

11.2.1.7 Literature review of impact of cormorants on fisheries in Europe

Summary

This is a summary review of the scientific literature relating to biology of cormorants and their interaction with fisheries and aquaculture. It is not comprehensive but aims to summarise available published information in order to help identify further research and knowledge needs.

As with many studies of predator-prey interaction, the basic biology of the predator (cormorant) is well known—it may be the most studied wild bird species in Europe; its diet is known (and the approximate biases in methods to study diet) but what is not well known is the overall impact of predation by cormorants on the prey populations. Prey populations can also react biologically and behaviourally such that it is not safe to scale-up the results of small scale studies. Further fish community interactions are also not known. There have been few studies by fish population biologists—most studies are by ornithologists or from the various “sectors” (aquaculture, angling, fisheries groups). There are a very few cases (e.g. aquaculture) where it is possible to measure consumption but these are very atypical, mitigation/prevention is mostly possible but it is impossible to scale these studies up to anything greater. Knowledge of damage prevention is reasonable and the effect on cormorant populations of various population control measures can be assessed. Wires *et al.* (2003) (see literature review) provides a good summary of the interaction.

Research needs

ICES has identified that the following issues are important for the further study, quantification and understanding of cormorant-fishery interactions.

- Population studies of relevant prey species of cormorants, including research on fish population dynamics, particularly the role of cormorants compared to other factors.
- Further impact studies, particularly studies in different fisheries and in a range of ecological situations.
- Further studies on cormorant behaviour, particularly research into how cormorants respond to regulation attempts, and the consequences of such actions with respect to numbers and distribution.
- Further quantification of movements, mortality/survival, immigration and emigration, especially in central and eastern parts of Europe (e.g. Poland, the Danube Delta).
- Investigation of density-dependent regulation and carrying-capacity effects of cormorant populations.

Regular, authoritative international synthesis of data on cormorants is recommended.

Introduction

In February 2009, the European Commission (DG Mare) requested that ICES conduct a scientific literature review of the impact of cormorants on fisheries in Europe. This followed the adoption, in December 2008, of a resolution by the European Parliament on the need for a European Cormorant Management Plan to minimise the increasing impact of cormorants on fish stocks, fishing and aquaculture.

The Commission perceived the need for some EU action especially to establish population levels, to provide guidance on the use of relevant derogations to the Birds' Directive, to bring together experts, Member States and other stakeholders in order to improve our knowledge on this issue and to establish on the best possible solutions. In requesting a literature review to support these actions, the Commission drew attention to two major current studies in Europe:

- **INTERCAFE**, (Interdisciplinary initiative to reduce pan-European cormorant-fisheries conflicts), a network of natural and social scientists established under COST Action 635. The project's main objective is to improve communication and sharing of European scientific knowledge in relation to cormorant-fisheries interactions and the management of human-wildlife conflicts.
- **Community intervention in inland fisheries**, ongoing study contracted by DG MARE under a Framework contract "studies linked to the implementation of the European Fisheries Fund".

DG Mare later clarified that it needed only a bibliographical review of available information and publications (scientific papers, reports, etc...) related to this topic. The requirement was later further defined as a need for an overview of our knowledge (and also identification of lack of knowledge) about cormorant impacts on fisheries and aquaculture in Europe, based on published research.

Overview of literature and summary of key sources of information

The review is organised into the following topics. Some literature covers more than one topic.

- 1) **Broad studies/literature**
- 2) **Demography**
 - 2.1 **Sub-species**
 - 2.2 **Breeding population size, trends, distribution**
 - 2.3 **Winter population size, trends, distribution**
 - 2.4 **Survival**
 - 2.5 **Movements**
 - 2.6 **Breeding biology and performance**
- 3) **Foraging biology**
 - 3.1 **General**
 - 3.2 **Habitat selection**
 - 3.3 **Feeding behaviour and ecology**
 - 3.4 **Diet and energetic**
 - 3.5 **Effects of cormorants on fish stocks**
- 4) **Human/fisheries interactions**
 - 4.1 **General (including overall assessments of the “problem”)**
 - 4.2 **Interactions in marine environments**
 - 4.3 **Interactions in freshwater environments**
 - 4.4 **Mitigation measures**
 - 4.5 **Population control measures**
 - 4.6 **Wider governance issues**

1) **Broad studies/literature**

Carss, D. N. 2004. Reducing the conflict between cormorants and fisheries on a pan-European scale. REDCAFE Final Report. Report of a Concerted Action funded by the European Union. Study contract no. Q5CA-2000-31387. 169 pp.

- Major European study. Formed foundation to INTERCAFE

Cramp, S. and Simmons, K. E. L. (eds) 1977. Cormorant *Phalacrocorax carbo*. Pp 200–207 in The birds of the western Palearctic. Vol. 1. Oxford University Press, Oxford.

- Standard text book

Hatch, J. J., Brown, K. M., Hogan, G. G. and Morris R. D. 2000. Great cormorant *Phalacrocorax carbo*. Birds of North America (Poole, A. and Gill, F. Eds.), No. 553. 32 pp.

- Standard text book. This species has only a limited range on the coasts of the NW Atlantic and interactions with fisheries have received little attention there. Over much of North America the counterpart to the cormorant in Europe is the double-crested cormorant which interacts with fisheries intensely (Hatch and Weseloh 1999—see below).

Hatch, J. J. and Weseloh, D. V. 1999. Double-crested cormorant (*Phalacrocorax auritus*). The Birds of North America, No.441.

- Standard text book—see above.

