Guidelines for Constructing and Deploying Common Loon Nesting Rafts

Christopher R. DeSorbo[1,*], Jeff Fair[2], Kate Taylor[3], William Hanson[4], David C. Evers[1], Harry S. Vogel[3], and John H. Cooley, Jr.[3]

Abstract - Artificial nesting islands, or rafts, are deployed in *Gavia immer* (Common Loon) territories to lessen the incidence of nest failures due to mammalian predation and water-level fluctuations. The effectiveness of this management tool has been demonstrated in other studies; however, improper construction and deployment can result in lowered nesting success. Despite widespread use of rafts, detailed construction plans and a protocol for deployment are lacking. We present the raft construction and deployment protocol currently followed by organizations specializing in loon management and research in New Hampshire and Maine, and discuss emerging concerns related to management using rafts.

Introduction

Gavia immer Brünnich (Common Loon, loon hereafter) is a highly charismatic piscivore that breeds throughout Canada and in the northern tier of the United States. Loon populations declined throughout much of their range during the twentieth century due to a combination of pressures such as shooting mortality, habitat loss and related human disturbance, and anthropogenically increased predator populations (see review in Evers 2007 and McIntyre and Barr 1997). While loon populations have recovered in portions of their range, anthropogenic factors including water-level fluctuations, predation, and contaminants continue to limit populations in regions of the northeastern US (DeSorbo et al. 2007, Evers 2007, Evers et al. 2008).

Limited terrestrial locomotion and resultant vulnerability to predation on land predispose Common Loons to construct nests at shoreline for aquatic escape (McIntyre 1988, Vermeer 1973). Loons generally prefer to nest on islands rather than mainland shorelines (McIntyre 1975, Olson and Marshall 1952, Titus and Van Druff 1981, Vermeer 1973), due to a lower potential for mammalian predation and human disturbance. Fluctuations in water level will cause nest failures regardless of nest location by flooding nests or stranding them some distance from the water (Barr 1986, Fair 1979, Reiser 1988, Vermeer 1973), and such failures have been noted to limit loon population productivity in numerous regions (Barr 1986, DeSorbo et al. 2007, Fair 1979, Merrie 1996, Sutcliffe 1979).

[1]BioDiversity Research Institute, 19 Flaggy Meadow Road, Gorham, ME 04038. [2]Fairwinds Wildlife Services, PO Box 2947, Palmer, AK 99645.[3] Loon Preservation Committee, 183 Lee's Mills Road, PO Box 604, Moultonborough, NH 03254. [4]FPL Energy Maine Hydro, 150 Main Street, Lewiston, ME 04240. [*]Corresponding author - chris.desorbo@briloon.org.

In the late 1960s, Mathisen (1969) noted that loons would nest on sedge mats intended for waterfowl. Within the next decade, biologists began placing sedge mats and cedar log rafts within loon territories, and loons readily nested and produced young from them (McIntyre and Mathisen 1977, Sutcliffe 1979). Conservation organizations subsequently increased raft deployments on New England lakes and partnered with industry to manage loon populations on hydroelectric reservoirs, where nest failures due to water-level fluctuation are common. Success of raft management programs on hydroelectric reservoirs led to their incorporation into hydroelectric project licenses overseen by the Federal Energy Regulatory Commission (FERC) (DeSorbo et al. 2007, Fair 1979, Fair and Poirier 1993). Similar management programs involving rafts have also been implemented on hydroelectric reservoirs and recreational fishing lakes in Scotland for *Gavia arctica* Linnaeus (Arctic Loon) and *Gavia stellata* Pontoppidan (Red-throated Loon) (Merrie 1979, 1996). Rafts have become a standard management tool used to varying degrees by conservation organizations, industry, and state and federal wildlife agencies on natural and impounded lakes throughout the northeastern (i.e., ME [FPL Energy Maine Hydro, BioDiversity Research Institute, Loon Preservation Committee], NH [Loon Preservation Committee, FPL Energy Maine Hydro], MA [Massachusetts Division of Recreation and Conservation] ,VT [Vermont Loon Recovery Project, Vermont Institute of Natural Science], NY [Wildlife Conservation Society]), midwestern (i.e., MI [Michigan Loon Preservation Association], WI [Wisconsin Department of Natural Resources, Project, Sigurd Olson Institute], MN [Minnesota Division of Ecological Services), and northwestern (WA [Loon Lake Association, Washington Department of Fish and Wildlife, US Forest Service]) US. Groups managing loon populations in the northeastern US (ME, NH, VT, NY) maintain generally similar raft construction and deployment protocols via discussion at annual meetings of the Northeastern Loon Working Group (www.BRILoon.org).

