

Levels of mercury in eggs of Red-throated Diver *Gavia stellata* and Black-throated Diver *G. arctica* in Southwest Sweden

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Abstract

In connection with surveys of breeding populations of *Gavia stellata* and *G. arctica* in Southwest Sweden 1978-91, unhatched eggs in abandoned nests were collected and analysed for mercury. In the investigated area, divers of both species primarily fish in oligotrophic lakes, many of them affected by air-borne acidifying pollutants. The level of mercury in *G. stellata* eggs was extremely high; in a sample of seven eggs from four breeding sites the mean concentration was 9.5 ppm dry weight with a range of 6.2-14.2 ppm, which is among the highest levels recorded for any bird species in Sweden. The concentrations in *G. arctica* eggs were lower: 1.0-2.4 ppm dry weight in samples from four breeding sites at circumneutral lakes, and on average 4.0 ppm (range 1.8-5.9 ppm) in a sample from four breeding sites at lakes affected by acidification. For *G. stellata*, all eggs contained mercury at levels where reproductive impairment is to be expected, and also single *G. arctica* eggs were so heavily contaminated that the risk of impairment must be considered. Fish samples from seven lakes indicated that potential prey fish (*Rutilus rutilus* and *Coregonus albula*, <20 cm) for *G. stellata* feeding chicks

contained higher concentrations of mercury in lakes affected by acidification. In one lake, fish contained levels about twice those reported to be associated with behavioural and reproductive disturbances in fish-eating birds. Also, single fish in two other lakes contained high concentrations of mercury. The results indicate that especially *G. stellata*, but also *G. arctica* in their breeding grounds in Southwest Sweden are exposed to levels of dietary mercury, sufficiently high for reproductive impairment to be expected, and that a connection exists to high levels of mercury in prey fish from freshwaters affected by acidification.

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Introduction

The Red-throated Diver *Gavia stellata* and the Black-throated Diver *G. arctica* are fish-eating bird species that have attracted attention in the national conservation work in the Nordic countries due to a combination of factors, including declining of fish populations in acidified lakes, disturbance from out-door recreational activities, and water level regulations (e. g. Andersson et al. 1980, Haga 1980a, 1980b, Pakarinen & Järvinen 1984, Götmark et al. 1989, Eriksson 1992).

The two species forage primarily in oligotrophic waters which often have a low natural alkalinity and are thus susceptible to acidification by air-borne pollutants. In addition to the strain of dealing with a reduced food supply in acidic lakes, predators on fish risk exposure

to increased levels of toxic metals through their food. Normally the exposure to cadmium, lead and aluminium is too low for any damage to occur, but the risk of exposure to mercury must not be neglected (Scheuhammer 1991). In the present paper we report high levels of mercury in eggs of Red-throated Diver and Black-throated Diver, as well as in potential prey fish, in an area with oligotrophic and acidic lakes in Southwest Sweden.

Study area

The study area covers the southern part of the county of Älvsborg (approx. 57°30'N, 12°45'E), Southwest

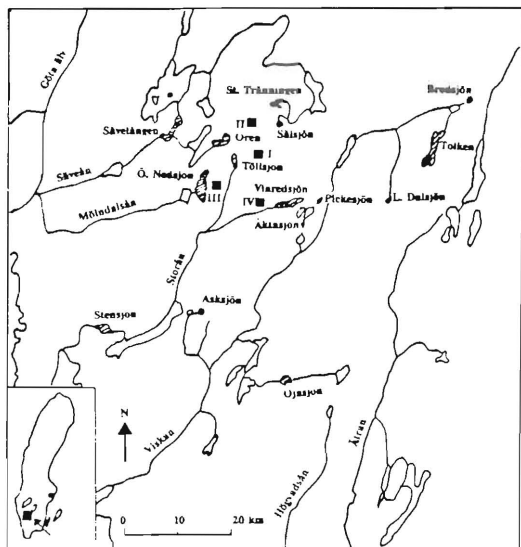


Figure 1. The study area in the southern part of the county of Älvsborg. Lakes mentioned in the text or tables are indicated. I-IV = sampling sites for Red-throated Diver eggs.