Keller, T., Carss, D., Helbig, A. J., Flade, M. (eds.) 2004. Cormorants: ecology and management at the start of the 21st Century: proceedings of the 5th International Conference on Cormorants, Freising December 2000. Die Vogelwelt, 124, Supplement

- Conference papers, individual papers included as relevant below

Moran Committee. 2001. Cormorants: the facts. Moran Committee, London. Available online at www.environment-agency.gov.uk. 4pp.

- Agreed balanced report from UK NGO and fishing interests

Nelson, J. B. 2005. Pelicans, cormorants and their relatives. Oxford University Press, Oxford. 661 pp.

- Standard text book

Nettleship, D. N. and Duffy, D. C. (eds) 1995. The double-crested cormorant: biology, conservation and management. Colonial Waterbirds, 18 (Special Publication 1). 256 pp.

- Series of papers on related ecologically equivalent North American species

van Dam, C. and Asbirk, S. (eds.) 1997. Cormorants and human interests. Informatie Kennis Centrum Natuurbeheer, Wageningen. 151 pp

- Wide background study

Wires, L.R., F.J. Cuthbert, D.R. Trexel and A.R. Joshi. 2001. Status of the double-crested cormorant (*Phalacrocorax auritus*) in North America. Final Report to USFWS. 359pp. available at: <http://digitalrepository.fws.gov/cgi-bin/showfile.exe?CISOROOT=/natdiglib&CISOPTTR=6745&filename=6746.pdf>

- Wide background study covering all aspects of the interaction of the ecologically equivalent species to great cormorant in North America

2) Demography

2.1 Sub-species

Carss, D. N. and Ekins, G. R. 2002. Further European integration: mixed sub-species colonies of great cormorants *Phalacrocorax carbo* in Britain - colony establishment, diet, and implications for fisheries management. *Ardea*, 90: 23–41.

- Evidence that the two European sub-species of cormorant can breed in the same colony, and that fisheries interactions are occurring with both sub-species

Goostrey, A., Carss, D. N., Noble, L. R. and Piertney, S. B. 1998. Population introgression and differentiation in the great cormorant *Phalacrocorax carbo* in Europe. *Molecular Ecology*, 7: 329–338.

- Separation of the two sub-species

Marion, L. 1995. Where two subspecies meet: origin, habitat choice and niche segregation of Cormorants *Phalacrocorax carbo carbo* and *P. c. sinensis* in the common wintering area (France) in relation to breeding isolation in Europe. *Ardea*, 83: 103–14.

- Title is good summary

Marion, L. and Le Gentil, J. 2006. Ecological segregation and population structuring of the cormorant *Phalacrocorax carbo* in Europe, in relation to the recent introgression of continental and marine subspecies. *Evolutionary Ecology*, 20: 193–216.

- Some differences between the two sub-species of cormorant still exist.

Newson, S. E., Hughes, B., Russell, I. C., Ekins, G. R. and Sellers, R. M. 2004. Sub-specific differentiation and distribution of great cormorants *Phalacrocorax carbo* in Europe. *Ardea*, 92: 3–10.

- Title is good summary

Winney, B. J., Litton, C. D., Parkin, D. T. and Feare, C. J. 2001. The subspecific origin of the inland breeding colonies of the cormorant *Phalacrocorax carbo* in Britain. *Heredity*, 86: 45–63.

- Cormorants from both sub-species breed in Britain

2.2 Breeding population size, trends, distribution

Population that uses EU in winter breeds also in Norway, western Russia, western Ukraine, Moldova, non-EU Balkan countries and Switzerland. If Cyprus (winter population <1000 individuals) included then also need knowledge in all other non-EU Black Sea states.

Bregnballe, T. and Gregersen, J. 1997. Changes in growth of the breeding populations of cormorants *Phalacrocorax carbo sinensis* in Denmark. *Supplemento alle Ricerche di Biologia della Selvaggina*, 26: 31–46.

- Title is good summary

Debout, G., Røy, N. and Sellers, R. M. 1995. Status and population development of cormorants *Phalacrocorax carbo carbo* breeding on the Atlantic coast of Europe. *Ardea*, 83: 47–59.

- Title is good summary (but note date)

Engström, H. 2001. The occurrence of the great cormorant *Phalacrocorax carbo* in Sweden, with special emphasis on recent population growth. *Ornis Svecica*, 11: 155–170.

- Rapid recent population growth in Sweden (in 2001)

Hagemeijer, W. J. M. and Blair, M. J. 1997. Cormorant. Pp 34–35 in *The EBCC atlas of European breeding birds: their distribution and abundance*. T. & A. D. Poyser, London.

- Standard text (but note date)

Lehikoinen, A. 2006. Cormorants in the Finnish archipelago. *Ornis Fennica* 83:34–46.

- Ten pairs first bred in 1996, rapid growth to nearly 3000 pairs in 2004. Large colonies did better than smaller colonies

Marion, L. 1997. Le Grand Cormoran en Europe: dynamique des populations et impacts. In: Clergeau, Ph. Ed. *Oiseaux à Risques*. INRA: 133–178.

- French review of population growth and impacts in Europe

Marion, L. 2003. Recent development of the breeding and wintering population of great cormorants (*Phalacrocorax carbo*) in France - Preliminary results of the effects of a management plan of the species. *Vogelwelt*, 124, Suppl.: 35–40.

- Management of cormorants has not had great effect in France

Parz-Gollner, R. 2003. Monitoring of the great cormorant *Phalacrocorax carbo sinensis* in Lower Austria (1996/97 - 1999/00): phenology, regional distribution and control actions. *Vogelwelt*, 124, Suppl.: 61–70.

