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Density and yield of the noble crayfish *Astacus astacus* in the River Skotsbergelva, SE Norway

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The population density and yield of the noble crayfish *Astacus astacus* was estimated on two localities in the River Skotsbergelva in the Halden river system, SE Norway, in August 1989. The estimated densities of catchable crayfish (>70 mm; caught in baited traps) varied between localities and with method of estimation. Mark — recapture estimates were much higher than comparable Leslie-estimates. Estimated densities varied from 0.47 to 0.93 crayfish m^{-2}. Yield of legal size crayfish varied from 2.4 to 23.6 kg ha^{-1}. Fishing mortality was estimated to 28—66%, being highest at the locality with the highest yield and exploitation.

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INTRODUCTION

The noble crayfish *Astacus astacus* (L.) is at its northern limit of distribution in Norway. The species is today threatened by the epidemic spreading of the crayfish plague *Aphanomyces astaci* throughout Europe. The crayfish plague was recorded in Norway in the River Glomma in 1987, and then in the Halden river system in 1989. Thus, some of the oldest and most productive crayfish populations in Norway are lost (Taugbøl et al. 1989, 1990).

In this paper we present data on density and yield of crayfish in the River Skotsbergelva, a part of the Halden river system. The study was part of a project aimed at studying the effect of habitat improvements on crayfish density and production. In October 1989 all the crayfish in the area were killed by the crayfish plague.

Few studies on density and yield are available from Norwegian waters. In Lake Steinsfjorden density was estimated to vary between 0.13 and 0.36 individuals >70 mm per square meter (Skurdal et al., in press). In other studies from Scandinavia and elsewhere densities have varied from 0.13 to 1.65 adults per square meter, with the highest densities in rivers and shallow ponds (Abrahamsson 1966, Cukerzis 1975, Niemi 1977, Dehli 1982, Jørgensen 1985).

MATERIAL AND METHODS

The Halden river system consists of a number of large lakes, most of them being in an advancing state of eutrophication (Skulberg & Kotai 1982). The fish community consists of 10—12 species, with roach *Rutilus rutilus* (L.), bleak *Alburnus alburnus* (L.), perch *Perca fluviatilis* L., and pike *Esox lucius* L. being the most abundant (see Vøllestad 1985).

We studied the noble crayfish at two well defined localities in the River Skotsbergelva within the Halden river system (SE Norway) in August 1989. Location 1 (area 3.5 ha) was chosen to include mainly habitat types usually not preferred by crayfish (soft bottoms, dense vegetation; Skurdal et al. 1988) in order to test the effect of habitat improvements on density and yield. Large parts of location 1 consisted of muddy bottoms with dense stands of vegetation. Location 2 (area 1 ha) was chosen to include habitat types close to optimal, thus consisting of a rocky shoreline with large quantities of stones and cobbles. Submerged vegetation was restricted to small areas close to the shore line. The water current velocity was low at both locations, and the mean water depth was between 4 and 5 m. The river has a well defined deep middle part, separating the two shorelines.

The crayfish was captured in baited traps from August 4. to 29. 1989. A total of 700 crayfish were marked and released at August 4., to allow the estimation of total number of catchable crayfish >70 mm in the area. The crayfish was marked by clipping the uropods and telson (Svärdson 1948). In the legal fishing period (from August 6. to September 14.) the fishermen operating in the area reported all marked crayfish and also reported on the total number above and below the legal size (95 mm total length). All crayfish captured during the fishing season were removed (only in the study area). On August 29. all the captured crayfish were measured to the nearest mm (total body length) and sexed, whereas on August 4. only 608 crayfish were measured and sexed.