It has been clearly demonstrated that rafts can improve nest success for loons nesting on lakes with (DeSorbo et al. 2007, Hancock 2000, Merrie 1996) and without (McIntyre and Mathisen 1977, Piper et al. 2002) significant fluctuations in water level. Rafts have played a substantial role in the loon population recoveries in New England. For example, approximately 21% of the loon chicks hatched in New Hampshire 1977–2005 were from rafts (K. Taylor, unpubl. data). Rafts are particularly effective in sustaining population productivity of loons on hydroelectric reservoirs in Maine and New Hampshire (DeSorbo et al. 2007), and similar findings have been reported for other loon species in Europe (Hancock 2000, Merrie 1996). Due to these successes, rafts are increasingly considered as a management solution to many anthropogenic pressures on loon populations. However, while raft construction plans have been outlined for designs targeting Arctic and Red-throated Loons (i.e., wire mesh plastic containers, wood-reinforced polystyrene blocks; Hancock 2000, Merrie 1996), no construction plans or protocols outlining when raft deployment is warranted are available for those typically used for Common Loons, despite widespread use. In this paper, we draw upon data and experience gathered from over two decades of loon management on natural lakes and hydroelectric reservoirs in the northeastern US by non-government organizations and industry. We present: (1) an established protocol to evaluate the need for loon raft deployment; (2) detailed plans for cedar-log raft construction; (3) guidelines for raft deployment, monitoring, and removal; and (4) a discussion of potential negative consequences associated with raft deployment based on extensive research in this and other studies conducted throughout North America and Europe.

Study Area and Methods

We present the protocol used to construct and deploy cedar log-style rafts throughout New Hampshire and northwestern Maine by conservation organizations (BioDiversity Research Institute, Loon Preservation Committee) and industry (FPLE Maine Hydro). The protocol represents cumulative knowledge developed over 1977–2006 from >150 territories (>500 raft-years) and generally reflects information agreed upon by partners in the Northeastern Loon Study Working Group. Variations of the cedar log construction design presented here have been used with comparable effectiveness (Belant and Anderson 1991, DeSorbo et al. 2007, Piper et al. 2002, Sutlciffe 1979). Other raft designs include anchored sedge mats (Mathisen 1969, McIntyre and Mathisen 1977), wire-mesh/plastic containers or wood-reinforced polystyrene blocks (for use with *G. stellata and G. arctica*; Hancock 2000, Merrie 1979), and PVC pipe frames. For this study, we considered the construction design and deployment of a raft to be effective if a loon pair built a nest on the raft and the site and method of deployment did not limit the ability of the pair to incubate the eggs to the point of hatching.

Loon pairs managed with rafts resided on natural and impounded lakes (reservoirs) throughout New Hampshire and western Maine. Natural lakes ranged in size from 14.5–18,043 ha, while reservoirs included hydroelectric water storage and peaking facilities (DeSorbo et al. 2007) ranging in size from 117–30,542 ha. Most study lakes were surrounded by mixed hardwood and conifer forests. Collectively, these lakes displayed a broad range of developmental and human pressures.

Results and Discussion

Protocol for evaluating need for rafts

Loon territories require individual evaluation to determine their suitability for management using rafts. Regular surveys are required to locate loon territories and document nest failures prior to deploying rafts. Recommended loon survey methodologies are presented elsewhere (DeSorbo et al. 2007, Piper et al. 2002). Current protocols call for deploying rafts only in established loon territories (an area of water defended by a loon pair for 4 consecutive weeks during the breeding season for 3 consecutive years; Evers 2001) in which shoreline predation or water-level fluctuation has caused nest failure for ≥3 consecutive years. Rafts can be deployed more readily when water levels increase >15 cm or decrease >30 cm during the loon nesting season (1 June–15 July in our study area) and nest failures due to water level fluctuations are common (Barr 1986, Belant and Anderson 1991, DeSorbo et al. 2007, Fair 1979, Sutcliffe 1979). Areas exhibiting extensive shoreline development are generally avoided because negative relationships have been noted between such factors and nest success (DeSorbo et al. 2007, Heimberger et al. 1983, Spillman 2006).

Most rafts used by loons are used during the first three years of deployment (DeSorbo et al. 2007, Hancock 2000, Merrie 1996, Piper et al. 2002). Some pairs may not use rafts due to a strong preference for natural sites. Thus, raft removal may be warranted if loons choose or successfully nest on natural sites over rafts for ≥3 consecutive years.