Undersökningsområdet i södra Älvsborgs län. Sjöar omnämnda i texten eller tabeller är markerade. I-IV = insamlingsplatser för smålomsäg.

Sweden, where surveys of the breeding populations of the two species of divers have been done since the 1970's (e. g. Ahlgren et al. 1991, Johansson 1991). The area is dominated by coniferous forests with *Picea abies* and *Pinus silvestris*, and forestry is the most wide-spread land-use activity. Most lakes are oligotrophic and circumneutral, if not acidified. The whole area is affected by acidifying pollutants, and field surveys during the early 1970's indicated that acidification of lakes, with pH-values regularly below 5.5, was already wide-spread more than 20 years ago (Almer 1972, Almer & Hanson 1980). Extensive liming programmes in order to restore fish stocks were initiated around 1980 and are still in progress (e. g. Brodin 1989).

In the study area, Red-throated Divers breed in small tarns (0.008-0.1 km²), often naturally devoid of fish, and the chicks are fed with fish caught in larger freshwater lakes up to a maximal distance of 7.7 km from the breeding site (Eriksson et al. 1990). The population consists of 15-20 breeding pairs and an additional number of non-breeding adults. Since the 1930's, the breeding population has been reduced by almost 50 %, and this decline has been related to habitat changes, such as drainage (for forestry) or overgrowth of *Sphagnum* mosses in the breeding tarns, and decline of fish stocks in adjacent fishing lakes (Eriksson et al. 1988).

Black-throated Divers breed in comparatively large lakes (0.1-12.1 km) in the study area (Eriksson 1987, Ahlgren et al. 1991), and food for the young is normally caught in the breeding lake. The population size is approximately 200 pairs (deduced from Arvidsson 1984). During 1968-1985 there was no significant change in the breeding success (Eriksson 1987), but there are indications of a decline in recent years (Ahlgren et al. 1991). The average reproduction was 0.40 halfgrown to fledged young per pair and year during 1968-1985. This rate is the same as in other areas in South Sweden (Andersson et al. 1980) and in Finland (Pakarinen 1989), and close to the minimum of 0.4-0.5 young per pair which Nilsson (1977) estimated to be necessary for the maintenance of a stable population.

Methods

Eggs

During the surveys of the breeding populations, unhatched eggs in nests abandoned after desertion or hatching were collected. Therefore, eggs not hatched due to high concentration of any harmful element may be overrepresented, and our sample does not necessarily reflect the average exposure of all eggs. The concentrations of mercury were investigated by neutron activation analysis according to methods described by Odsjö & Sondell (1982). For breeding sites from which more than one egg were analysed, we used the mean concentration in our calculations. The sampling sites are shown in Fig. 1.

Fish

From seven lakes, known to be used by foraging Red-throated Divers (according to Eriksson et al. 1988), samples of Roach *Rutilus rutilus*, and from two lakes also Vendace *Coregonus albula*, were taken during May-September 1991. For both species, only fish smaller than 20 cm were collected. The fish species and sizes were chosen in order to reflect the diet given by Red-throated Divers feeding chicks in the study area (Eriksson et al. 1990). For the analyses of mercury, axial muscle tissue was used. The sampling lakes are shown in Fig. 1.

Lakes

The lakes included in our study have been subjected to measurements of different parameters of water quality since the early 1970's. Lakes where declines in pH below 5.5 have been recorded were classified as "affected by acidification".

Table 1. Concentrations of mercury and organochlorines in eggs of Red-throated Diver, collected 1986-1991, in South-west Sweden. Sampling sites are shown in Fig. 1.

Halterna av kvicksilver och klorerade kolväten i smålomsägg, insamlade 1986-1991, i sydvästra Sverige. Provtagningsplatserna är markerade i Fig. 1.