The initial available population was computed using simple mark-recapture techniques (Ricker 1975):

$$\hat{N} = (M + 1)(C + 1)/(R + 1)$$

where M is the number of marked individuals in the population, C is the total number of captured and controlled individuals and R is the number of recaptures. The 95% confidence interval of this estimate is approximated as $2\sqrt{\mathrm{Var}\ \hat{N}}$, where

$$\mathrm{Var}\ \hat{N} = \hat{N}^2 (\hat{N} - M)(\hat{N} - C)/(\hat{N} - 1) MC$$

The initial available population ($\hat{N}_0$) was also estimated using Leslie's method (Ricker 1975) which utilizes the relationship between population density and catch per unit of effort

$$CPUE = q\bar{N}, \text{ and}$$

$$\bar{N} = \hat{N}_0 - C_t, \text{ thus giving}$$

$$CPUE = q\hat{N}_0 - qC_t,$$

where N is the mean population size, C_t is the cumulative catch in the fishing period and q is the catch efficiency (assumed to be constant).

Yield was estimated based on the total catch of legal sized crayfish. The mean lengths of male and female crayfish in the total catch were computed, and the mean weights were estimated using length-weight relationships provided by Skurdal & Qvenild (1986):

Males: $\log W\,(g) = -1.971 + 3.518 \log L\,(mm)$

Females: $\log W\,(g) = -1.697 + 3.180 \log L\,(mm)$

RESULTS

At location 1 a total of 880 crayfish were caught in the period from August 4. to 29. Of these, 263 (29.9%) were legal sized (Fig. 1), giving a total yield of legal size crayfish of 8.6 kg (45% males). This is equivalent to a yield of 2.4 kg legal size crayfish per ha. At location 2 a total of 3200 crayfish were caught, with 818 above the minimum legal size (25.6%) (Fig. 1). The total yield of legal size crayfish was 23.6 kg (55% males), or 23.6 kg per ha.

At location 2 the catch per unit of effort (CPUE; number of crayfish caught per trap night; mean CPUE ± SD = 10.3 ± 4.7, range 3.7 - 17.8) was much higher than at location 1 (4.6 ± 1.7, range 2.9 - 7.9). The CPUE decreased with time at both locations, stabilizing at 3 crayfish per trap night at location 1 and 5 crayfish per trap night at location 2. The effort varied from 13 to 68 traps per night at location 1 (total 261 trap nights or 75 trap nights ha^{-1}) and from 11 to 34 traps per night at location 2 (total 305 trap nights or 305 trap nights ha^{-1}).

The length distribution varied between locations and with time within locations (Fig. 1). At both locations the frequency of small crayfish in the catches increased between August 4. and August 29. (X^2-tests; $P<0.001$ at both locations). Also the sex distribution changed with time within locations. At August 4. the sex distribution did not deviate significantly from a 1:1 distribution (X^2-tests; $P>0.05$ at both locations). At both locations the frequency of females was higher at August 29. than at August 4. ($P<0.001$). However, the sex-distribution did not differ significantly from a 1:1 distribution at August 29. at location 2 ($P>0.05$).

At location 1 the number of marked and recaptured crayfish was large enough to give a good mark-recapture estimate. Based on the daily catches and recaptures estimates for