- Austrian studies

Rusanen, P., Mikkola-Roos, M. and Asanti, T. 2003. Current research and trends of Finland's great cormorant *Phalacrocorax carbo sinensis* population. *Vogelwelt*, 124 Suppl.: 79–82.

- Finnish studies

Samusenko, I. and Kozulin, A. 1997. Population dynamics of cormorants and key-factors determining expansion in Belarus. *Supplemento alle Ricerche di Biologia della Selvaggina*, 26: 73–79.

- Studies in Belarus

van Eerden, M. R. and Gregersen, J. 1995. Long-term changes in the northwest European population of cormorants *Phalacrocorax carbo sinensis*. *Ardea*, 83: 61–79.

- Great population increase on continent

van Eerden, M. R., Koffijberg, K. and Platteeuw, M. 1995. Riding the crest of the wave: possibilities and limitations for a thriving population of migratory cormorants *Phalacrocorax carbo* in man-dominated wetlands. *Ardea*, 83: 1–9.

- Habitat alteration in wetlands (ponds etc.) offer opportunities for cormorants

Wernham, C. V., Armitage, M., Holloway, S. J., Hughes, B., Hughes, R., Kershaw, M., Madden, J. R., Marchant, J. H., Peach, W. and Rehfisch, M. M. 1999. Population, distribution, movements and survival of fish-eating birds in Great Britain. BTO Research Report no. 185. Department of the Environment, Transport and the Regions, London. ISBN 1-85112-3237.

- Numbers of cormorants have increased and more are occurring inland in UK

2.3 Winter population size, trends, distribution

Blanco, G., Velasco, T., Grijalbo, J. and Ollero, J. 1994. Great cormorant settlement of a new wintering area in Spain. *Colonial Waterbirds*, 17: 173–180.

- Increasing numbers of wintering cormorants in Spain

Marion, L. 1994. Evolution numérique et préférences écologiques des grands cormorans hivernant en France. *Alauda*, 62: 13–26.

- Increasing numbers of cormorants wintering in France

Marion, L. 2003. Recent development of the breeding and wintering population of great cormorants (*Phalacrocorax carbo*) in France - Preliminary results of the effects of a management plan of the species. *Vogelwelt*, 124, Suppl.: 35–40.

- Updated version of previous study–management having relatively little effect

Parz-Gollner, R. 2003. Monitoring of the great cormorant *Phalacrocorax carbo sinensis* in Lower Austria (1996/97 - 1999/00): phenology, regional distribution and control actions. *Vogelwelt*, 124, Suppl.: 61–70.

- Austrian studies–numbers increasing in winter in ice-free areas

Reymond, A. and Zuchuart, O. 1995. Perch fidelity in cormorants *Phalacrocorax carbo* outside the breeding season. *Ardea*, 83: 281–284.

- Cormorants tend to return to same roosting area in winter

Richner, H. 1995. Wintering cormorants *Phalacrocorax carbo carbo* in the Ythan estuary, Scotland: numerical and behavioural responses to fluctuating prey availability. *Ardea*, 83: 193–198.

- Relatively low numbers use estuary, but increase when prey more abundant

van Eerden, M. R. and Munsterman, M. J. 1986. Importance of the Mediterranean for wintering cormorants *Phalacrocorax carbo sinensis*. *Mediterranean marine avifauna* (eds MEDMARAVIS and X. Monbailliu), pp. 123–141. Springer, Berlin.

- Summarises Mediterranean studies, but note date

van Eerden, M. R. and Munstermann, M. J. 1995. Sex and age dependent distribution in wintering cormorants *Phalacrocorax carbo sinensis* in western Europe. *Ardea*, 83: 285–298.

- Some differentiation of age and sex distributions

2.4 Survival

Frederiksen, M. and Bregnballe, T. 2000. Evidence for density-dependent survival of adult cormorants from a combined analysis of recoveries and resightings. *Journal of Animal Ecology*, 69: 737–752.

- Birds feeding in high density areas do not survive as well as those at lower densities

Frederiksen, M. and Bregnballe, T. 2000. Diagnosing a decline in return rate of 1- year-old cormorants: mortality, emigration or delayed return? *Journal of Animal Ecology*, 69: 753–761.

- Understanding variation in recruitment to a colony

Frederiksen, M. and Bregnballe, T. 2001. Conspecific reproductive success affects age of recruitment in a great cormorant *Phalacrocorax carbo sinensis* colony. *Proceedings of the Royal Society of London, series B*, 268: 1519–1526.

- A colony that is producing more young attracts younger first-time breeders

Hénaux, V., Bregnballe, T. and Lebreton, J. D. 2007. Dispersal and recruitment during population growth in a colonial bird, the great cormorant *Phalacrocorax carbo sinensis*. *Journal of Avian Biology*, 38: 44–57.

- A growing population tends to disperse more

Wernham, C. V. and Peach, W. J. 1999. Use of ring recoveries to monitor long-term changes in the survival rates of British and Irish cormorants. *Bird Study*, 46 (suppl.): S189–197.

- Ring recoveries indicate that British cormorants are surviving longer than in earlier years

2.5 Movements

Bregnballe, T., Frederiksen, M. and Gregersen, J. 2006. Effects of distance to wintering area on arrival date and breeding performance in great cormorants *Phalacrocorax carbo*. *Ardea*, 94: 619–630.

- Later arrival leads to poorer breeding

Bregnballe, T., Frederiksen, M. and Gregersen, J. 1997. Seasonal distribution and timing of migration of cormorants *Phalacrocorax carbo sinensis* breeding in Denmark. *Bird Study*, 44: 257–276.