Sampling site	Year	Hg, ppm dry weight	Note
<i>Provtagningsplats</i>	<i>År</i>	<i>torrvikt</i>	<i>Anmärkning</i>
I	1986-91	7.4	Mean of 3 eggs (6.2, 6.6, 9.4 ppm). <i>Medelvärde för 3 ägg.</i>
II	1991	6.8	
III	1991	14.2	
IV	1991	9.5	Mean of 2 eggs (8.5, 10.4 ppm). <i>Medelvärde för 2 ägg.</i>
Mean ± S.E.		9.5 ± 1.8	
<i>Medelvärde ± S.E.</i>			

Results and discussion

Eggs

For Red-throated Diver, the number of analysed eggs is small: a total of seven eggs from four breeding sites. The levels of mercury were remarkably high, on average 9.5 ppm dry weight (Table 1). In a study of Common Loon *Gavia immer* in a mercury-contaminated area in Canada, Barr (1986) concluded that disturbances in behaviour and reproduction were associated with mercury levels of 2-3 ppm wet weight in the eggs, and recorded a reduced breeding success at sites with an average concentration of 1.4 ppm wet weight. If these results apply also for Red-throated Diver, impairment in the reproduction cannot be excluded. (We used a conversion factor of 7 for comparisons with figures based on dry weight, see Lindberg et al. (1983) for Peregrine Falcon *Falco peregrinus*)

For Black-throated Diver, a total of 11 eggs from eight breeding sites were analysed. The average concentrations of mercury (1.5 and 4.0 ppm dry weight in non-acidic and acidic waters, respectively) were lower than for Red-throated Divers and comparable to those recorded by Barr (1986) for Common Loon outside highly contaminated areas in Canada. The average concentration of mercury was more than 2.5 times higher in samples collected at lakes affected by acidification (Table 2; $P=0.10$, two-tailed Mann-Whitney U test for comparison between circumneutral lakes and lakes affected by acidification). Single eggs contained mercury at such a high level that possible reproductive impairment cannot be excluded.

Table 2. Concentrations of mercury and organochlorines in eggs of Black-throated Diver, collected 1978-1991, in South-west Sweden. Sampling sites are shown in Fig. 1.

Halterna av kvicksilver och klorerade kolväten i storlomsägg, insamlade 1978-1991, i sydvästra Sverige. Provtagningsplatserna är markerade i Fig. 1.

Sampling site	Year	Hg, ppm dry weight	Note
<i>Provtagningsplats</i>	<i>År</i>	<i>torrvikt</i>	<i>Anmärkning</i>
A. Not acidic, circumneutral lakes (not lime-treated) <i>Ej sura, okalkade sjöar</i>			
Lake Bredsjön	1985	1.0	
Lake Lilla Dalsjön	1984	1.4	
Lake Tolken	1987	1.2	
Lake Sälsjön	1987-91	2.4	Mean of 3 eggs (2.3, 2.4, 2.4 ppm). <i>Medelvärde för 3 ägg.</i>
Mean ± S.E.		1.5 ± 0.3	
<i>Medelvärde ± S.E.</i>			

B. Lakes affected by acidification^a.

Sjöar påverkade av försurning^a.

Lake Äktasjön	1984	3.5	
Lake Asksjön	1988	5.9	
Lake Pickesjön	1978	4.9	Means of 2 eggs (4.3, 5.4 ppm). <i>Medelvärden för 2 ägg.</i>
Lake Stora Tränningen	1978	1.8	
Mean ± S.E.		4.0 ± 0.9	
<i>Medelvärde ± S.E.</i>			

^aLakes with pH regularly below pH 5.5, at least before lime-treatment. All lakes except Stora Tränningen were limed when the egg samples were collected. *Sjöar med pH regelbundet under 5,5, åtminstone före kalkning. Alla sjöar utom Stora Tränningen var kalkade när ägg samlades in.*

Fish

There was a tendency for higher concentrations of mercury in fish collected in lakes affected by acidification than in non-acidic lakes (Table 3; $P=0.10$, two-tailed Mann-Whitney U test for comparison between circumneutral lakes and lakes affected by acidification). In one lake, Ören, the concentrations were much above the level of 0.3-0.4 ppm wet weight in prey, which Barr (1986) found to be associated with disturbances in behaviour and reproduction in the Common Loon. In two other lakes, Töllsjön and Öjasjön, single fish contained mercury above this level.