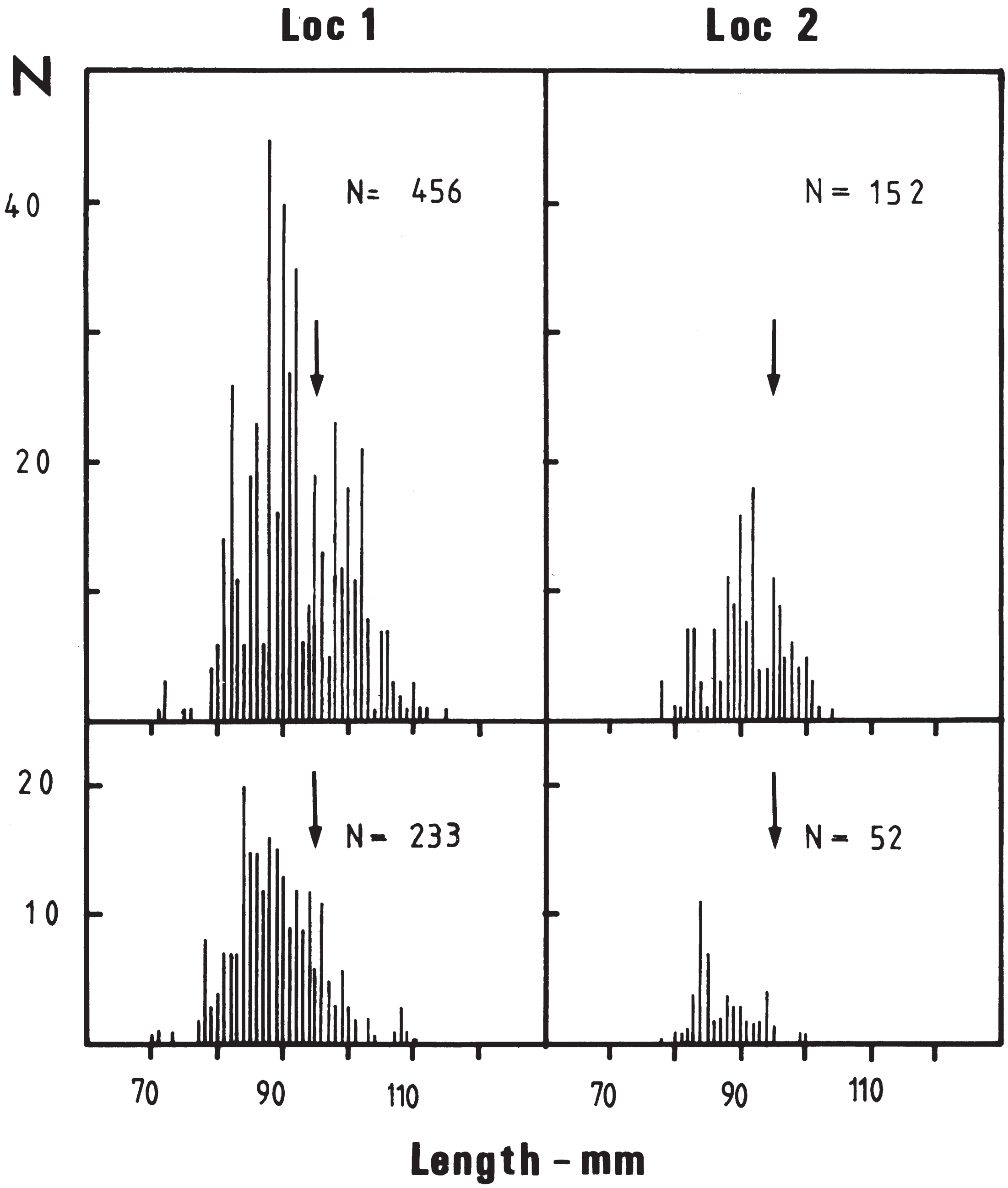

Fig. 1. Length distribution of noble crayfish caught at location 1 (left) and 2 (right) in the River Skotsbergelva at August 4. (upper panels) and 29. in 1989 (lower panels). Legal size limit is indicated by an arrow.

Table 1. Estimation of the population size of noble crayfish at location 1 in the River Skotsbergelva in August 1989. M_i = number of marked crayfish present in the population each day, C_i = number of catched crayfish on day i, R_i = number of recaptured crayfish on day i, $\hat{N}_i$ = estimated initial number of crayfish present based on the recaptures on day i, and CI = 95% confidence interval of the individual estimates of population size.

