TEXTE 80/2003

ENVIRONMENTAL RESEARCH OF THE FEDERAL MINISTRY OF THE ENVIRONMENT, NATURE CONSERVATION AND NUCLEAR SAFETY

Research Report 201 86 211
UBA-FB 000441e

Economic Impact of the Spread of Alien Species in Germany

by

Dr. Frank Reinhardt
Dipl.-Volkswirt Markus Herle
Dipl.-Biologe Finn Bastiansen
Prof. Dr. Bruno Streit

J.W. Goethe-University Frankfurt/Main
Biological and Computer Sciences Division
Department of Ecology and Evolution

Summary Report

Introduction

This study provides an overview of the annual economic costs arising in Germany from neobiota, in which 20 representative species have been examined in detail. This study thus represents a snapshot of current real annual costs. The accruing annual costs assessed for the whole of Germany are divided into three categories: a) direct economic harm, exemplified by damage caused by alien species; b) ecological damage, necessitating care and protection of endangered native species, ecological communities, and ecosystems; c) costs for control measures to contain aggressively invasive exotic species. Predicted spread of exotic species is also included in this category.

General description

This study of the economic affects of neobiota is the first of its kind in Europe. It is in every way a pioneering effort, and its successes notwithstanding, should be substantiated by further studies. This is especially needed because this study was carried out over a specific and extremely limited period of time. Nevertheless, this investigation covers a broad spectrum of species and problem areas. As recommended by the *European Strategy on Invasive Alien Species* T-PVS (2002) 8, such investigations need to be conceived as multiyear projects, in order to achieve representative surveys, and to enable analyses such as *willingness-to-pay* analysis. These are particularly important for costs ascribed to “ecological damage”, and for species that threaten indigenous flora or fauna. In several instances, costs of measures to combat invasive species were used a minimal estimates. Because of the variable nature of available data, and the variable ecological properties of non-native species, there was no uniform treatment applicable to all alien species. However, this can be viewed as a virtue—undue reliance upon simplifying economic models frequently obscures the reality of biological invaders. If need be, these invasive species can be incorporated into groups with similar biology.

Case studies

Species that are health hazards

Ragweed (*Ambrosia artemisiifolia*) and giant hogweed (*Heracleum mantegazzianum*) were investigated.

Ragweed

Ragweed engenders strong allergies, including allergic asthma. It is still the subject of debate whether this plant is already established in Germany, or whether it is being continually reintroduced (for example, by means of birdseed). What is underestimated, however, is that ragweed has been present in Germany for many years, and its effects may take years to be fully manifest. Ragweed threatens to become much more widespread in the future, particularly if annual average temperatures continue to increase. The amounts provided in the literature for direct and indirect costs associated with ragweed do not include the loss in quality of life due to ragweed induced pathologies (Table 1). Consequently, the figures provided should be viewed as low-end estimates of costs ascribed to ragweed.

Ragweed plays no recognizable role as an agricultural weed; no additional costs could be assigned. Because its occurrence is predominantly in human-influenced regions, no interactions with native species are documented.

Table 1: Summary of annual costs incurred by ragweed infestation in Germany.
Data taken from national and international publications, and medical specialists
Upper and lower limits are taken from the publications. Cost in €.

	Incurred Costs	Upper and Lower Limits	Remarks
allergic asthma	24,500,000.00	16,400,000.00 to 36,100,000.00	annual direct and indirect costs
allergic rhinitis (hay fever)	7,600,000.00	3,400,00.00 to 13,800,00.00	annual direct and indirect costs
ecological damage	none		
eradication costs	none		
Total	**32,100,000.00**	19,800,000.00 to 49,900,000.00	

Giant Hogweed

Hogweed (*Heracleum mantegazzianum*) causes severe burns upon skin contact, and hence highly variable costs. Where overlap occurs with other problem areas, these are enumerated (for example, see Table 8). No quantifiable benefit or use could be shown for these plants (Table 2).

Table 2: Summary of annual costs incurred by giant hogweed infestation in Germany. Numbers are based upon results of several surveys, and extrapolated to obtain nation-wide estimates. Upper and lower limits in public health and municipalities derive from various sources, all other results are low-end estimates. Costs in €.