Raft construction

Uniform diameter dry cedar logs were notched 15–20 cm from each end with an axe or chainsaw. Notched ends were articulated to form a square and nailed together using galvanized spikes (Fig. 1). Green or black plastic snow/safety fence (BF Products, Inc., product #BF 236A, mesh size 13 mm) with holes ≤7.5 cm diameter (to prevent entrapment of young) was stretched tightly across the frame, extended slightly underneath each log to seclude

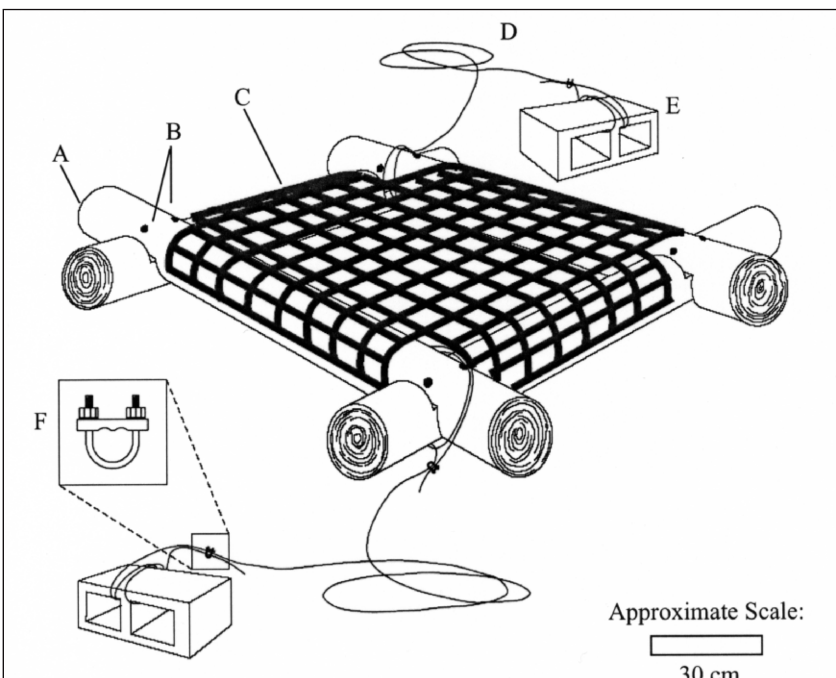

Figure 1. Construction of a Common Loon (*Gavia immer*) raft. See Table 1 for accurate scaling. Inset shows cable clamps used to attach cables to anchor blocks. Mesh size of plastic snow fence not to scale. Consult text and Table 1 to avoid entrapment of young.

sharp edges, and nailed to the top surface with galvanized roofing nails. Plastic-coated cables were fastened to cinder block anchors from diagonally opposing corners of each raft using cable clamps. Anchor-line length (>2 times water depth, typically 4–10 m) was determined by depth and the extent of water-level fluctuations within territories. Some rafts were fitted with a wire mesh arched over the raft and covered in Nylon "leaf cut" hunting blind camouflage (e.g., Bushy Ridge Camouflage Systems™) to obscure nests from avian predators (Fair 1993; Fig. 2) and decrease the flushing sensitivity of incubating loons (C.R. DeSorbo, pers. observ.). Wire fencing was attached to rafts using galvanized staples, and camouflage was attached to fencing using plastic cable ties. Additionally, some authors add ramps made of wood or 30-cm fire hose to allow newly hatched young to return to rafts while adults incubate the remaining eggs (Belant and Anderson 1991, Piper et al. 2002). Dimensions and costs of the components needed to construct a raft and optional avian cover are listed in Table 1.

Vegetation and nest material. Available vegetation was used on rafts to represent natural nesting habitat. Preference was given to vegetation that can grow on rafts such as *Sphagnum* spp. (peatmosses), *Carex* spp. (sedges), and *Calamagrostis* spp. (grasses, e.g., *Calamagrostis canadensis* (Michx.) Beauv. [bluejoint grass]) (www.itis.usda.gov) abundant in lacustrine habitats in the northeastern US. Grassy sod (sections approximately 15–30 cm^2) was removed from local shoreline habitat, and after removing excess soil, the sections were arranged around the perimeter of the platform to buffer interior materials from wind and wave erosion. Lastly, approximately 30–60 cm^3 of additional nesting material (e.g., grass, moss, humus) was piled in the center of each raft for loons to fashion into a nest. Rafts exhibiting predominantly grassy vegetation may attract grazing or, occasionally, nesting *Branta*