- The migrations of cormorants breeding in Denmark

Frederiksen, M., Bregnballe, T., van Eerden, M. R., van Rijn, S. and Lebreton, J. D. 2002. Site fidelity of wintering cormorants *Phalacrocorax carbo sinensis* in Europe. *Wildlife Biology*, 8: 241–250.

- Cormorants tend to return to areas where they previously wintered

Lekuona, J. M. and Campos, F. 2000. Site fidelity of cormorants *Phalacrocorax carbo* wintering in southern France and northern Spain. *Ring and Migration*, 20: 181–185.

- Cormorants tend to return to areas where they previously wintered

Wernham, C. Ekins, G and Sellers, R.M. 2002. Great cormorant (Cormorant) *Phalacrocorax carbo*. Pp 133–138 in: Wernham, C. V., Toms, M. P., Marchant, J. H., Clark, J. A., Siriwardena, G. M. and Baillie, S. R. *The migration atlas: movements of the birds of Britain and Ireland*. T. & A.D. Poyser, London.

- Comprehensive description of movements of cormorants within and to/from Britain and Ireland

2.6 Breeding biology and performance

Bregnballe, T. 2006. Age-related fledgling production in great cormorants *Phalacrocorax carbo*: influence of individual competence and disappearance of phenotypes. *Journal of Avian Biology*, 37: 149–157.

- Improvements in individual competence more important than disappearance of poorer breeders from population

Newson, S. E., Hughes, B., Hearn, R. and Bregnballe, T. 2005. Breeding performance and timing of breeding of inland and coastal breeding cormorants *Phalacrocorax carbo* in England and Wales. *Bird Study*, 52: 10–17.

- Inland breeding birds had higher breeding output due to better survival during late development

Schjørring, S. 2001. Ecologically determined natal philopatry within a colony of great cormorants. *Behavioral Ecology*, 12: 287–294.

Schjørring, S., Gregersen, J. and Bregnballe, T. 1999. Prospecting enhances breeding success of first-time breeders in the great cormorant, *Phalacrocorax carbo sinensis*. *Animal Behaviour*, 57: 647–654.

- Title is good description

Schjørring, S., Gregersen, J. and Bregnballe, T. 2000. Sex difference in criteria determining fidelity towards breeding sites in the great cormorant. *Journal of Animal Ecology*, 69: 214–223.

- Females more faithful to natal colony than males

3) Foraging biology

3.1 General

Carss, D. N., Bevan, R. M., Bonetti, A., Cherubini, G., Davies, J., Doherty, D., El Hili, A., Feltham, M. J., Grade, N., Grandeiro, J. P., Grémillet, D., Gromadzka, J., Harari, Y. N. R. A., Holden, T., Keller, T., Lariccia, G., Mantovani, R., McCarthy, T. K., Mellin, M., Menke, T., Mirowska-Ibron, I., Muller, W., Musil, P., Nazirides, T., Suter, W., Trauttmansdorff, J. F. G., Volponi, S. and Wilson, B. 1997. Techniques for assessing cormorant diet and food intake: towards a consensus view. *Supplemento alle Ricerche di Biologia della Selvaggina*, 26: 197–230.

- Key reference on sources of bias and advantages and disadvantages of various dietary study techniques.

Grémillet, D., Wilson, R. P., Gary, Y. and Storch, S. 1999. Three-dimensional space utilization by a marine predator. *Marine Ecology Progress Series*, 183: 263–273.

- Uses both radio-tracking and time-depth recorder to investigate the foraging ecology of breeding great cormorants

Hughes, B., Bevan, R. M., Bowler, J. M., Still, L., Carss, D. N., Marquiss, M., Hearn, R. D. and Bruce, J. H. 1999. Feeding behaviour of fish-eating birds in Great Britain. Report to Department of the Environment, Transport and the Regions, London. 249 pp.

- Comprehensive report on feeding by cormorants and other fish-eating birds in Great Britain

Kirby, J. S., Holmes, J. S. and Sellers, R. M. 1996. Cormorants *Phalacrocorax carbo* as fish predators: an appraisal of their conservation and management in Great Britain. *Biological Conservation*, 75: 191–199.

- Summary of feeding pressure from cormorants in Great Britain

3.2 Habitat selection

Grémillet, D., Argentin, G., Schulte, B. and Culik, B. M. 1998. Flexible foraging techniques in breeding cormorants *Phalacrocorax carbo* and shags *Phalacrocorax aristotelis*: benthic or pelagic feeding? *Ibis*, 140: 113–119.

- Cormorants tend to feed on benthic fish, but can feed socially in water column

Musil, P. and Janda, J. 1997. Habitat selection by the cormorant *Phalacrocorax carbo* on South Bohemian fishponds. *Ekologia Polska*, 45: 173–180.

- Prefer open to overgrown fishponds

Musil, P., Janda, J. and de Nie, H. 1995. Changes in abundance and selection of foraging habitat in cormorants *Phalacrocorax carbo* in the Southern Bohemia (Czech Republic). *Ardea*, 83: 247–254.

- Increase in numbers and use of open fish ponds

3.3 Feeding behaviour and ecology

Čech, M., Čech, P., Kubečka, J., Prchalová, M. and Draščík, V. 2008: Size selectivity in summer and winter diets of great cormorant (*Phalacrocorax carbo*): does it reflect season-dependent difference in foraging efficiency? *Waterbirds*, 31: 438–447.