	Incurred Costs	Upper and Lower Limits	Remarks
public health	1,050,000	309,000 to 1,960,000	annual costs, may show strong regional variation
conservation areas	1,170,000	1,170,000 to ?	lower limit of annual costs
eradication on roadways	2,340,000	2,340,000 to ?	ower limit of annual costs
community eradication	2,100,000	1,200,000 to 3,700,000	annual costs
eradication	53,000		German Rail
eradication in rural districts	5,600,000	5,600,000 to ?	lower limit of annual costs
Total	**12,313,000**	0 to 14,770,000	

Forestry

Red oak (*Quercus rubra*) and black cherry (*Prunus serotina*) were investigated.

Red oak

Red oak is poorly exploited by indigenous fauna, and consequently represents an "ecological desert" to the native biological community. The prospects for red oak eradication in forestry are slim, because the industry would then experience a drop in revenues of some € 716,000. However, should the political will to remove these trees from the landscape prevail, a ban on further planting of this species in forestry would be the most sensible measure. Over the course of a few decades, existing red oak numbers would thus be successively reduced. On the other hand, in some instances active eradication efforts might be necessary in conservation areas. Because these exist in rare and isolated patches, cost assessment for these eradication efforts is omitted.

Black Cherry

The massive presence of black cherry generates deep shade, and inhibits the natural forest succession, and threatens the understory plant community. In the case of black cherry (*Prunus serotina*), control measures could also be foregone. This would entail economic losses for those areas overgrown by black cherry, affecting the long-term yield of spruce. This would however entail "abandonment" of those areas and with them the mandate for sustainable forestry (§ 11 Federal Forestry Regulations), and contravene the goal of forests in a natural state (Federal Conservation Act (§5 (5)). In addition, the value of affected forests for tourism would be significantly reduced (§1, Federal Forestry Regulations). Moreover, black cherry could spread to as yet uninhabited potential habitat, generating additional costs of some € 1.2 billion. In pure economic and commercial terms, the costs of removing black cherry (*Prunus serotina*) are not justifiable, because maintenance of these black cherry stands to harvestable size could minimize losses. However, there is a lack of direct evidence that would indicate whether these measures would lead to the predicted harvest, for example, whether the sandy soil preferred by this species will sustain growth to harvestable size (Table 3).

Table 3: Summary of annual costs arising from average problem areas in Germany containing dense stands of black cherry. Data for projections from soil type, land use, and cost statements from affected forest districts. Upper and lower limits are one standard deviation from mean value. Costs in €.

	Incurred Costs	Lower and Upper Limits	Remarks
direct costs	1,400,000	830,000 to 2,500,000	
costs to conservation areas	3,400,000	1,500,000 to 3,700,000	tree removal
control measures in forestry	20,700,000	13,300,000 to 33,400,000	yearly maintenance
Total	25,500,000	15,630,000 to 39,600,000	

Agriculture

The lesser grain borer (*Rhyzopertha dominica*), Sawtoothed grain beetle (*Oryzaphilus surinamensis*) and the flour moth (*Ephestia kuehniella*) were investigated.

Lesser grain borer and sawtoothed grain beetle

The lesser grain borer is a representative of the superfamily Bostrichoidae, which, in addition to being a pest on starch-containing products, can also cause losses in silviculture and wood products industries. The costs accruing from the latter are not shown. Indirect costs, such as those resulting from product recalls, could only be estimated, because commercial sources would not divulge such information (Table 4).

Table 4: Summary of annual costs arising from saw-toothed grain beetle and lesser grain borer infestations in Germany. Calculations based upon information from BBA-Berlin and BLE, likewise grain production figures for 2001 (BBA-Bonn). Upper and lower limits are one standard deviation from mean value. Costs in €.

	Incurred Costs	Lower and Upper Limits	Remarks
direct costs	8,600,000	3,400,000 to 13,700,000	stock inventory only
indirect costs	6,800,000	4,300,000 to 17,100,000	research, consultation, and recalls
ecological damage	unquantifiable		
control measures	4,000,000	3,500,000 to 4,500,000	stock inventory only
Total	**19,400,000**	11,200,000 to 35,300,000	

Flour moth

The additional costs accruing from flour moth infestations of stored grain and grain products are little known, and could only be estimated in this study. Estimates are conservative, accordingly the resulting amount of € 4.8 million is a minimum estimate, not least because data from losses in private households is entirely lacking. Likewise, commercial data were not forthcoming, because the relevant companies did not want to give the impression that their products could be in contact with storage pests or vermin. Presumably, real costs are much higher than the figures provided here.