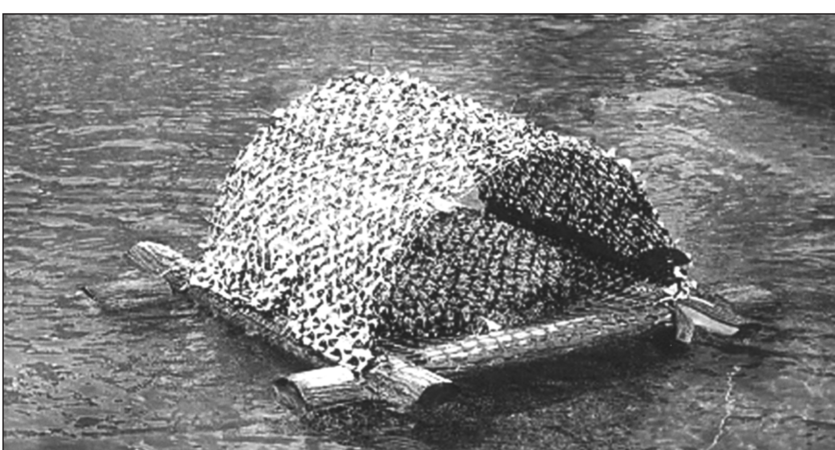

Figure 2. A Common Loon (*Gavia immer*) raft on Mooselookmeguntic Lake, ME. Raft includes optional avian cover to obscure eggs and incubating loons from aerial predators and humans. Water depth in this case is less than typical for raft deployments and reflects water-level drawdowns that occurred after hatching. Photo credit: Lucas Savoy.

canadensis Linnaeus (Canada Goose) in some areas, potentially lessening their attractiveness as nest sites to loons (H. Vogel, pers. observ.). Commercial sphagnum moss or straw mixed with heavier vegetation to lessen erosion can be used as nesting material where sensitive plant communities or restricted shoreline access limits collection.

Buoyancy. Logs that do not dry adequately from deployment in previous years, "green" cedar logs (i.e., recently cut), or excessively heavy nesting material can cause rafts to float low in the water, resulting in nest failure due to flooding of eggs. In such cases, dry cedar logs, sealed plastic bottles or nonpolluting dock or insulation foam may be attached beneath the frame. Buoyancy is sufficient if half the log framework is above the waterline. Nesting materials, especially the nest bowl, should remain free from standing water.

Raft deployment, monitoring, and removal

Raft deployment. Loons arrive shortly after ice out in mid-to-late April in New Hampshire and Maine, and nest initiations typically begin in late May to early June. Rafts were deployed immediately after ice out, optimally at least 1–2 weeks prior to the onset of seasonal nesting activity. Raft lines, anchors, logs, and snow fencing were inspected for wear or winter damage

Table 1. Materials list and approximate cost required to construct one loon nesting raft.

ID[A]	Item	Quantity	Dimensions[B]	Cost/unit[C]	Total cost[C]
A	Cedar logs	4	1.5–2.0 m (L), 15–30 cm (D)	9.00 ea.	36.00
B	Galvanized spikes	8	17.8 cm (L), 7.5 mm (D)	0.40 ea.	3.20
C	Plastic snowfence[D,E]	1	1.6 m (L) x 1.2 m (W), 13-mm square mesh	3.22/m	5.16
D	Plastic-coated wire cable	2	7 m (L), 6.4 mm (D) 3–4.8-mm steel core (D)	1.16/m	16.24
E	Cinder blocks	2	11 kg; 39 cm (L) x 19 cm (H) x 11 cm (W)	1.68 ea.	3.36
F	Cable clamps[F]	4	6.4 mm	0.79 ea.	3.16
n/s	Galvanized roofing nails	40	3.0 cm (L)	2.15/100	2.15
			Raft materials total:		69.27
Avian Cover:					
n/s	Wire fencing[D]	1	3.0 m (L) x 1 m (W), 3.5 mm wire (D), 6.0-cm squares)	3.0/m	9.00
n/s	Camouflage material[D]	1	2.5 m (L) x 1 m (W)	8.06/m	20.15
n/s	Galvanized fence staples	10	2.5 cm (L)	2.15/100	2.15
n/s	Plastic cable ties	30	10.2 cm (L)	2.00/40	2.00
			Avian cover materials total:		33.30
			Raft + avian cover materials total:		102.57

[A]Identifier letters correspond with those on Figure 1. n/s = not shown on Figure 1.
[B]L = length, W = width, H = height, D = diameter.
[C]Costs given in US dollars, in Maine, June 2007.
[D]Linear meter cost calculated from cost of typical minimum quantity available for purchase, typically 15–30 m.
[E]Mesh size shown on Figure 1 not to scale. Consult text and table for appropriate mesh size to avoid entrapment of young.
[F]Carabiners ($2.00 ea.) can be used to join anchor lines to raft, allowing anchor detachment for transport and storage.

(i.e., decay, holes, cracks) before deployment. It is highly recommended that only one raft be placed per territory and only where a suitable site for placement exists (Fig. 3).