- Much larger fish taken during winter than summer, probably due to deliberate selection—this causes apparent increase in foraging efficiency in winter

Dirksen, S., Boudewijn, T. J., Noordhuis, R. and Marteijn, E. C. L. 1995. Cormorants *Phalacrocorax carbo sinensis* in shallow eutrophic freshwater lakes: prey choice and fish consumption in the non-breeding period and effects of large-scale fish removal. *Ardea*, 83: 167–184.

Enstipp, M. R., Grémillet, D. and Jones D. R. 2007. Investigating the functional link between prey abundance and seabird predatory performance. *Marine Ecology Progress Series*, 331: 267–279.

Grémillet, D., Kuntz, G., Delbart, F., Mellet, M., Kato, A., Robin, J.-P., Chaillon, P.-E., Gendner, J.-P., Lorentsen S.-H. and Le Maho, Y. 2004. Linking the foraging performance of a marine predator with local prey abundance. *Functional Ecology*, 18: 793–801.

Johansen, R., Barrett, R. T. and Pedersen, T. 2001. Foraging strategies of great cormorants *Phalacrocorax carbo carbo* wintering north of the Arctic Circle. *Bird Study*, 48: 59–67.

- Deliberate selection of larger fish in winter enabled compensation for higher mid-winter energetic needs and shorter daylight

Strod, T., Arad, Z., Izhaki, I. and Katzir, G. 2005. Cormorants keep their power: visual resolution in a pursuit-diving bird under amphibious and turbid conditions. *Current Biology*, 14: R376–R377.

3.4 Diet and energetic

Čech, M., Čech, P., Kubečka, J., Prchalová, M. and Draščík, V. 2008: Size selectivity in summer and winter diets of great cormorant (*Phalacrocorax carbo*): does it reflect season-dependent difference in foraging efficiency? *Waterbirds*, 31: 438–447.

- Much larger fish taken during winter than summer, probably due to deliberate selection—this causes apparent increase in foraging efficiency in winter

Grémillet, D., Dey, R., Wanless, S., Harris, M. P. and Regel, J. 1996. Determining food intake by great cormorants (*Phalacrocorax carbo*) and European shags (*Phalacrocorax aristotelis*) with electronic weighing units. *Journal of Field Ornithology*, 67: 637–648.

Grémillet, D., Schmid, D. and Culik, B. 1995. Energy requirements of breeding great cormorants *Phalacrocorax carbo sinensis*. *Marine Ecology Progress Series*, 121: 1–9.

Grémillet, D., Storch, S. and Peters, G. 2000. Determining food requirements in marine top-predators: a comparison of three independent methods in great cormorants *Phalacrocorax carbo*. *Canadian Journal of Zoology*, 78: 1567–1579.

Grémillet, D., Wright, G. A., Lauder A., Carss, D. N. and Wanless, S. 2003. Modelling the daily food requirements of wintering great cormorants: a bioenergetics tool for wildlife management. *Journal of Applied Ecology*, 40: 266–277.

- Good model of food requirements

Keller, T. M. and Visser, G. H. 1999. Daily energy expenditure of great cormorants *Phalacrocorax carbo sinensis* wintering at Lake Chiemsee, southern Germany. *Ardea*, 87: 61–69.

Trapp, J. L., Lewis, S. J. and Pence, D. M. 1999. Double-crested Cormorant impacts on sport fish: literature review, agency survey, and strategies. p. 87–96. in M.E. Tobin (ed.) Symposium on Double-crested Cormorants: population status and management issues in the Midwest. USDA/APHIS Technical Bulletin No. 1879.

- Review of 25 studies on double-crested cormorant studies, 1923–1994. Wires *et al.* 2001 updated this review.

3.5 Effects of cormorants on fish stocks

Belyea, G. Y., Maruca, S. L., Diana, J. S., Schneeberger, P. J., Scott, S. J., Clark, R. D. and Ludwig, J. P. 1999. Impact of double-crested cormorant predation on the yellow perch population in Les Cheneaux islands of Michigan. p. 47-59. In M. E. Tobin [ed.] Symposium on double-crested cormorants: population status and management issues in the Midwest. USDA/APHIS Tech. Bull. No. 1879.

- Study of impact on a fishery. Found no appreciable effect of cormorants.

Britton, J. R., Harvey, J. P., Cowx, I. G., Holden, T., Feltham, M. J., Wilson, B. R., and Davies, J. M. 2003. Key factor analysis to assess cormorant depredation on inland fisheries in the UK. Pp. 14–27 in I. Cowx (ed), Interactions between fish and birds: implications for management. Oxford: Fishing News Books, Blackwell Science Ltd.

Burnett, J. A. D., Ringler, N. H., Lantry, B. F. and Johnson, J. H. 2002. Double-crested cormorant predation on yellow perch in the eastern basin of Lake Ontario. *Journal of Great Lakes Research*, 28: 202–211.

- Double-crested cormorants may cause decline of fish stocks. The number of subadult yellow perch consumed by cormorants indicated that the increase in mortality can be explained only by predation from cormorants.

EIFAC 1996. Summary report of the *ad hoc* working party on prevention and control of bird predation: effects of cormorant predation on fish populations. European Inland Fisheries Advisory Commission report, EIFAC/XIX/96/Inf. 11.

Johansen, R., Pedersen, T. and Barrett, R. T. 1999. Cormorants (*Phalacrocorax carbo carbo*) as predators in a cod (*Gadus morhua* L.) enhancement area in north Norway. Pp. 334–339 in Howell, B., Moksness, E. and Svasand, T. (eds) Stock enhancement and sea ranching, Fishing News Books, London.

- Study in a cod-enhancement area indicates that cormorants are an important source of mortality of cod in the enhancement area aged 0.5-4 years old.