Table 5: Summary of annual costs arising from flour moth infestation in Germany. Projections based upon information from exterminators, and data from the Federal Office of Biology (BBA-Berlin) on grain production. Upper and lower limits are estimated, all costs in €.

	Incurred Costs	Lower and Upper Limits	Remarks
direct costs	780,000	780,000 to ?	private households? product recalls?
ecological damage	none		
monitoring	204,000	20,000 to 200,000 ?	in storage facilities
control measures	1,800,000	1,800,000 to 2,300,000 ?	gas treatment
control measures	1,300,000	1,300,000 to 2,000,000 ?	pest strips
control measures	700,000	700,000 to 7,000,000 ?	in private households
Total	**4,784,000**	4,600,000 to 12,280,000	

Fisheries and aquaculture

Muskrat and the American crayfish were investigated.

Muskrat

Damage from muskrat is derived mainly from breached weirs in areas where no trappers are employed. A non-representative survey yielded additional annual expenditures of € 1.6 million in Germany. This estimate is likely a minimum estimate. Meanwhile, employment of muskrat trappers in federal areas would cost over € 16 million. Purely with respect to fisheries and aquaculture, this would be an economically unjustifiable measure. However, because there are also waterways maintenance costs and public health concerns involved, a comprehensive control program could be justified, moreover the eradication of muskrat in Germany is mandated by Recommendation 77 of the Bern Convention (Table 6).

Table 6: Summary of annual costs arising from muskrat in Germany. Data for projections from published sources and results of surveys. Upper and lower limits are 1 standard deviation from mean value. Costs in €.

	Incurred Costs	Lower and Upper Limits	Remarks
waterways maintenance	2,300,000	2,000,000 to 2,500,000	data from 1996 and 1997
commercial fish hatcheries	1,600,000	1,000,000 to 2,700,000	projections based on data from 3 firms
public health concerns	4.600,000	71,000 to 9,100,000	questionable data
control measures	3,300,000	2,900,000 to 3,600,000	fulltime trappers
control measures	47,000	8,600 to 85,800	annual costs for traps
control measures	600,000	45,000 to 680,000	trappers, (Waterways an Shipping)
Totals	**12,447,000**	6,024,600 to 18.665,800	

American crayfish

No current costs could be identified that are unambiguously caused by American crayfish (*Oronectes limosus*), because neither methods to combat infestations, nor the losses to fisheries and aquaculture from crayfish plague (*A. astaci*, carried by the American crayfish) are known. If farming of the European crayfish *A. astacus* should increase in coming years, such losses are to be expected. Breeding and release of farmed crayfish could also suppress or threaten remaining populations of locally adapted European crayfish. Consequently, there is a need for further research to identify those populations, which are operational conservation units, and to place these under protection.

Communities

The chestnut leaf miner moth (*Cameraria ohridella*) and the cause of Dutch elm disease (*Ceratocystis ulmi*) were investigated.

Chestnut leaf miner moth

The chestnut leaf miner moth mainly infests horse chestnut trees, and causes a fall-like loss of foliage. In the five cities investigated, the additional costs associated with removal of debris generated by leaf miner moth infestations run to € 450,000 annually. Extrapolated to the whole of built-up areas in Germany predicts annual expenditure of € 8 million. It should be noted that removal of deadfall is not necessarily indicated as an effective means of control, and until an effective means to control these pests is found, costs are accumulating annually. Should the findings of Thomiczek and Pfister (1997b), and Rau (2000) not be borne out, and horse chestnuts in inhabited regions ultimately die, a loss of an estimated € 10.7 billion would ensue, reckoned as the value of a 30-year old tree at € 7,700, multiplied by the 1.4 million trees extant in Germany.

Dutch elm disease

Following surveys of the five cities of Berlin, Cologne, Munich, Frankfurt am Main, and Darmstadt, the number of elm trees in built-up areas in Germany was reckoned at 16,000. Of these, on average 412 die each year, and need to be removed to prevent a public hazard. Removal and replanting costs total € 4,200, but the worth of a mature tree in an urban setting that has received decades of care is placed at € 7,700 (Balder, 1997). Reckoning solely the cost of removal and replanting, the nationwide costs total € 1.7 million. The lost value of mature trees comes to an additional € 3.2 million. If dead trees were to be replaced with disease-resistant varieties, the value of the new plantings would rise approximately € 160,000, to a total cost of some € 1.9 million.