Ideal deployment sites were located in protected coves and away from recreational areas and motorboat or paddling thruways (Hiemberger et al. 1983, Titus and VanDruff 1981) to minimize the impacts of wind, waves, and human disturbance on nesting loons. Rafts were anchored 3–50 m from shore, in water at least 1 m deeper than the greatest expected water-level draw down. Optimal deployment sites (i.e., those exhibiting a high frequency of use) were often located near historical nest sites because loons exhibit high nest-site fidelity (McIntyre 1975, Strong and Bissonette 1987). One anchor was positioned in a direction directly into the prevailing wind and wave source; the other was stretched out directly opposite (Fig. 3). Anchor

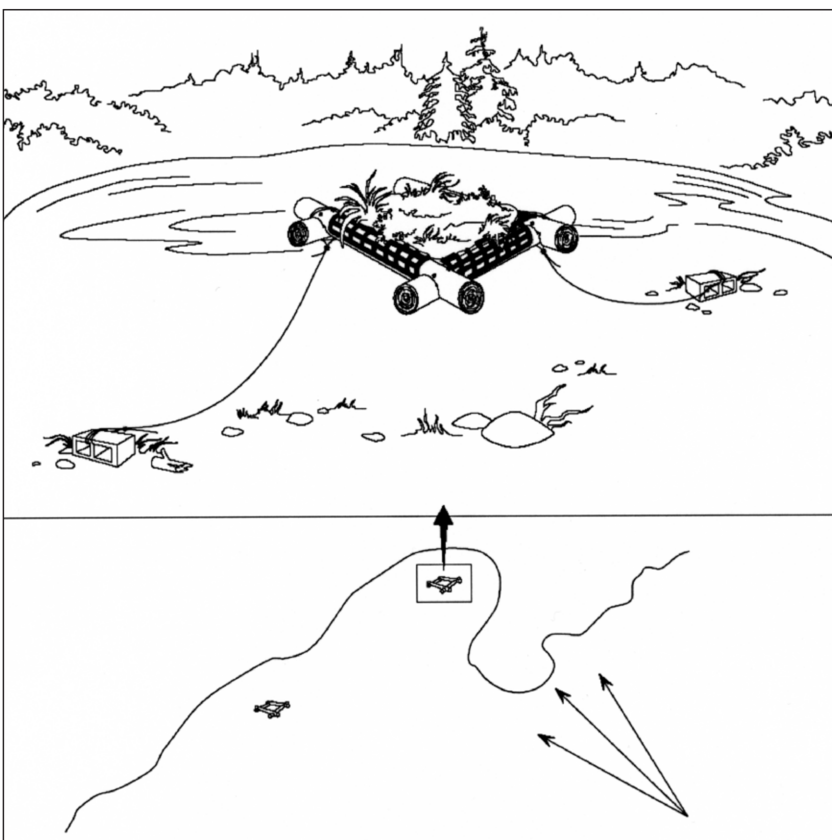

Figure 3. Proper anchoring and placement of a raft within Common Loon (*Gavia immer*) territories. Upper pane represents a cove within a loon territory, displayed from an aerial perspective in lower pane. Consult text for dimension and scale information. Placement should consider prevailing wind and wave direction (represented by arrows in lower figure), locations of historical nest sites, and human use patterns. Lower raft in bottom pane represents a poor choice for placement due to exposure from prevailing winds.

lines incorporated slack in order to accommodate water level changes, with 0.5 m of slack on lakes with stable water levels, and 1.0–1.5 m on those exhibiting water-level fluctuations similar to those described for impoundments above (see further descriptions in DeSorbo et al. 2007).

Monitoring raft condition. Rafts required monitoring at least once every 10–14 days throughout the season to ensure proper position, buoyancy, anchorage, and adequate nesting material. Lakes with highly fluctuating water levels, such as those on many hydroelectric reservoirs (DeSorbo et al. 2007, Fair 1979, Merrie 1996), often require increased monitoring frequency due to a greater potential for raft drifting or shallow-water stranding.

Post-season raft removal. Rafts were removed from lakes in the late summer to prevent damage from ice and prolonged soaking. Once cleared of vegetation, rafts were leaned against trees or placed on top of anchor blocks to facilitate drying before further transport. Well-formed nest bowls can be removed intact from rafts and reused the following season. Rafts were typically stored along shorelines above the highest possible water level.

Potential ecological impact of rafts

Due to their popularity, rafts are increasingly considered as a means of improving loon nesting success. However, rafts are sometimes sought or deployed unnecessarily (K. Taylor, pers. observ.). Oversight by qualified managers is required to avoid high incidences of improperly constructed or unnecessarily deployed rafts. Those interested in deploying rafts in New Hampshire or Vermont are referred to conservation authorities managing loons in those states for guidance and oversight (i.e., Loon Preservation Committee, Vermont Institute Natural Science, Vermont Loon Recovery Project). Similar concerns have prompted a review and permit process with state agencies before interested parties deploy rafts in New York (D. Adams, NY State Department of Environmental Conservation, Albany, NY, pers. comm.), and Wisconsin (M. Meyer, Wisconsin Department of Natural Resources, Rhinelander, WI, pers. comm.).