Differences between species

The concentrations of mercury in eggs of the Red-throated Diver were on average 3 times those in Black-throated Diver eggs. In the study area, the two species differ in their selection of fishing lakes (Eriksson & Sundberg 1991). If this difference also reflects preferences for different prey species, the Red-throated Diver presumably tend to forage on cyprinid and salmonid fish (such as Roach and Vendace, respectively), while Black-throated Diver to a large extent feeds on Perch *Perca fluviatilis*. Thus, the higher levels of mercury in eggs of Red-throated Divers is somewhat surprising: Meili (1991) found, in a comparison between Perch and Roach of 15-20 cm length in two Swedish lakes, higher concentrations of mercury in Perch.

For both species, the levels of mercury in eggs were higher than those reported for fish-eating raptors in Sweden. For Osprey *Pandion haliaetus*, which to some extent forage in the same kind of lakes as the two species of divers, the mean level of mercury was only 1.0 ppm dry weight in a sample of 167 eggs collected during 1962-73 at different sites in Sweden (Odsjö & Sondell 1982). Similar levels were found in a sample of 55 Osprey eggs collected in Southwest Sweden 1974-82 (Ahlgren & Eriksson 1984). In a highly contaminated population of White-tailed Sea Eagle *Haliaeetus albicilla* in the Baltic Sea, the mean level was 4.6 ppm dry weight in a sample of 75 eggs collected during 1965-78 (Helander et al. 1982). It is also worthwhile to consider, that for Peregrine Falcons, the mean level of mercury was 2.7 ppm dry weight in a sample of 15 eggs collected in northern Sweden during 1972-81 and 2.5 ppm dry weight for 24 eggs from southern Sweden during the same period (Lindberg et al. 1983). Thus, the mercury levels in eggs of Red-throated Divers are among the highest recorded for any bird species in Sweden, and the concentrations in eggs of Black-throated Divers were at the same level as those recorded in Peregrine eggs during 1972-81. A comparison of the mercury content in muscle and liver samples from adult birds at Lake Päijänne, Finland, during 1972-74 indicated that the Black-throated Diver is more susceptible to mercury exposure than other bird species, such as Great Crested Grebe *Podiceps cristatus*, Goldeneye *Bucephala clangula*, Red-breasted Merganser *Mergus serrator* and five Laridae species (Särkkä et al. 1978a, 1978b).

Differences between lakes

The number of lakes included in the study is small. Nevertheless, our results, indicating elevated levels of mercury in fish and Black-throated Diver eggs from lakes affected by acidification conform with the gene-

ral knowledge that mercury levels in fish increase in acidified lakes (e. g. Håkanson 1980, Johansson 1980, Björklund et al. 1984) and that predators on fish are expected to be susceptible (e. g. Wiener 1987, Scheuhammer 1991).

Liming of lakes

Lime treatment has proved effective, not only in restoring fish stocks in acidified lakes (e. g. Bengtsson et al. 1980, Eriksson et al. 1983, Nyberg et al. 1986, Eriksson & Tengelin 1987), but also in reducing the concentrations of mercury in fish (e. g. Björklund et al. 1984, Håkanson et al. 1990). From this perspective, it is remarkable that the highest concentrations of mercury in potential prey fish for divers were recorded in limed lakes (Table 3 B), although we lack information to conclude whether concentrations should be even higher if the lakes concerned had not been treated. Improved liming techniques in order to reduce the exposure to toxic metals may be in conflict with other nature conservation goals, however, especially if liming of wetland habitats proves necessary.