Keller, T., Vordermeier, T., von Lukowicz, M. and Klein, M. 1997. The impacts of cormorants on fish stocks of several Bavarian water bodies with special emphasis on the ecological and economical aspects. *Supplemento alle Ricerche di Biologia della Selvaggina*, 26: 295–311.

Lantry, B. F., Eckert, T. H., Schneider, C. P. and Chrisman, J. R. 2002. The relationship between the abundance of smallmouth bass and double-crested cormorants in the eastern basin of Lake Ontario. *Journal of Great Lakes Research*, 28: 193–201.

- An increase of population of cormorants led to a decline in survival of young smallmouth bass.

Leopold, M. F., van Damme, C. J. G. and van der Veer, H. W. 1998. Diet of cormorants and the impact of cormorant predation on juvenile flatfish in the Dutch Wadden Sea. *Journal of Sea Research*, 40: 93–107.

- In summer 1992 and 1993, cormorant predation accounted for 49.5% and 27.3%, respectively, of the total stage mortality in 0-group plaice *Pleuronectes platessa*.

Marteijn, E. C. L. and Dirksen, S. 1991. Cormorants *Phalacrocorax carbo sinensis* feeding in shallow eutrophic freshwater lakes in The Netherlands in the non-breeding period: prey choice and fish consumption. Pp. 135–155 in Eerden, M. R. van and Zijlstra, M. Proceedings workshop 1989 on cormorants *Phalacrocorax carbo*. Rijkswaterstaat, Lelystad.

- Lack of overlap in diet of cormorants and catches of commercial fishermen mean that little effect of former on later in this study.

Mous, P. J. 2000. Interactions between fisheries and birds in IJsselmeer, The Netherlands. PhD Thesis Wageningen University. ISBN 90-5808-183-4.

- Cormorants affect the fisheries of the IJsselmeer through predation on perch and pikeperch.

Staub, E., Krämer, A., Müller, R. Ruhlé, Ch and Walter, J. 1992. Einfluss des Kormorans (*Phalacrocorax carbo*) auf Fischbestände und Fangerträge in der Schweiz. Schriftenreihe Fischerei, 50: 1–138.

- See below

Staub, E., Egloff, K., Krämer, A. and Walter, J. 1998. The effect of predation by wintering cormorants *Phalacrocorax carbo* on grayling *Thymallus thymallus* and trout (*Salmonidae*) populations: two case studies from Swiss rivers. Comment. Journal of Applied Ecology, 35: 607–610.

- Staub *et al.* (1992) reached the conclusion that cormorant predation was additional to natural mortality, Suter (1995b) considered it compensatory. This comment shows that Suter's paper masks a change in the age pyramid. Some statistical dispute also.

Suter, W. 1995a. Are Cormorants *Phalacrocorax carbo* wintering in Switzerland approaching carrying capacity? An analysis of increase patterns and habitat choice. Ardea, 83: 255–266.

Suter, W. 1995b. The effect of predation by wintering cormorants *Phalacrocorax carbo* on grayling *Thymallus thymallus* and trout (*Salmonidae*) populations: two case studies from Swiss rivers. Journal of Applied Ecology, 32: 29–46.

- Found no evidence to support predictions of negative effects on fish population dynamics from cormorant predation. Predation intensity positively correlated with yield. Angling effects need to be taken into account. See Staub *et al.* 1998 for comment.

Suter, W. 1997. Roach rules: shoaling fish are a constant factor in the diet of cormorants *Phalacrocorax carbo* in Switzerland. Ardea, 85: 9–27.

4) Human/fisheries interactions

4.1 General (including overall assessments of the 'problem')

Carss, D. N., Bell, S. and Marzano, M. 2009. Competing and coexisting with cormorants. Pp. 99–121 in Heckler, S. (ed.) Landscape, process and power: re-evaluating traditional environmental knowledge. Berghahn Books, New York.

- Cormorant-fisheries interactions occur at a local level and are probably best managed at that scale. Four case studies from REDCAFE and IMEW are used as illustrations. Inter-disciplinary research and understanding is needed to understand the problems and find solutions. Good summary of the various cormorant-fisheries issues.

Duffy, D. C. 1995. Why is the double-crested cormorant a problem? Insights from cormorant ecology and human sociology. Colonial Waterbirds, 18 (Special Publication 1): 25–32.

- Long history of interaction between cormorants and fishermen; more recent interaction with fish farmers. Cormorants are opportunist, adaptable and highly attracted to food concentrations. Little evidence of effects at population scale, probably are effects at local scale. Cormorants are very susceptible to disturbance at colonies, but difficult to link colony to individual problem areas and disturbance may just lead to dispersion into smaller colonies.

Engström, H. 2001. Effects of great cormorant predation on fish populations and fishery. PhD Thesis, University of Uppsala. 39 pp.

Wires, L. R., Carss, D. N., Cuthbert, F. J. and Hatch, J. J. 2003. Transcontinental connections in relation to cormorant-fisheries conflicts: perceptions and realities of a "bête noire" (black beast) on both sides of the Atlantic. Vogelwelt 124, Suppl.: 389-400.

- A good summary of the interaction

4.2 Interactions in marine environments

Bildsøe, M., Jensen, I. B. and Vestergaard, K. S. 1998. Foraging behaviour of cormorants *Phalacrocorax carbo* in pound nets in Denmark: the use of barrel nets to reduce predation. *Wildlife Biology*, 4: 129–136.