The potential that rafts might induce negative or unforeseen consequences for loons is seldom considered. Since the inception of rafts, managers have discussed whether raft deployments on a waterbody can encourage loon territory occupancy in previously unoccupied lakes or territories, or nesting in territories with no prior nesting history (McIntyre and Mathisen 1977, Piper et al. 2002, Sutcliffe 1979). While McIntyre and Mathisen (1977) did not find rafts to lure loons to previously loon-less lakes, Piper et al. (2002), recorded a case where a "rarely used lake without a record of breeding suddenly hatched chicks." Similarly, at least ten monitored territorial loon pairs in Vermont used rafts for their first documented nesting attempt in >15 years (E. Hanson, Vermont Institute Natural Science, Quechee, VT, unpubl. data). These findings support the line of thought that rafts may prompt territory establishment and nesting in some cases. Several observations in Maine additionally suggest that territory type and population density may also be important factors. In two territories on Aziscohos Lake (1999 and 2000; Oxford County), rafts deployed in an effort to lure loons from consistently failure-prone natural nest sites resulted in 2 different loon pairs nesting on natural and raft sites simultaneously (only 400 m apart in one case) and distinct shifts in territory boundaries. This approach to territory acquisition, in which intruders take control over a portion of an existing territory, has been described as a territory insertion (Arcese 1989, Piper et al. 2000).

The ecological significance of islands to loon productivity has been demonstrated (Munro 1945, Olson and Marshall 1952, Vermeer 1973), and natural islands and rafts within territories are likely evaluated similarly by loons. Therefore, the potential ecological consequences of adding islands to a territory should be carefully considered. For example, Mager (2005) found lower loon productivity in the year he deployed rafts, and suspected that raft additions resulted in an increased tendency for intruders to swim near resident pairs and higher mate displacement rates (see also Mager et al. 2008). In our study, new neighboring loon pairs on Aziscohos Lake were in frequent conflict despite territory boundary shifts. Piper et al. (2006) investigated the influence of permanent territory features and other factors on the number of conspecific intrusions in loon territories as a means of understanding territorial prospecting. That study found little evidence that permanent territory features, including islands, influenced the number of conspecific intrusions, and strong evidence that the presence of loon chicks in current or previous years positively influenced intrusion rates (see also Piper et al. 2000). Therefore, given that rafts can dramatically increase chick production at lakes (DeSorbo et al. 2007, Piper et al. 2002), they may also indirectly lead to increased frequency of conspecific intrusions, or increased competition for resources, potentially resulting in density-dependent impacts in some populations (Ferrer and Donazar 1996, Laughlin 1965), increased nest failure rates, or juvenile mortality.

Nest failure can result from improperly constructed or deployed rafts. For example, rafts with inadequate buoyancy may be attractive nest sites to loons, but can result in nest failure as materials become increasingly waterlogged over time. Improperly anchored rafts (i.e., anchor lines too short or too long) can similarly result in nest failure, especially in the presence of fluctuating water levels. Loon territories lacking protected areas are inappropriate for raft management, as high exposure to wind and wave action can result in eggs getting wet or rolled out of nests, or nonuse by loons (Merrie 1996; C.R. DeSorbo, pers. observ.). Lightweight raft designs (small diameter cedar logs, PVC pipe frames) can be particularly vulnerable to wind and wave action (K. Taylor, pers. observ.). For this reason and the numerous environmental and human health hazards associated with the manufacture and disposal of PVC plastic (Thornton 2002), we recommend cedar-log style rafts rather than lightweight alternatives for large-scale use. The considerable task of transporting cedar log rafts has been noted (Piper et al. 2002). Thoroughly drying rafts prior to transport as described above and in Table 1 can remarkably reduce raft weight to facilitate deployment and removal.

Loon territories exhibiting high levels of shoreline development and human activity (DeSorbo et al. 2007, Heimberger et al. 1983, Spillman 2006) are generally poor choices for raft management, as it often predisposes nesting pairs to disturbances in incubation (K. Taylor, pers. observ.). Floating ropes and signs, especially when enforced by volunteers, are effective in improving loon nest success (H. Vogel, unpubl. data) and can be viable management options at sites with high levels of human activity. Raft deployments in some areas might also predispose loons to predation. Loon nests in our study area located close to nesting *Haliaeetus leucocephalus* Linnaeus (Bald Eagle), or *Larus argentatus* Pontoppidan (Herring Gull) were frequently predated. Predation of loon eggs or young by these predators or *Corvus corax* Linnaeus (Common Raven) has been documented (Alvo and Blancher 2001; Douglas and Reimchen 1988; J. Fair, pers. observ.). Although not documented to our knowledge, it is plausible that some predators, such as *Larus* spp. and *Corvus* spp., might eventually learn to associate rafts with loon eggs, and such cases might require consideration when managing loon populations at sites with high densities of these opportunistic predators. Use of avian covers is generally recommended, especially in these situations.