Table 7: Summary of costs arising from the chestnut leaf-miner moth in Germany. Data from published survey results from 5 major urban centers. Upper and lower limits are 1 standard deviation from mean value. Costs in €.

	Incurred Costs	Lower and Upper Limits	Remarks
litter removal	8,000,000	720,000 to 15,900,00	control measure
fertilizing afflicted trees	11,200,000	9,300,000 to 17,900,000	
Totals	**19,200,000**	10,020,000 to 33,800,000	

In cities, giant hogweed (*Heracleum mantegazzianum*) is targeted for eradication, because of its potential as a public health hazard. These efforts engender annual costs of € 2 million. In addition, in some communities, black cherry, muskrat, and several other neobiotic species are also targeted. However, there are insufficient data available for these.

Table 8: Summary of annual costs arising from selected species in German communities. Costs in €.

	Incurred Costs	Lower and Upper Limits	Remarks
chestnut leaf-miner moth	19,200,000	10,020,000 to 33,800,000	leaf-litter removal and fertilization
giant hogweed	2,100,000	1,200,000 to 3,700,000	control measures
Dutch elm disease	1,700,000	1,200,000 to 4,600,000	removal and replanting
	3,200,000	2,200,000 to 8,400,000	lost value of dead trees
Totals	**26,200,000**	14,620,000 to 50,500,000	

In total, the species described generate direct annual losses to municipalities in Germany of around € 26.2 million. In addition, there is the lost value of over € 3 million, deriving from the long-term care of deceased elm trees. The mortality in elm trees is likely to continue over the next 40 years, and in that time will lead to total losses of some € 191.8 million. A similar situation obtains for chestnut leaf-miner moths, unless a workable means is found to control this insect soon. Until such time, prophylactic fertilization to hinder the damage inflicted by this moth will generate annual costs of € 11 million.

Waterways and rivers

Zebra mussels (*Dreissena polymorpha*) and Japanese knotweed (*Fallopia* sp.) were investigated.

Zebra mussel

The zebra mussel no longer causes any demonstrable costs or losses. It must be noted however, that in the course of its massive proliferation and spread, the native biological communities, especially those of federal waterways, have been permanently affected. The huge costs currently attributed to these neozooans in the United States are not, or are no longer, applicable to Germany. This is primarily due to the fact that measures have already been taken decades ago to accommodate the presence of zebra mussels, in which water intakes for industry and drinking water have been relocated to lower depths. In addition, the numbers of zebra mussels has declined because of interspecific competition with other neozooan taxa.

Japanese knotweed

Japanese knotweed, due to its invasive presence along waterways, causes serious breaches in embankments. In the largest known patches of knotweed (*Fallopia sp.*) in Germany, found in the southwest (Baden-Württemberg), some 460 km of riverbank and canals are infested with knotweed, with between 3 to 100 % of affected bank area inhabited by this plant. In Federal Waterways and related waters, a worker with mowing equipment was necessary to combat knotweed growth. In calender years 1991 and 1992, one-time losses of over DM 20 million resulted from dikes overgrown by knotweed. In this instance, manmade (trapezoidal) embankments were particularly effected. These areas saw the first efforts to institute control measures directed against these plants. By 1999, the costs of embankment restoration/maintenance had dropped to € 330,000. The assumption, that between 5 and 15 % of knotweed stands are monotypic may at first glance seem too high. However, given the rapid vegetative reproduction of this species, these estimates should be seen as conservative. In addition, knotweed can be found along terrestrial roadways. Special handling by Streets and Traffic authorities are ineffective. With respect to railroad tracks, it could be shown that control efforts along just 1% of total track would lead to annual costs of € 2.4 million. In addition, waterways maintenance necessitated by muskrat (*Ondatra zibethicus*, Table 9) probably generate extra costs of more than € 2.3 million.

Table 9: Summary of annual costs arising from selected species in waterways and watercourses in Germany. Costs in €.