Eschbaum, R., Veber, T., Vetemaa, M. and Saat, T. 2003. Do cormorants and fishermen compete for fish resources in the Väinameri (eastern Baltic) area ? Pp. 72–83 in: Cowx, I. G. ed. *Interactions between fish and birds: implications for management*. Fishing News Books.

4.3 Interactions in freshwater environments

Adamek, Z., Klinger, H. and Staub, E. 1997. Cormorants in Europe—the evaluation of EIFAC/FAO questionnaire campaign. *Supplementi alle Ricerche di Biologia della Selvaggina*, XXVI: 347–353.

Freshwater aquaculture

Noakes, D. J., Fang, L., Hipel, K. W. and Kilgour, D. M. 2003. An examination of the salmon aquaculture conflict in British Columbia using the graph method for conflict resolution. *Fisheries Management*, 10: 123–137.

- As much about conflict resolution techniques as cormorant-fisheries

Freshwater 'put and take'

Stewart, D. C., Middlemas, S. J., Gardiner, W. R. Mackay, S. and Armstrong, J. D. 2005. Diet and prey selection of cormorants (*Phalacrocorax carbo*) at Loch Leven, a major stocked trout fishery. *Journal of Zoology* 267: 191–201.

Freshwater angling

Davies, J. M. and Feltham, M. J. 1997. Investigation into the impacts of cormorants *Phalacrocorax carbo carbo* on angling catches on a river system. *Ekologia Polska*, 45: 273–278.

de Nie, H. 1995. Changes in inland fish populations in Europe in relation to the increase of the Cormorant *Phalacrocorax carbo sinensis*. *Ardea*, 83: 115–122.

Feltham, M. J., Davies, J. M., Wilson, B. R., Holden, T., Cowx, I. G., Harvey, J. P. and Briton, J. R. 1999. Case studies of the impact of fish-eating birds on inland fisheries in England and Wales. Report to Ministry of Agriculture, Fisheries and Food, London. 406 pp.

Forney, J. 1993. Some observations on cormorant-fish interactions on Oneida Lake. *New York Chapter—American Fisheries Society Newsletter*, September 1993, pp. 8–13.

- Start of a series of studies that showed considerable impact of double-crested cormorants on the fish population of a lake.

Glahn, J. F., Harrel, J. B. and Vyles, C. 1998. The diet of wintering double-crested cormorants feeding at lakes in the southeastern United States. *Colonial Waterbirds* 21: 446–452.

- Study of impact on a fishery. Found no appreciable/low effect of cormorants.

NYSDEC Special Report 1999. Final Report: To assess the impact of Double-crested Cormorant predation on the smallmouth bass and other fishes of the eastern basin of Lake Ontario. New York State Department of Environmental Conservation, Bureau of Fisheries, and United States Geological Survey, Biological Resources Division. February 1.

Rudstam, L. G., VanDeValk, A. J., Adams, C. M., Coleman, J. T. H., Forney, J. L., Richmond, M. E. 2004. Cormorant predation and the population dynamics of walleye and yellow perch in Oneida lake. *Ecological Applications*, 14: 149–163.

- Good description of study of double-crested cormorants on a lake where substantial impact was evident.

Russell, I. C., Dare, P. J., Eaton, D. R. and Armstrong, J. D. 1996. Assessment of the problem of fish-eating birds in inland fisheries in England and Wales. Report to Ministry of Agriculture, Fisheries and Food, London. 130 pp.

Simmonds, R. L. Jr., Zale, A. V. and Leslie, D. M. Jr. 2000. Modeled effects of double-crested cormorant predation on simulated reservoir sport and forage fish populations in Oklahoma. *North American Journal of Fisheries Management*, 20: 180–191.

- Modelled impacts (based on scientific data) showed substantial impact of cormorants on stocks caught by angling. This effect disappeared in second year due to natural reduction in cormorant numbers.

VanDeValk, A.J., Adams, C. M., Rudstam, L. G., Forney, J. L., Brooking, T. E., Gerken, M. A., Young, B. P. and Hooper, J. T. 2002. Comparison of angler and cormorant harvest of walleye and yellow perch in Oneida Lake, New York. *Transactions of the American Fisheries Society*, 131: 27–39.

Freshwater other

Engström, H. 2001. Long-term effects of cormorant predation on fish communities and fishery in a freshwater lake. *Ecography*, 24: 127–138.

4.4 Mitigation measures

Evans, K., Impey, A., and Gough, S. 1997. A preliminary study of fish refuges as a means of mitigating perceived cormorant damage to a put and take fishery. BTO Research Report, 184. British Trust for Ornithology, Thetford.

Marquiss, M. and Carss, D. 1994. Fish-eating birds: assessing their impact on freshwater fisheries. Institute of Terrestrial Ecology R&D report 15. National Rivers Authority, Bristol. 15pp.

- Dietary studies suggest little damage to fisheries over much of range in UK. Some damage to fish populations and some damage to small enclosed systems. Evidence is mostly anecdotal. No study has shown that killing birds prevents damage to fisheries. Current strategy of only licensing kills when evidence of serious damage available, and further research considered appropriate.

Marquiss, M., Carss, D. N., Armstrong, J. D. and Gardiner, R. 1998. Fish-eating birds and salmonids in Scotland. The Scottish Office Agriculture and Fisheries Department, Edinburgh. 156 pp.

McKay, H. V., Furness, R. W., Russell, I. C., Parrott, D., Rehfish, M. M., Watola, G., Packer, J., Armitage, M., Gill, E. and Robertson, P. 1999. The assessment of the effectiveness of management measures to control damage by fish-eating birds to inland fisheries in England and Wales. Report to Ministry of Agriculture, Fisheries and Food, London. 254 pp.