Conclusions

Rafts can improve reproductive success of nesting loons; however, negative consequences can result from improper construction or deployment. Rafts are not equal in ecological value to natural nest-site alternatives, and do not fully mitigate systemic problems for loon populations, such as rapid development of nesting habitat, artificially enhanced predator populations, or fluctuating water levels. Rafts are recommended only after monitoring has indicated a consistent (≥3 years) nest-failure history due to predation or water-level fluctuation, and other preventative approaches such as education, habitat protection, water-level stabilization, and limiting access by cordoning off nest areas, have failed. The cost of materials to build a raft is approximately $70–100 US dollars (depending on inclusion of an avian cover), which is relatively inexpensive considering that a raft can be used for ≥10 years if properly maintained. Adherence to the protocols presented in this study will aid in ensuring that rafts are constructed and deployed appropriately to achieve maximum benefit for loon populations.

Acknowledgments

S. Murphy drafted the raft diagrams in this manuscript. E. Hanson, Vermont Institute of Natural Science, Vermont Loon Recovery Project, shared insightful experience, unpublished data, and general comments. D. Adams and M. Meyer provided general information. Many biologists aided in deploying rafts and developing the techniques presented in this paper, especially K. Murphy, S. Murphy, L. Savoy, and D. Yates. Thanks to the many volunteers that aided in deploying, maintaining, removing, and storing loon rafts on their property. Thanks to J. Paruk, J. Schmutz, and two anonymous reviewers for providing helpful comments on this manuscript.

Literature Cited

Alvo, R., and, P.J. Blancher. 2001. Common Raven, *Corvus corax*, observed taking an egg from a Common Loon, *Gavia immer*, nest. The Canadian Field–Naturalist 115(1):168–169.

Arcese, P. 1989. Territory acquisition and loss in male Song Sparrows. Animal Behaviour 37(1):45–55.

Barr, J.F. 1986. Population dynamics of the Common Loon (*Gavia immer*) associated with mercury-contaminated waters in northwestern Ontario. Canadian Wildlife Service, Ottawa, ON, Canada. Occasional Paper 56. 23 pp.

Belant, J.L., and R.K. Anderson. 1991. Common Loon, *Gavia immer*, productivity on a northern Wisconsin impoundment. Canadian Field–Naturalist 105(1):29–33.

DeSorbo, C.R., K.M. Taylor, D.E. Kramar, J. Fair, J.H. Cooley, Jr., D.C. Evers, W. Hanson, H.S. Vogel, and, J.L. Atwood. 2007. Reproductive advantages for Common Loons using rafts. Journal of Wildlife Management 71(4):1206–1213.

Douglas, S.D., and, T.E. Reimchen. 1988. Reproductive phenology and early survivorship in Red–throated Loons, *Gavia stellata*. Canadian Field–Naturalist 102(4)701–704.

Evers, D.C. 2001. Common Loon population studies: Continental mercury patterns and breeding territory philopatry. Ph.D. Dissertation. University of Minnesota, St. Paul, MN. 102 pp.

Evers, D.C. 2007. Status assessment and conservation plan for the Common Loon in North America. US Fish and Wildlife Service, Hadley, MA.

Evers, D.C., L.J. Savoy, C.R. DeSorbo, D.E. Yates, W. Hanson, K.M. Taylor, L. Siegel, J.H. Cooley, Jr., M.S. Bank, A. Major, K. Munney, B. Mower, H.S. Vogel, N. Schoch, M. Pokras, M.W. Goodale, and J. Fair. 2008. Adverse effects from environmental mercury loads on breeding Common Loons. Ecotoxicology 17(2):69–81.

Fair, J.S. 1979. Water-level fluctuations and Common Loon nest failure. Pp. 57–63, *In* S.A. Sutcliffe (Ed.). Proceedings of the Second North American Conference on Common Loon Research and Management. National Audubon Society. Syracuse, NY. 160 pp.

Fair, J. 1993. A cover for loon rafts to obstruct avian depredation. Pp. 325–326, *In* L. Morse, S. Stockwell, and M. Pokras (Eds.). The Loon and its Ecosystem: Status, Management, and Environmental Concerns. Proceedings of the 1992 Conference on the Loon and its Ecosystem. US Fish and Wildlife Service, Concord, NH. 247 pp.

Fair, J., and, B.M. Poirier. 1993. Managing for Common Loons on hydroelectric project reservoirs in northern New England. P. 221, *In* L. Morse, S. Stockwell, and M. Pokras (Eds.). The Loon and its Ecosystem: Status, Management, and Environmental Concerns. Proceedings of the 1992 Conference on the Loon and its Ecosystem. US Fish and Wildlife Service, Concord, NH. 247 pp.