August	M_i	C_i	R_i	$\hat{N}_i$	CI
4.	548				
7.	548	154	50	1667	1302—2036
8.	498	166	38	2137	1559—2715
9.	460	71	12	2553	1279—3827
11.	448	91	19	2065	1261—2869
12.	429	63	8	3058	1170—4946
17.	421	86	10	3338	1468—5208
18.	411	51	6	3061	903—5219
24.	405	65	6	3828	1091—6565
29.	399	233	24	3744	2369—5119
Total	548	980	173	3095	2743—3447

each fishing day was calculated (Table 1). The estimates increased from approximately 1700 crayfish on August 7. to approximately 3700 on August 29. The daily estimates fluctuated, but an increase throughout the whole period was evident. The overall mean (estimated from the total number of recaptures) was 3095 crayfish (95% confidence interval: 2743—3447) or 0.089 crayfish m^{-2}. The percentage of recaptures decreased from 32% at August 7. to 10—12% from August 12. onwards.

At location 1 the Leslie method (Fig. 2) gave a population estimate of 1648 crayfish (95% CI: 1267—2030) or 0.047 crayfish m^{-2}. This estimate is significantly lower than the overall mean mark-recapture estimate (t-test; $P<0.001$), but is almost identical to the mark-recapture estimate made on August 7. (after the first night of legal fishing; Table 1).

At location 2 the number of marked crayfish was too low to perform daily mark-recapture estimates and, therefore, we calculated population size from the cumulative catches (Fig. 3). In total 152 crayfish were marked. Of these 52 were recaptured later, together with 3148 unmarked individuals. The estimate is stabilized from August 12. onwards, reaching a level of 0.93 crayfish m^{-2} at August 29. (95% C.I.: 7212 —11304). The stabilization of the estimate is most clearly expressed by the reduction in the coefficient of variation of the estimates. The Leslie estimate (0.50 crayfish m^{-2}; 95% CI: 0.36 — 0.63; Fig. 2) was very much lower than the mark-recapture estimate (t-test; $P<0.001$).

DISCUSSION

There are few estimates of density and yield available for noble crayfish in Norway. At the best location in the River Skotsbergelva we registered a yield of more than 20 kg per ha; this compares favourably with previous reports from Norway (1—5 kg ha^{-1}; Qvenild & Skurdal 1986, Vøllestad 1988) and Sweden (mean for 77 lakes: 3 kg ha^{-1}; Svärdson 1948). These lower values are comparable to that found at the less favourable habitat at location 1 in the River Skotsbergelva. The high yield at location 2 may be due to a number of factors, one is the fact that the production in rivers generally is higher than in lakes (see summary in Jørgensen 1985). This is mainly because more of the total area is suitable for crayfish production in rivers compared to lakes since among other factors the deeper parts of a lake do not produce crayfish (see Skurdal et al. 1988). Another reason is the high productivity of the Halden river system, it being in an advancing state of eutrophication (Skulberg & Kotai 1982). The present study also documents the potential effect of habitat improvements on crayfish production.

The fishing effort was rather high during the study, but even at the end of the study a relative large fraction of legal sized crayfish was available. Qvenild & Skurdal (1986) estimated that 75—91% of the harvestable population in Lake Steinsfjorden was harvested each year. It was not possible to estimate fishing mortality directly in the present study. One approximation may, however, be to compare the actual catch in each location with the estimated number of crayfish in that location. Calculating in this way, fishing mortality is between 28 and 53% at location 1, and between 35 and 64% at location 2.

The present study clearly demonstrates the difficulties involved in estimating crayfish densities. One of the problems is associated with the molting cycle of the crayfish. In Norway two annual molts are common for males, whereas mature females usually molt only once each year (Skurdal & Qvenild 1986). The results presented may indicate