Moran Committee. 2002. Protecting your fishery from cormorants. Moran Committee, London. Available online at www.environment-agency.gov.uk. 24 pp.

- A report by both those concerned about cormorant impact and nature conservationists. Attempts to achieve a balance with some success.

Russell, I. C., Goldsmith, D., Cook, A. C., Parrott, D., Allcock, J. and Barry, J. 2005. Habitat use by roach (*Rutilus rutilus* L.) and perch (*Perca fluviatilis* L.) in response to the presence of cormorants (*Phalacrocorax carbo* L.) and artificial refuges. Pp. 211–222 in: Spedicato, M. T., Lembo, G. and Marmulla, G. (eds.) *Aquatic telemetry: advances and applications*. Proceedings of the fifth conference on fish telemetry. Rome, FAO/COISPA.

Russell, I., Parrott, D., Ives, M., Goldsmith, D., Fox, S., Clifton-Dey, D., Prickett, A. and Drew, T. 2008. Reducing fish losses to cormorants using artificial fish refuges: an experimental study. *Fisheries Management and Ecology*, 15: 189–198.

4.5 Population control measures

Belant, J. L., Tyson, L. A. and Mastrangelo, P. A. 2000. Effects of lethal control at aquaculture facilities on populations of piscivorous birds. *Wildlife Society Bulletin*, 28: 379–384.

Bédard, J., Nadeau, A. and Lepage, M. 1995. Double-crested cormorant culling in the St. Lawrence River estuary. *Colonial Waterbirds*, 18 (Special Publication 1): 78–85.

- History of reducing a population from c18 000 pairs to 12 000 pairs using spraying of eggs (to kill them) and shooting about 2000 birds. Continuing control measures required to reduce to 10 000 pairs and maintain there.

Bédard, J., Nadeau, A. and Lepage, M. 1999. Double-crested cormorant culling in the St. Lawrence River estuary: results of a 5-year program. Symposium on double-crested cormorants: population status and management issues in the Midwest (ed. M. E. Tobin), pp. 147–154. United States Department of Agriculture, Animal and Plant Health Inspection Service.

Bregnballe, T., Goss-Custard, J. D. and Durell, S. E. A. le V. dit 1997. Management of cormorant numbers in Europe: a second step towards a European conservation and management plan. In: van Dam, C. and Asbirk, S. eds *Cormorants and Human Interests*. IKC natuur beheer, Wageningen: 62–122.

Frederiksen, M., Lebreton, J.–D. and Bregnballe, T. 2001. The interplay between culling and density-dependence in the great cormorant: a modelling approach. *Journal of Applied Ecology*, 38: 617–627.

- Density dependence means that culling has to be intensive and continuous to reduce cormorant populations; however a reduction in population may not affect adverse interaction with fishing/fish farming interests and actions to control or reduce damage probably more cost-effective.

Frederiksen, M., Lebreton, J. D. and Bregnballe, T. 2003. Modelling the effect of winter culls on great cormorant *Phalacrocorax carbo sinensis* population size in Europe: the importance of spatial variability in culling intensity. *Die Vogelwelt*, 124 (suppl.): 325–330.

Green, R. E. 2008. Assessing the impact of culling on population size in the presence of uncertain density dependence: lessons from a great cormorant population. *Journal of Applied Ecology*, 45: 1683–1688.

- Demonstrates weaknesses of Smith *et al.* 2008 who made estimates of the strength of density dependence without allowing for count error. Density-independent effects not allowed for either. Smith *et al.* study unreliable for decisions on population management. Culled populations may tend to decline more rapidly than expected and may not stabilise.

Keller, T. and Lanz, U. 2003. Great cormorant *Phalacrocorax carbo sinensis* management in Bavaria, southern Germany - What can we learn from seven winters with intensive shooting? *Vogelwelt*, 124, Suppl.: 339–348.

Keller, T., von Lindeiner, A. and Lanz, U. 1998. Cormorant management in Bavaria, southern Germany—shooting as a proper management tool? *Cormorant Research Group Bulletin*, 3: 11–15.

Marion, L. 2003. Recent development of the breeding and wintering population of Great Cormorants (*Phalacrocorax carbo*) in France - Preliminary results of the effects of a management plan of the species. *Vogelwelt*, 124, Suppl.: 35–40.

McKay, H. V., Furness, R. W., Russell, I. C., Parrott, D., Rehfish, M. M., Watola, G., Packer, J., Armitage, M., Gill, E. and Robertson, P. 1999. The assessment of the effectiveness of management measures to control damage by fish-eating birds to inland fisheries in England and Wales. Report to Ministry of Agriculture, Fisheries and Food, London. 254 pp.

Parz-Gollner, R. 2003. Monitoring of the great cormorant *Phalacrocorax carbo sinensis* in Lower Austria (1996/97 - 1999/00): phenology, regional distribution and control actions. *Vogelwelt*, 124, Suppl.: 61–70.

Smith G. C., Parrott D. and Robertson P. A. 2008. Managing wildlife populations with uncertainty: cormorants *Phalacrocorax carbo*. *Journal of Applied Ecology*, 45: 1675–1682.

- Authors of a UK report that led to an increase in culling to control damage to inland fisheries in England. Criticised by Green *et al.* (2008).

4.6 Wider governance issues

Rauschmayer, F. and Behrens, V. 2008. Legitimacy of Species Management. The Great Cormorant in the EU. Pp. 55–74 in Keulartz, J. and Leistra, G. (eds.): *Legitimacy in European Nature Conservation Policy: Case Studies in Multilevel Governance*, Springer.