Ferrer, M., and, J.A. Donazar. 1996. Density-dependent fecundity by habitat heterogeneity in an increasing population of Spanish Imperial Eagles. Ecology 77(1): 69–74.

Hancock, M. 2000. Artificial floating islands for nesting Black-throated Divers *Gavia arctica* in Scotland: Construction, use, and effect on breeding success. Bird Study 47(2):165–175.

Heimberger, M., D. Euler, and, J. Barr. 1983. The impact of cottage development on Common Loon reproductive success in central Ontario. Wilson Bulletin 95(3): 431–439.

Laughlin, R. 1965. Capacity for increase: A useful population statistic. Journal of Animal Ecology 34(1):77–91.

Mager III, J.N. 2005. What information is communicated by the territorial yodel of male Common Loons (*Gavia immer*)? Ph.D. Dissertation. Cornell University, Ithaca, NY. 171 pp.

Mager III, J.N., C. Walcott, and W.H. Piper. 2008. Nest platforms increase aggressive behavior in common loons. Naturwissenschaften 95(2):141-147.

Mathisen, J.E. 1969. Use of man-made islands as nesting sites of the Common Loon. Wilson Bulletin 81(3):331.

McIntyre, J.W. 1975. Biology and behavior of the Common Loon (*Gavia immer*) with reference to its adaptability in a man-altered environment. Ph.D. Dissertation. University of Minnesota, Minneapolis, MN. 230 pp.

McIntyre J.W. 1988. The Common Loon: Spirit of Northern Lakes. University of Minnesota Press, Minneapolis, MN. 228 pp.

McIntyre, J.W., and, J.F. Barr. 1997. Common Loon (*Gavia immer*). *In* A. Poole and F. Gill (Eds.). The Birds of North America, No. 313.The Birds of North America, Inc., Philadelphia, PA. 32 pp.

McIntyre, J.W., and, J.E. Mathisen. 1977. Artificial islands as nest sites for Common Loons. Journal of Wildlife Management 41(2):317–319.

Merrie, T.D.H. 1979. Success of artificial island nest-sites for divers. British Birds 71(1):32–33.

Merrie, T.D.H. 1996. Breeding success of raft-nesting divers in Scotland. British Birds 89 (7):306–309.

Munro, J.A. 1945. Observations of the loon in the Cariboo Parklands, British Columbia. Auk 62(1):38–49.

Olson, S.T., and, W.M. Marshall. 1952. The Common Loon in Minnesota. University of Minnesota Press, Minneapolis, MN. Occasional Paper Number 5. 77 pp.

Piper, W.H., K.B. Tischler, and, M. Klich. 2000. Territory acquisition in loons: The importance of take-over. Animal Behaviour 59(2):385–394.

Piper, W.H., M.W. Meyer, M. Klich, K.B. Tischler, and, A. Dolsen. 2002. Floating platforms increase reproductive success of Common Loons. Biological Conservation 104(2):199–203.

Piper, W.H., C. Walcott, J.N. Mager III, M. Perala, K.B. Tischler, E. Harrington, A.J. Turcotte, M. Schwabenlander, and, N. Banfield. 2006. Prospecting in Common Loons: Intruders use conspicuous adults to find cryptic chicks. Behavioral Ecology 17(6):881–888.

Reiser, M.H. 1988. Effects of regulated lake levels on the reproductive success, distribution, and abundance of the aquatic bird community in Voyageurs National Park, Minnesota. US Department of the Interior, National Park Service, Omaha, NB. Research/Resources Management Report MWR-13.

Spillman, C.A. 2006. Effects of lakeshore development on Common Loon productivity in the Adirondack Park, New York. M.Sc. Thesis. State University of New York, College of Environmental Science and Forestry, Syracuse, NY. 60 pp.

Strong, Paul I.V., and J.A. Bissonette. 1987. Effects of nest-site loss on Common Loons, *Gavia immer*. Canadian Field–Naturalist 101(4):581–583.

Sutcliffe, S.A. 1979. Artificial Common Loon nesting site construction, placement, and utilization in New Hampshire. Pp. 111–116, *In* S.A. Sutcliffe (Ed.). Proceedings of the Second North American Conference on Common Loon Research and Management. National Audubon Society. Syracuse, NY.

Thornton, J. 2002. Environmental impacts of polyvinyl chloride building materials. Healthy Building Network, Washington DC.

Titus, J.R., and, VanDruff, L.W. 1981. Response of the Common Loon to recreational pressure in the Boundary Waters Canoe Area, northeastern Minnesota. Wildlife Monographs 79(4). 59 pp.

Vermeer, K. 1973. Some aspects of the nesting requirements of the Common Loon in Alberta. Wilson Bulletin 85(4):429–435.