	Incurred Costs	Lower and Upper Limits	Remarks
zebra mussel	unquantifiable		suppression of natural communities, species
knotweed	7,000,000	3,500,000 to 10,500,000	embankment repair, annually
	6,200,000	5,900,000 to 6,600,000	control measures, annually
	16,700,000	12,300,000 to 21,200,000	embankment reinforcement, annually
muskrat	2,300,000	2,000,000 to 2,500,000	data from 1996, 1997)
Total	**32,200,000**	23,700,000 to 40,800,000	

Terrestrial Roadways

Narrow-leaved ragweed (*Senecio inaequidens*) and Japanese knotweed (*Fallopia* spp.) were investigated.

Narrow-leaved ragweed

Because narrow-leaved ragweed is not susceptible to the most commonly used herbicide, glyphosphate, this plant causes additional annual expenditures of € 100,000 for control measures along railroad track. However, a survey of streets and traffic authorities in Hesse indicated no additional expenditures attributed to this neophytic species.

In addition to the species already mentioned, giant hogweed also causes increased expense for streets maintenance. A survey of the Hessian streets and traffic authorities that have jurisdiction for federal and state roadways reveals additional annual costs of € 2.3 million attributable to hogweed. It is anticipated that still other additional costs will accrue because of extra mowing along roadsides necessitated by hogweed proliferation. However, no data were available to quantify these costs. Authors' personal observations indicate that hogweed is mowed only once per year, in the course of normal mowing operations. This has no effect upon the incidence or further spread of this neophytic species—to effect control, mowing would need to be undertaken several times per year.

Table 10: Summary of annual costs for roadways in Germany arising from selected species. Costs from German Rail are real expense, and have no upper or lower estimated limits. Upper and lower limits for costs caused by hogweed to German Rail could not be ascertained, and are estimated. Upper and lower limits for knotweed are estimated at one standard deviation from a mean value. Costs in €.

	Incurred Costs	Lower and Upper Limits	Remarks
narrow-leaved ragweed	100,000		around rail installations
butterfly bush	None		
giant hogweed	53,000		only in public access areas
	2,300,000	2,300,000 to ?	along federal and state roadways
knotweed	2,400,000		along rail installations
Totals	**4,853,000**	4,453,000 to 5,153,000	

Endangerment of native species

Dikerogammarus villosus and lupine (*Lupinus polyphyllus*) were investigated.

Dikerogammarus villosus

Dikerogammarus villosus has permeated German federal waterways since the end of the 20th Century, and has largely supplanted the native amphipod fauna. In this instance, willingness to pay analysis would be an appropriate measure of the public's disposition to finance the maintenance of native biological communities. However, such an analysis could not be carried out on the necessary scale for this study. Hampicke (1991) describes this kind of analyses for various animal species. This, students in the USA evinced a willingness to pay between $US 42.50 and 57.00 per person per year to protect humpbacked whales. For minnows, by contrast, the willingness to pay for species protection was given at only $ 4.70 to $ 13.20 annually. In the case of amphipods, willingness to pay would presumably be much lower. If only 1 % of the figures cited for minnows were to be spent, this would correspond to € 0.048 to 0.136 per year per person. Given a population of 81.5 million in Germany, this predicts a willingness to pay € 3.9 to 11 million annually.

Lupine

In the Lange Rhon conservation area, lupine (*Lupinus polyphyllus*) occupies 20 hectares of alpine meadow, and in these patches, suppresses the native populations of arnica (*Arnica montana*), a protected species. Germany-wide, such stands occupy approximately 100 hectares, habitat which would otherwise be suitable for arnica. These patches of habitat (yellow oak-grass and matgrass meadow) are mostly under the care of nature conservation authorities, and are mowed once a year. However, to support growth of oak and mat grasses, these meadows would need an additional annual mowing. Because the clippings resulting from a second mowing would not need to be removed and disposed of, additional costs resulting from a second mowing would only cost € 300/hectare, leading to annual additional costs of € 30,000.

In the case of lupine, it is conceivable that this species could supplant native species in other habitats. More comprehensive measures dealing with these areas would, in the worst-case scenario, necessitate additional costs of € 1.4 million, maximum.

Recommendation 77 (1999) of the 1979 Bern Convention

The American Mink (*Mustela vison*) and bullfrog (*Rana catesbeiana*) were investigated. Recommendation 77 of the Bern Convention mandates eradication of both species in Europe.