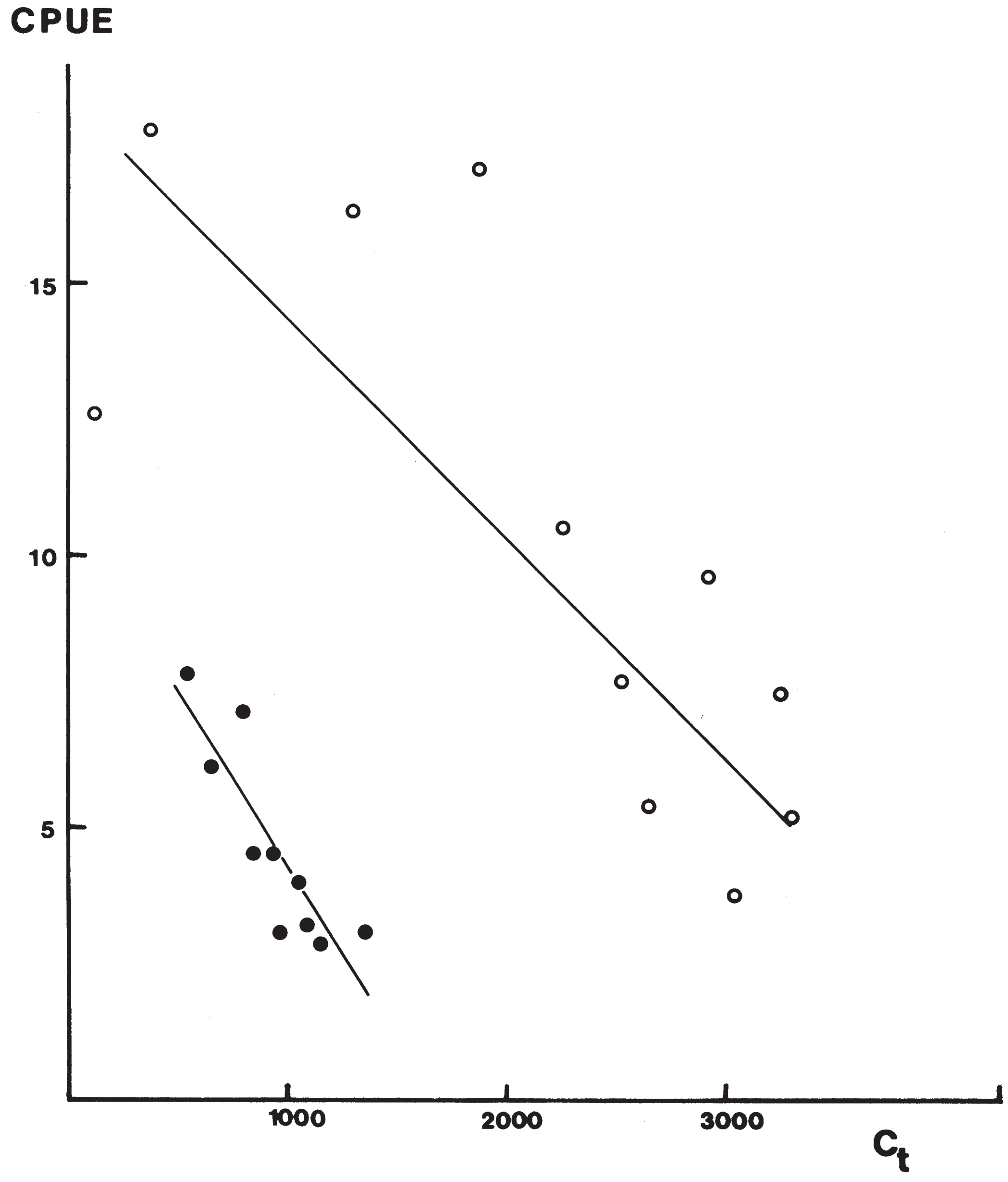

Fig. 2. Relationship between catch per unit of effort (CPUE) and the cumulative catch (C_t) at location 1 (filled circles) and 2 (open circles) in the River Skotsbergelva August 1989. Location 1: CPUE = 12.045 - 0.0068C_t, r = -0.842, N = 10, P<0.005; Location 2: CPUE = 18.386 - 0.0037C_t, r = -0.773, N = 11, P<0.005.