Final comments

Our results can be summarized as follows: (1) Eggs of Red-throated Diver from Southwest Sweden contain mercury at very high levels, and reproductive impairment is probable, (2) the average level of mercury in eggs of Black-throated Diver is considerably lower, but individual eggs have high concentrations, and (3) in some lakes in Southwest Sweden, fish of species and size delivered to chicks of Red-throated Divers contain mercury at levels which have been associated with behavioural and reproductive disturbances in the Common Loon in Canada.

Eriksson (1992) concluded that the Red-throated Diver is more susceptible than the Black-throated Diver to the ecological changes in acidified lakes. Red-throated Divers rely, to a higher degree than Black-throated Divers, on fish susceptible to low pH-values. Black-throated Diver may also benefit from the increased abundance of aquatic insects in lakes with reduced predation from fish and may make use of the increased water transparency in acidified waters. The present results indicate that higher concentrations of mercury in eggs of Red-throated Diver may also be contributing to a higher susceptibility in this species.

Temporal or geographical coincidence between decreased population size or breeding success in birds and exposure by acidifying pollutants have been primarily attributed to indirect effects of pH or metals on the quantity or quality of food, sometimes in combination with habitat changes, while toxic effects of metals on

Table 3. Concentrations of mercury (ppm wet weight) in axial muscle tissue from fish, <20 cm, collected during May-September 1991 in South-west Sweden. Sampling sites are shown in Fig. 1.

Halterna av kvicksilver (ppm våtvikt) i ryggmuskelprover från fisk, <20 cm, insamlade i maj-september 1991 i sydvästra Sverige. Provtagningsplatserna är markerade i Fig. 1.

Sampling site <i>Provtagningsplats</i>	Roach <i>Mört</i>		n	Vendace <i>Siklöja</i>		n
	Mean ± S.E. <i>Medelv.±S.E.</i>	Range <i>Intervall</i>		Mean ± S.E. <i>Medelv.±S.E.</i>	Range <i>Intervall</i>	
A. Not acidic, circumneutral lakes ^a						
<i>Ej sura sjöar^a</i>						
Lake Stensjön	0.13 ± 0.02	<0.10-0.18	5	–	–	–
Lake Sävelången	0.21 ± 0.02	0.14-0.28	5	0.18 ± 0.03	0.12-0.28	5
Lake Viaredssjön	0.11 ± 0.01	<0.10-0.16	5	–	–	–
Lake Öjasjön	0.17 ± 0.02	0.11-0.23	5	0.25 ± 0.04	0.15-0.37	5
Lake Östra Nedsjön	0.14 ± 0.01	0.12-0.17	5	–	–	–
Mean ± S.E.	0.15 ± 0.02			0.22 ± 0.04		
<i>Medelvärde ± S.E.</i>						
B. Lakes affected by acidification ^b						
<i>Sjöar påverkade av försurning^b</i>						
Lake Töllsjön	0.23 ± 0.06	0.12-0.43	5	–	–	–
Lake Ören	0.80 ± 0.07	0.55-0.97	5	–	–	–
Mean ± S.E.	0.52 ± 0.23			–		
<i>Medelvärde ± S.E.</i>						

^aLakes Öjasjön and Östra Nedsjön are lime-treated. *Öjasjön och Östra Nedsjön är kalkade.*

^bLakes with pH regularly below pH 5.5, at least before lime-treatment (both lakes are limed). *Sjöar med pH regelbundet under 5,5, åminstone före kalkning (båda sjöarna är kalkade).*

reproductive success or survival have been regarded as less important (e. g. Schreiber & Newman 1988, Eriksson 1991). The present indications that foraging in lakes affected of acidification, through the consumption of fish contaminated with high levels of mercury, might have contributed to a decreased population size. It is doubtful that liming cannot be a final strategy in order to solve the problems treated in the present paper, a reduction of the emissions of acidifying pollutants is the only long-term solution.