Mink

It can be shown that the revenues generated by the sale of mink pelts are in no way sufficient to cover the costs of hiring state employees to trap these animals. This would only be lucrative for the individual who pursues this activity in his spare time. It should be noted that this emphasis upon exploiting the mink to foster its eradication leads to the animals only being trapped in the wintertime. This in turn can in some circumstance lead to a lessening of intraspecific competition, with the net effect of aiding the overall mink population. Consequently, the installation of official trappers is unavoidable, if a total eradication of mink is to be achieved (Table 11).

The costs given here are the current, real costs that accrue annually in Germany. However, should an eradication effort like that envisioned in the Bern Convention actually be undertaken, these costs would rise to at least €12.9 million to 21.5 million, and in the worst case, up to € 43 million. Should the American mink spread to inhabit all of Germany, eradication costs would run from € 49 million to 81.6 million, and € 163 million for the worst-case scenario. These expenditures would also apply to the eradication of muskrat.

Table 11: Summary of annual costs arising from the American mink in Germany. Calculations based upon survey results and published figures. Upper and lower limits are 1 standard deviation from mean value. Costs in €.

	Incurred Costs	Lower and Upper Limits	Remarks
economic losses	minimal		
benefits	- 87,000	- 31,000 to -144,000	revenues from pelts
ecological damage	indeterminate		
control measures	4,300,000	3,800,000 to 4,700,000	wages for mink trappers
	6,400	4,200 to 8,600	trap costs
Totals	**4,200,000**	3,800,000 to 4,600,000	

Bullfrog

Upon its appearance in a new habitat, the bullfrog (*Rana catesbeiana*) supplants all native amphibians. The State Office for the Environment in Karlsruhe pumped out the five bullfrog-infested ponds under their jurisdiction, with the help of 20 volunteers and the fire department, in the process removing all bullfrog adults and larvae. In addition, these ponds were subject to electrofishing. The costs of these measures were assigned as follows: the labor of 20 volunteers, spread over the course of a year, would be equivalent to one full-time employee, hence € 50,000 annually; costs for pumping and electrofishing run to € 500 and € 1,200 per day, respectively. Thus, a total sum of € 53,000 per pond per year, and for all five ponds, and a sum of € 270,000, annually was result.

Table 12: Summary of annual costs arising from control efforts for mink and bullfrog in Germany, as mandated by Guideline 77 of the Bern Convention. Costs in €.

	Incurred Costs	Lower and Upper Limits	
mink	4,200,000	3,800,000 to 4,600,000	control measures
bullfrog	270,000	260,000 to 520,000	control measures
Totals	**4,470,000**	4,060,000 to 5,120,00	

Were it to begin today, a campaign to eradicate mink and bullfrogs would cost at least 4 million euros annually. The duration of this campaign would depend upon its intensity, but would presumably require at least 10 years to complete. For mink, sale of pelts could yield at least € 440,000 in revenues; other uses for this species do not exist. Subject to the spread of the many species that are listed in Recommendation 77, it is anticipated that these costs will greatly increase, if measures are not undertaken expeditiously. If mink spread to all of Germany, the cost of state-employed trappers would rise to over € 16 million, and it is doubtful whether one trapper per district would suffice.

Summary and Outlook

In total, the costs described here for 20 species come to an average of € 167 million annually. Lower and upper estimates are € 100 million and € 265 million, respectively. Table 13 shows the costs in the respective problem areas. Costs for species, which are public health hazards, are especially high. This can be attributed to the generally high costs of health care, and to the relatively complete data set that is available for health-related expenses. In addition, there are large associated expenses for lost work, and mortality, etc. Likewise, high maintenance costs accrue in the area of waterways maintenance, which are mainly due to knotweed, and the embankment breaches these plants cause. Lower costs are encountered in fisheries and aquaculture. It must be assumed that the real costs are higher than those reported here, because the surveys carried out for this study cannot be taken as representative. Moreover, muskrat and American crayfish, two species investigated in this study, cause relatively little damage. Further studies should investigate other aspects pertinent to fisheries and aquaculture. The same holds for terrestrial roadways.

Table 13: Summary of costs, accruing to selected species in Germany in the respective problem areas. Costs in €.