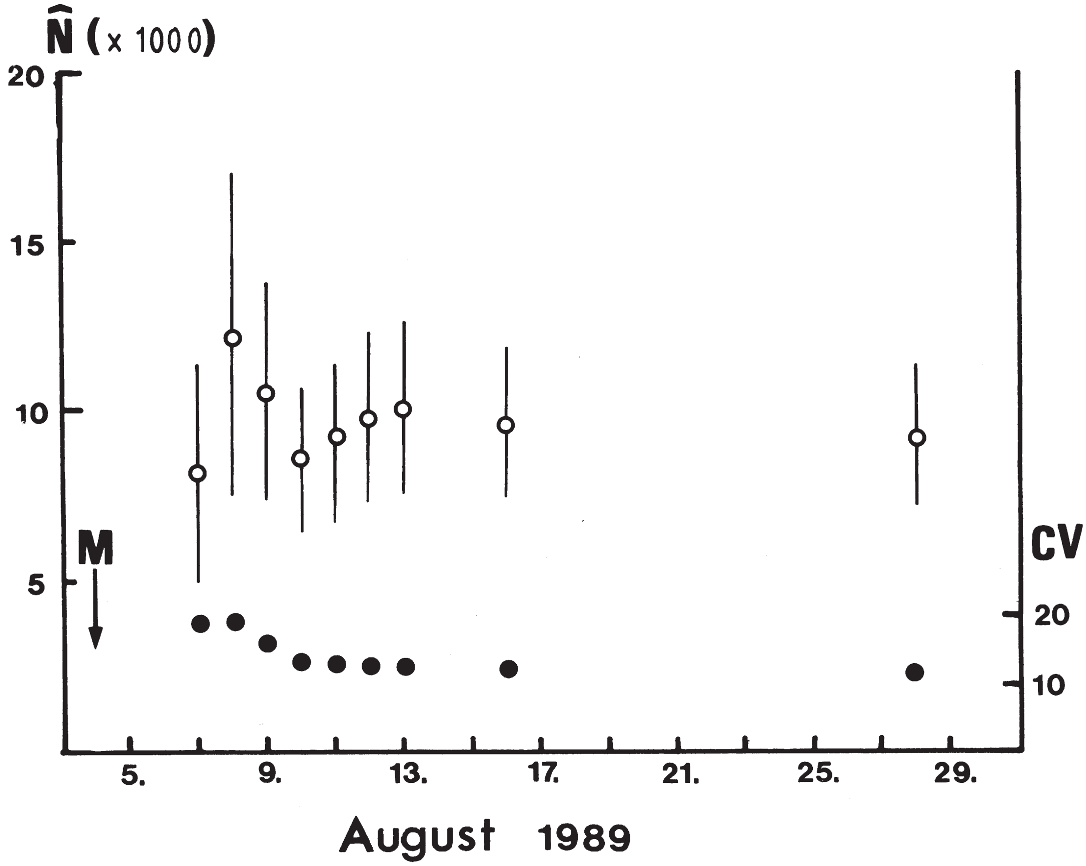

Fig. 3. Variation in estimated density (mean and 95% confidence interval) of crayfish with time after marking (August 4) at location 2 in the River Skotsbergelva August 1989 (open circles). The estimates are based on cumulative recaptures of marked crayfish. Also given is the coefficient of variation (CV) of the individual estimates (filled circles).

that female crayfish recruit to the catchable population in early August. It was also evident that the crayfish being caught late in the season were smaller than those being caught at the start of the fishing period. One reason for this may be that the largest crayfish either molt earlier or are more active than the smaller crayfish. This is in accordance with the results of Qvenild and Skurdal (1989) showing low catchability of small crayfish. It was also evident that males and females had different catchabilities, probably because of differences in activity and also trap selectivity (Abrahamsson 1983, Qvenild & Skurdal 1989).

We estimated population sizes using two different methods, Leslie's method and a mark-recapture method. Leslis's method gave on average very much lower estimates than the mark-recapture estimate. Both estimates are of course affected by the differential catchability of the crayfish. Such variation in catchability as observed in this study, will lead to an underestimation of the initial population size when the Leslie method is used, whereas it will lead to an overestimation when a mark-recapture method is used. These two estimates may therefore be regarded as upper and lower estimates of density.

