to track NIS down once permitted, and indicating which of the classes should be more closely surveyed.

We calculated the number of reported permit records out of the total number of permits issued, first for our database as a whole and then for each taxon (including permits issued for indigenous species). We found a reporting rate of 66% for the entire database (birds—69%; reptiles—65%; mammals—60%; amphibians—49%).

Table 2 depicts the number of records on imported species as well as imported-out-of-requested (and permitted) individuals by categories of ecological risk within each taxon. All documented records were considered, including reports of 'zero'. One half of the existing reported permit records (1,167) were reports of 'zero' imports (52%), that is, permits that remained unexploited, with similar reporting rates for both categories of ecological risk.

We compared imported-out-of-requested (and permitted) ratios for each of the four taxa, finding a significant difference (one-way ANOVA; $F = 67.32$; $df = 3$; $P < 0.001$; Tukey post-hoc test $P < 0.05$): reptiles and birds had lower imported/requested ratios when compared with mammals and amphibians.

We found a generally high rate of reporting within categories V and VI: 80% (35 species) of repeated permits for reptiles and 87% (43 species) of repeated permits for birds were reported in at least five of the six years. All records refer to non-ecological risk species (False).

For non-ecological risk reptiles and amphibians, one of the six years (2001 and 2005, respectively) accounts for most (62% and 80%, respectively) of the missing reports. 2001 was found to be problematic in the ecological risk NIS category as well, accounting for 50% of the missing reports of amphibians, about 40% of the missing reports of reptiles, and about 71% of the missing reports of birds.

In our entire analysis we took the INPA categories at face value. After all, our goal was to see how useful was the permit system in minimizing the risk of invasive terrestrial vertebrates, as reflected in its database. However, we did conduct a brief survey based upon the Web of Science database, to gain some insight into the conservation status of the imported species worldwide. Of the 64 'True' category, 23 species appear to be CITES listed, so it is possible that some of the risky species are in fact not risky as invaders but as endangered species. Nevertheless, of these 23 species, at least 9 species appear also to have become naturalized or invasive elsewhere e.g. green and black poison dart frog (*Dendrobates auratus*), zebra waxbill (*Amandava subflava*) so the bulk of the database is adequate.

Discussion

Introduction was identified as a critical stage in vertebrates' invasion process. Vertebrates have a low probability of success in reaching a new geographic region but a high potential to establish and spread once they have already arrived there (Jeschke and Strayer 2005). Therefore, a science-based import

Table 2 Number of records on imported species and imported-out-of-requested individuals by categories of ecological risk within each taxon (including reports of 'zero')

		Amphibians	Reptiles	Mammals	Birds
Ecological risk	Reported records	15	29	6	8
	% within risk category records	45	56	50	32
	Imported-out-of-permitted individuals	1,162/3,140	21/401	7/199	1,376/695,411
Non-ecological risk	Reported records	17	334	65	693
	% within risk category records	53	66	61	69
	Imported-out-of-permitted individuals	31/816	11,096/81,224	1,998/29,570	133,741/1,357,682

regulation system and a quantitative assessment of its performance could significantly decrease this risk.

Our study revealed several major flaws in the Israeli trade regulatory decision-making process in evaluating and addressing the potential ecological impact of NIS: the importation of species that are known invasives, some in highly significant numbers, in particular many amphibians and reptiles; no legal requirement or procedures for conducting a formal risk assessment (ERA) (see Justo-Hanani 2006); the retention of 'False' risk status for species for which ERAs suggests otherwise; no clear trend of decline in the importation of high risk species; and inadequate reporting. The minor changes in the trends in this regard (see Figs. 2, 3) suggest that INPA is trying to improve its performance, but that much remains to be done.

A regulatory framework can be a powerful tool for controlling undesirable introductions of NIS (Shine 2000; Miller 2004; Shine et al. 2005). However, a regulatory structure based on vague institutional mandates rather than coherent performance standards produces dissatisfying policy outcomes. Our results identify serious concerns common within regulatory decision-making processes, particularly when conflicts between trade interests and potential ecological outcomes are left to the full discretion of licensing authorities (see also Shine 2000; Miller and Fabian 2004). Except for birds, no class showed a significant trend of decline in permit numbers over the years. No data exist regarding number of permit applications denied out of numbers applied for, so we cannot assess whether there is a reduction in the percentage of permits granted. Indeed the fact that such a record does not exist is a regulatory concern.

That we found no clear reduction of number of species in three of four vertebrate classes permitted suggests that the Israeli regulatory system has not responded to the increase in global awareness of this issue within the study time span. Furthermore, ecological risk was not found to be a significant predictor of regulatory performance in our study (see Fig. 3). In what may be the study's most problematic finding, we found considerable importation of species permitted even after they were already known to be invasive in Israel (see above), as was with other species with known ecological risk potential. For example, there were ongoing imports of American mink (*Mustela vison*), red eared slider (*Trachemys scripta elegans*), Carolina anole (*Anolis carolinensis*), tokay gecko (*Gekko gecko*). Moreover, while many ecological risk assessments (ERAs) were indeed conducted, many more species imported were not subject to ERA. It should be noted that a significant percentage of the 'False' risk species actually have a history of invasiveness in other parts of the world, for example, three reptiles species, Indian/Burmese Python (*Python molurus bivititattus*) (1,485 individuals permitted), *Boa constrictor*(*1,472*), Common tegu (*Tupinambis teguixin*) (399), and it is quite possible that a professional ERA would recommend that they no longer be permitted for importation.