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Sammanfattning

Kvicksilvernivåer i ägg av smålom Gavia stellata och storlom Gavia arctica i sydvästra Sverige.

Både smålommen och storlommen har uppmärksamats i det svenska fågelskyddsarbetet. Latenta hotfaktorer är bl. a. minskad tillgång på fisk i försurade vatten, störningar och olämplig reglering av vattenståndet (t. ex. Andersson m. fl. 1980, Haga 1980a, 1980b, Pakarinen & Järvinen 1984, Götmark m. fl.

1989, Eriksson 1992). Båda arterna fiskar till stor del i näringsfattiga sjöar som ofta har en naturligt låg buffertförmåga och därför är sårbara för försurning. Förutom ett minskat födounderlag riskerar predatorer på fisk i sura sjöar att utsättas för en ökad exponering av giftiga metaller, inkl. kvicksilver (t. ex. Scheuhammer 1991).

Undersökningsområde och metoder

I samband med inventeringar, utförda på frivillig och ideell basis, av de häckande bestånden av smålom och storlom i södra delen av Älvsborgs län har okläckta ägg, som lämnats kvar i övergivna eller kläckta bon, insamlats och analyserats med avseende på deras kvicksilverinnehåll. I undersökningsområdet (Fig. 1) häckar smålommen i småsjöar och tjärnar (0,008-0,1 km²), som ofta är naturligt fisktomma, och ungarna matas med bytesfisk (i huvudsak mörtartad och laxartad fisk upptill 20 cm längd) från större sjöar belägna upptill 7,7 km från häckningsplatsen (Eriksson m. fl. 1990). Det häckande smålombsbeståndet består av 15-20 par plus ett antal icke häckande, adulta fåglar. Beståndets storlek har i det närmaste halverats sedan 1930-talet (Eriksson m. fl. 1988). Storlommen häckar i större sjöar (0,1-12,1 km²; Eriksson 1987, Ahlgren m. fl. 1991) och föda till ungarna hämtas normalt i häckningssjön. Beståndet uppgår till ungefär 200 par (baseras på uppgifter från Arvidsson 1984), och under perioden 1968-85 låg den genomsnittliga ungproduktionen på 0,40 halvstora-flygga ungar per par och år (Eriksson 1987), eller nära den nivå på 0,4-0,5 ungar per par som Nilsson (1977) beräknat vara ett minimum för att vidmakthålla en oförändrad storlek av beståndet. Sedan mitten av 1980-talet har ungproduktionen gått ner i området (Ahlgren m. fl. 1991).

Från sju sjöar, som används av fiskande smålommar, insamlades under perioden maj-september 1991 mört, och från två av sjöarna även siklöja, av högst 20 cm längd. För analyserna av kvicksilver användes ryggs-muskelprover.

Resultat och diskussion

I smålomsäggen (totalt sju ägg från fyra olika häckningsplatser) uppmättes extremt höga halter av kvicksilver (medelvärde: 9,5 ppm torrsvikt, Tabell 1). I kanadensiska undersökningar noterades en minskad häckningsframgång hos islom vid ett kvicksilverinnehåll i äggen på ungefär samma nivå (Barr 1986). I storlomsäggen (elva ägg från åtta häckningsplatser) var kvicksilverhalterna lägre och på ungefär samma nivå som Barr (1986) rapporterade för islom häckande i områden med låg påverkan av kvicksilver i Canada. Den genomsnittliga nivån var 1,5 ppm torrsvikt i prover

från fyra icke försurade sjöar, jämfört med i medeltal 4,0 ppm torrsvikt i ägg insamlade vid fyra sjöar påverkade av försurning (Tabell 2, $P=0,10$, tvåsidigt Mann-Whitney U-test för jämförelse mellan icke sura och försurningspåverkade sjöar). Enstaka ägg innehöll så höga koncentrationer av kvicksilver att man inte bör utesluta risken för fortplantningsstörningar.