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REFERENCES

Abrahamson, S. 1966. Dynamics of an isolated population of the crayfish *Astacus astacus* Linné. *Oikos* 17, 96—107.

Abrahamson, S. 1983. Trappability, locomotion, and diel pattern of activity of the crayfish *Astacus astacus* and *Pacifastacus leniusculus* Dana. *Freshwater Crayfish* 5, 239—253.

Cukerzis, J. 1975. Die Zahl, Struktur und Produktivität der isolierten Population von *Astacus astacus* Linné. *Freshwater Crayfish* 2, 513—527.

Dehli, E. 1982. *Virkninger av rask eutrofiering og vasspestinvasjon* Elodea canadensis *på krepsen* Astacus astacus *i Jarenvannet, Hadeland.* Cand. scient. thesis, University of Oslo, Norway.

Jørgensen, H. 1985. *En undersøgelse af populationsbiologien hos flodkrebsen* Astacus astacus *Linné.* Specialrapport, Institutt for Populationsbiologi, Universitetet i København. 66 pp.

Niemi, A. 1977. Population studies on the crayfish *Actacus astacus* in the river Pylijoki. *Freshwater Crayfish* 3, 81—94.

Qvenild, T. & Skurdal, J. 1986. The yield of a heavily exploited population of *Astacus astacus* in Lake Steinsfjorden, S.E. Norway. *Freshwater Crayfish 6,* 194—198.

Qvenild, T. & Skurdal, J. 1989. Does increased mesh size reduce non-legalsized fraction of *Astacus astacus* in trap catches? *Freshwater Crayfish 7,* 277—284.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. *Bull. Fish. Res. Board Can. 191,* 382 pp.

Skulberg, O. & Kotai, J. 1982. Haldensvassdraget — vannkvalitet og forurensningsvirkninger. *Norwegian Institute of Water Research, Report 0-70219,* 179 pp.

Skurdal, J., Fjeld, E., Hessen, D. O., Taugbøl, T. & Dehli, E. 1988. Depth distribution, habitat segregation and feeding of the crayfish *Astacus astacus* in Lake Steinsfjorden, S. E. Norway. *Nordic J. Freshw. Res. 64,* 113—119.

Skurdal, J. & Qvenild, T. 1986. Growth, maturity, and fecundity of *Astacus astacus* in Lake Steinsfjorden, S. E. Norway. *Freshwater Crayfish 6,* 182—186.

Skurdal, J., Qvenild, T. & Taugbøl, T. 1990. Mark-recapture experiments with the noble crayfish *Astacus astacus* in Lake Steinsfjorden, S. E. Norway. *Freshwater Crayfish* in press.

Svärdson, G. 1948. Stunted crayfish populations in Sweden. *Rep. Inst. Freshw. Res. Drottningholm 29,* 135—145.

Taugbøl, T., Håstein, T., Qvenild, T. & Motzfeld, M. 1989. Krepsepesten i Norge. Status og fremtidsutsikter. *Fylkesmannen i Hedmark, Miljøvernavdelingen, Report no. 24,* 8 pp.

Taugbøl, T., Nashoug, O. & Vøllestad, L. A. 1990. Krepsepesten i Norge. Spredning i 1989 og forsøk på gjenoppbygging. *Fylkesmannen i Hedmark, Miljøvernavdelingen, Report no. 36,* 13 pp.

Vøllestad, L. A. 1985. Biology of ruffe *Acerina cernua* in the Halden River System, Norway. *Fauna (Blindern) 38,* 13—17 (in Norwegian with English summary).

Vøllestad, A. 1989. Krepsefisket i Østfold i 1989. *Fylkesmannen i Østfold, Miljøvernavdelingen, Report 11-1989,* 14 pp.

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