Problem area	**Average**	**lower limit**	**upper limit**
hazardous species	37,750,000	20,180,000	60,960,000
forestry	24,800,000	15,300,000	38,500,000
agriculture	24,084,000	15,800,000	47,580,000
fisheries and aquaculture	1,600,000	1,000,000	2,700,000
communities	26,200,000	14,620,000	50,500,000
waterways	32,200,000	23,700,000	40,800,000
terrestrial roadways	4,853,000	4,453,000	5,153,000
displacement of native species	30,000		
Bern Convention	4,470,000	4,060,000	5,120,000
Totals	**155,987,000**	**99,113,000**	**251,313,000**

Costs associated with the displacement of native species by lupine and *Dikerogammarus*, as well as the losses accruing to species listed in the Bern Convention are minimal estimates, because it has been impossible to assign a monetary value to loss of biodiversity within the scope of this study.

Tabelle 14: Summary of costs arising from selected neobiota in Germany.

Species	Average	Lower limit	Upper limit
Ragweed	32,100,000	19,800,000	49,900,000
Giant hogweed	12,313,000	10,619,000	14,770,000
Red oak	- 716,000	- 375,000	- 1, 050,000
Black cherry	25,500,000	15,630,000	39, 600,000
Lesser grain borer and saw-toothed grain beetle	19,400,000	11,200,000	35,300,000
Flour moth	4,784,000	4,600,00	12,280,000
Hairy galinsoga	none		
Muskrat	12,447,600	6,024,600	18,665,800
American crayfish	indeterminate		
Chestnut leaf-miner moth	19,200,000	10,020,000	33,800,000
Dutch elm disease agent	5,060,000	3,510,000	13,420,000
Zebra mussel	indeterminate		
Knotweed	32,300,000	23,700,000	41,000,000
Narrow-leaved ragweed	100,000		
Butterfly bush	none		
Dikerogammarus villosus	indeterminate		
Lupine	30,000		
Mink	4,200,000	3,800,000	4,600,000
Bullfrog	270,000	260,000	520,000
Totals	**166,988,600**	**108,788,600**	**262,805,800**

National strategy to halt the spread of neobiota

To halt the spread of neobiota, measures to improve habitat for native species, and the establishment of regional coordinators for environmental issues are recommended. A central finding during this study was that personal contacts were decisive in determining the quality of information obtained. The concept of a coordinator arose from these experiences. This chapter is intended to provide the basis for discussion regarding continuing studies of these issues.

Measures

The current study provides an opportunity for decision-makers at all levels to make judgements and devise policy. Particularly with regard to future encounters with invasive species, more comprehensive studies need to be carried out.

Scientific investigations of those species that cause ecological damage are urgently needed, to garner more information about these species, and their interaction with their environment. Control measures can then be directed towards, and tailored to, the threats posed by the respective species. In this way, control measures will be optimized, and costs reduced. At the same time, additional, comprehensive studies incorporating multiple neobiotic species dealing with the economic consequences of their spread are necessary. To the extent that this is possible, these studies should be used to derive unified, general criteria to evaluate the ecological and economic impact of immigrant species.

Effective control of neobiota requires a unified legal and regulatory basis. Currently, a variety of overlapping national and international laws govern the disposition of a variety of species. This is exemplified by the German regulations (fisheries, hunting, and forest regulation) and CITES. A thorough overhaul of legal provisions, and a unified approach--at least within Europe--is necessary.

Greater coordination and integration is needed, not just in the legal arena, but also in the practical aspects of dealing with invasive species. This is particularly relevant for information exchange among interested parties and officials charged with the responsibility of controlling neobiota. As described in Ewel *et al.* (1999), the proposal of the European Strategy against Invasive, Non-native Species, and the "Guidelines for prevention, introduction, and countermeasures directed against the effects of non-native organisms that threaten ecosystems, habitats, or species" calls for the implementation of national databases accessible to other nations, which would facilitate coordinated activities, and provide for sharing of acquired knowledge. This should include and involve the interested public. Public education and inclusion would be important to monitoring, because newly arrived exotic species would be more quickly noticed. Likewise, returning vacationers would prevent the introduction of non-native species by returning vacationers. Inclusion of specific interest groups, such as farmers, would likewise contribute greatly to control and monitoring efforts. Decision-makers, as well as citizens' groups (for example, conservation organizations, and especially youth groups), should be brought into this work. Integrated efforts by various groups and officials offer great promise in stemming the problems caused by invasive alien species.