Som jämförelse kan nämnas att för fiskätande rovfåglar var genomsnittsvärdet bara 1,0 ppm torrsvikt i fiskguseägg insamlade på skilda platser i Sverige 1962-73 (Odsjö & Sondell 1982) och liknande värden har uppmätts i fiskguseägg insamlade i sydvästra Sverige 1974-82 (Ahlgren & Eriksson 1984). I det av kvicksilver och klorerade kolväten kraftigt exponerade beståndet av havsörn vid Östersjön var medelvärdet 4,6 ppm torrsvikt i ägg insamlade 1965-78 (Helander m. fl. 1982). Det genomsnittliga innehållet av kvicksilver i ägg från pilgrimsfalk var ungefär 2,5 ppm torrsvikt under perioden 1972-81 (Lindberg m. fl. 1983). Kvicksilvernivåerna i smålomsägg är således bland de högsta som uppmätts i svenska fågelägg, och i storlomsägg ligger halterna på ungefär samma nivå som för pilgrimsfalk under 1970-talet. I en undersökning av bl. a. kvicksilverhalterna i muskel- eller leverprover från olika fåglar vid sjön Päijänne, Finland, var storlommen kraftigt belastad jämfört med andra arter, såsom skäggdopping, knipa, småskrake, fisktärna och fyra måsararter (Särkkä 1978a, 1978b).

En tendens till högre halter av kvicksilver i fisk från försurningspåverkade sjöar noterades (Tabell 3, $P=0,10$, tvåsidigt Mann-Whitney U-test för jämförelse mellan icke sura och försurningspåverkade sjöar). I sjön Ören låg koncentrationerna väsentligt över den nivå på 0,3-0,4 ppm vätvikt, där man kan påräkna störningar i beteende och fortplantning hos islom (Barr 1986). I två andra sjöar, Töllsjön och Ojasjön, innehöll enstaka fiskar höga halter av kvicksilver.

Även om antalet sjöar i undersökningen är litet, indikerar analyserna av såväl storlomsägg som fisk att belastningen av kvicksilver är högre i försurningspåverkade sjöar. Tidigare undersökningar, sammanfattade av Eriksson (1992), antyder att smålommen är mer sårbar än storlommen för de ekologiska förändringarna i sura sjöar. Smålommen är mer beroende av försurningskänsliga fiskar, och storlommen torde i viss mån kunna tillgodgöra sig fördelarna med den ökade tillgången på vattenlevande insekter i sjöar med en minskad predation från fisk och det ökade siktdjupet i sura vatten. I allmänna översikter av hur fåglar och däggdjur påverkas av försurning har man i regel ansett att det i första hand är indirekta effekter på t ex födotillgång eller fodans kvalitet som är viktiga, medan toxiska effekter av metaller bedömts vara av mindre betydelse (t. ex. Schreiber & Newman 1988, Eriksson 1991). I den här studien finns indikationer på att en kraftig

exponering av kvicksilver, genom födointag i försurningspåverkade sjöar, kan ha medverkat till en tillbakagång i det häckande beståndets storlek av smålom i sydvästra Sverige.

Kalkning används inte bara för att höja pH-värdet, för att därigenom återskapa betingelser för livskraftiga fiskbestånd, utan också för att minska belastning av kvicksilver i fisk (t. ex. Björklund m. fl. 1984, Håkansson m. fl. 1990). Det är därför anmärkningsvärt att de högsta koncentrationerna av kvicksilver noterats i kal-

kade sjöar (Tabell 3 B), låt vara att man inte vet hur höga koncentrationerna skulle ha varit om sjöarna inte kalkats. Förbättrade kalkningsmetoder torde emellertid enbart ge kortsiktiga vinster, och kan dessutom komma i konflikt med andra naturvårdssträvanden, speciellt om kalkning på land i s. k. utströmningsområden blir aktuell. Minskade utsläpp av försurande ämnen är den enda långsiktiga lösningen på den typ av problem som vi behandlat.