Laws and/or regulatory guidelines serve to promote certain values, contributing to the establishment of societal norms that authorities would otherwise have difficulty enforcing. Success of efforts to address biodiversity threats depends to a large degree on how well scientific knowledge is translated into policy (Rohlf 1991; Chertow and Esty 1997; Drake et al. 2005); this idea should guide the NIS-associated decision-making process. Because terrestrial vertebrates are popular pets and desirable aesthetic subjects, they can easily find their way into the wild. Legally binding requirements for ERAs should therefore be an integral part of regulatory policy for NIS (see also Simberloff 2005), and ecological criteria for ERAs should be specified within legislation. Examples exist in Australia and New Zealand, as well as the State of Minnesota, where ERAs based on ecological criteria have become part of legislation. Consequently, surveillance of NIS movement into these countries is considered to be improved (Christensen 2004; Shine 2000; Miller 2004).

Without reliable reporting and data registration, evaluation of policy priorities and their implementation becomes practically impossible. Moreover, this situation seriously hinders our ability to carry out ecological research to address potential risks and outcomes of current policies. Only 66% of our database contains reports on actual importation. The 'True' risk species' situation is even worse—with only 47% of their records actually reported as imported or not imported. Thus, present procedures fail to generate data that could assist ecologists in dealing with invasion as a potential problem. Ambiguity regarding the very existence of NIS in the market is a serious limitation that arose in previous studies, because reference to market presence or actual introductions is missing from most data

sources (Kraus 2003; Dehnen-Schmutz et al. 2007). Missing or inadequate data severely constrain the ability of governmental authorities to assess the need for preventive and/or monitoring measures. Improving the quality of information regarding NIS distribution has recently been identified as a national priority in European countries, as the identity and exact number of introduced NIS in many cases remain unclear (UNEP and COE 2006).

The recent 'vision and action plan' of the permit system issued by the U.S. Fish and Wildlife Services (USFWS 2002) serves as an example of regulatory action dedicated to scientific and conservation needs. Reporting requirements vary according to permit type; queries, including data tracking, are aimed at accumulating information and thus improving data availability and promoting scientific certainty. These should also be the objectives of regulatory decision-making regarding NIS in Israel and elsewhere. In the INPA regulatory process, inspections aimed at exploring compliance levels with regulation are rare, making data on the actual presence of NIS in the market uncertain and unreliable. Consequently, current data are inadequate for NIS invasion studies and long-term monitoring.

Data on importation purposes and NIS origin are essential for reliable, long-term evaluation of invasion pathways (Ricciardi et al. 2000). Studies of invasion pathways of terrestrial vertebrates identified various trends over time, using these purposes as indicators (Kraus 2003; Jeschke and Strayer 2005). We found no reference within the INPA permit database to these matters. The massive importation of amphibians and reptiles for trade is a significant factor contributing to their establishment (Butterfield et al. 1997; Kraus 2003). We found that reptiles and amphibians dominate the records (70%) of positive ecological risk species permitted with no significant reduction in number of permits over the years (for example, African clawed toad [*Xenopus laevis*]. However, we cannot tell what percentage of permits were granted to research laboratories, for example, and what other permits were granted for the pet trade.

Where retailers' reports were provided, we found a significant difference between the numbers of individuals permitted and the numbers actually imported, implying permit quotas of wider volumes than those actually used, particularly in birds. Possibly large-volume permit-requests are submitted by pet retailers owing, in part, to variation in supply at their countries of origin. These results imply that trade volumes are dictated by retailers rather than by regulators, suggesting that a more effective governmental intervention should be attained by tougher barriers to NIS importation (Shine 2000; Genovesi and Shine 2003).

During the past couple of years, INPA staff has asserted that additional steps are being taken to improve their performance within the current regulatory framework (Nemtzov 2009). Our statistical analysis fails to detect such an improvement and we hope that future studies find it reflected in the permit system database. Be that as it may, the serious lacunae detected in our study (voluntary ERAs, no legally binding framework, inadequate reporting etc.), remain unchanged.

As better policies are sought for controlling undesirable NIS introductions (GISP 2008), data-driven regulation should be a fundamental element in implementing policy on NIS. It is widely accepted that preventing the entry of NIS is the most ecologically sound and cost-effective approach to controlling biological invasions (Mack et al. 2000); still, prevention of entry is hampered in many cases by the lack of a strong regulatory framework (Shine 2000; Genovesi and Shine 2003). Scientists have an important role to play in quantifying regulatory decision-making and analyzing the efficacy of conservation policies, as well as in improving them through the establishment of criteria for effective, science-based regulation.

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