THE NORTH AMERICAN BANDER'S MANUAL
FOR
SHOREBIRDS
(Charadriiformes, suborder Charadrii)

A product of the
North American Banding Council

C. L. Gratto-Trevor
Science and Technology Branch
Environment and Climate Change Canada
Prairie and Northern Wildlife Research Centre
115 Perimeter Road
Saskatoon, SK S7N 0X4

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PREFACE

The purpose of the publications of the North American Banding Council is to provide for all banders in North America the basic information to safely and productively conduct bird banding. This manual is an integral part of other publications, primarily The North American Banders' Study Guide (North American Banding Council 2001; http://www.nabanding.net/other-publications/). It is assumed that the person reading this manual already has fully read that guide. Further, we also assume that the introductory material on pages 1-40 in Pyle (1997) also has been read. With this background, this manual will augment the information that pertains especially to shorebirds. The Banders' Study Guide is intended to cover various aspects of banding that are across taxa; where this manual covers only the shorebirds. In addition to an Instructor's Guide, for persons training banders, the North American Banding Council has produced other taxon-specific manuals for hummingbirds, passerines and near passerines, raptors, and waterfowl. The Council is also producing manuals for seabirds, and perhaps other groups. While some of the material in this manual may apply to taxa other than shorebirds, the material was included if the primary use by banders would be with shorebirds. For instance, the traps for catching shorebirds are covered in this manual, although similar traps are used for landbirds and waterfowl. The Publications Committee felt, however, that the special adaptations required for capture of these quite different taxa merited separate treatment in the taxon-specific manuals.

We trust that this guide will be read by all banders and trainers involved in shorebird banding. This is a truly cooperative venture, representing many hours of work by many individuals and their institutions and including, as much as possible, all responsible views of banding in North America. We trust that the final product is worthwhile to those involved in the capture and banding of shorebirds.

—The Publications Committee of the
North American Banding Council
C. John Ralph, Chair

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—C.L. Gratto-Trevor

1. INTRODUCTION

With few exceptions, shorebird banding programs in North America are for short-term studies, carried out with a specific objective in mind. Often, the banders have little experience with shorebirds, and 'learn as they go', with some opportunities to question the limited number of experienced shorebird banders in Canada and the United States. Although many of the techniques used in the capture and handling of shorebirds are similar to those used for passerines, there are a number of differences. This manual attempts to compile in one document the information necessary for shorebird banding. It adds to the more general information provided in the North American Bander's Study Guide (North American Banding Council 2001; http://www.nabanding.net/other-publications/), and identifies ways in which shorebird banding differs from that of other bird groups. North American shorebird species covered by this manual are listed in Table 1 with AOU four-letter codes and numbers, scientific names, recommended band sizes, summary of sexing and ageing techniques, potential handling and banding problems, and Birds of North America references.

The information included in this manual was obtained from published sources, the experiences of the author in banding shorebirds since 1976 in Arctic, interior, and coastal locations of Canada, as well as from experiences in co-ordinating color marking of shorebirds in North America. Drafts of the manuscript were sent to many experienced shorebird banders (see Acknowledgements), and their responses added immensely to the manual's content and accuracy.

Capture and banding techniques, as well as potential problems, vary greatly according to location, species, season, and objectives of the study. This manual will point out known differences in techniques, problems, and potential solutions.

Bander's Code of Ethics

1. *Banders are primarily responsible for the safety and welfare of the birds they study so that stress and risks of injury or death are minimized.* Some basic rules:
   - handle each bird carefully, gently, quietly, with respect, and in minimum time - capture and process only as many birds as you can safely handle
   - close traps or nets when predators are in the area
   - do not band in inclement weather
   - frequently assess the condition of traps and nets and repair them quickly - properly train and supervise students
   - check nets as frequently as conditions dictate
   - check traps as often as recommended for each trap type - properly close all traps and nets at the end of banding - do not leave traps or nets set and untended
   - use the correct band size and banding pliers for each bird - treat any bird injuries humanely

2. *Continually assess your own work to ensure that it is beyond reproach.*
   - reassess methods if an injury or mortality occurs
   - ask for and accept constructive criticism from other banders

3. *Offer honest and constructive assessment of the work of others to help maintain the highest standards possible.*
   - publish innovations in banding, capture, and handling techniques - educate prospective banders and trainers
   - report any mishandling of birds to the bander
   - if no improvement occurs, file a report with the Banding Office

4. *Ensure that your data are accurate and complete, are submitted in a timely fashion to the responsible agency or organization, and are appropriately used to advance valid scientific purposes*

5. *Obtain prior permission to band on private property and on public lands where authorization is required*

2. THE BANDER'S CODE OF ETHICS

Bird banding is used around the world as a major research tool. When used properly and skillfully, it is both safe and effective. The safety of banding depends on the use of proper techniques and equipment and on the expertise, alertness, and thoughtfulness of the bander.

The Bander's Code of Ethics applies to every aspect of banding. The bander's essential responsibility is to the bird. Other things matter a lot, but nothing matters so much as the health and welfare of the birds you are studying. Every bander must strive to minimize stress placed upon birds and be prepared to accept advice or innovation that may help to achieve this goal.

Methods should be examined to ensure that the handling time and types of data to be collected are not prejudicial to the bird's welfare. Be prepared to streamline procedures of your banding operation, either in response to adverse weather conditions or to reduce a backlog of unprocessed birds. If necessary, birds should be released unbanded, or the trapping devices should be temporarily closed. Banders should not consider that some mortality is inevitable or acceptable in banding. Every injury or mortality should result in a reassessment of your operation. Action is then needed to minimize the chance of repetition. The most salient responsibilities of a bander are summarized in the Bander's Code of Ethics; more details are found in Section 13 of the Banders' Study Guide.

Banders must ensure that their work is beyond reproach and assist fellow banders in maintaining the same high standards. Every bander has an obligation to upgrade standards by advising the Banding Offices of any difficulties encountered and to report innovations.

Banders have other responsibilities too. They must submit their banding data to the Banding Offices promptly, reply promptly to requests for information, and maintain an accurate inventory of their band stocks. Banders also have an educational and scientific responsibility to make sure that banding operations are explained carefully and are justified. Finally, banders banding on private property have a duty to obtain permission from landowners and ensure their concerns are addressed.

3. PERMITS REQUIRED

Shorebirds are protected by the Migratory Bird Convention Act in Canada and the Migratory Bird Treaty Act in the U.S. Although shorebirds are considered nongame migratory birds in Canada and the U.S., more accurately shorebirds are migratory game birds with completely closed seasons for all species except Wilson's Snipe and American Woodcock. Therefore, one needs a banding permit from the U.S. Bird Banding Laboratory (USGS, PWRC, Bird Banding Laboratory, 12100 Beech Forest Road, STE-4037, Laurel, Maryland 20708-4037, USA) to band shorebirds in the United States, or from the Canadian Banding Office (Canadian Wildlife Service, Environment and Climate Change Canada, Bird Banding Office, NWRC-CWS, Carleton University, Raven Road, Ottawa, ON K1A 0H3 Canada) to band shorebirds in Canada, with special permission to use mist nets as required. Few shorebird studies involve merely putting a metal band on a bird, so one will need additional permission from the banding office to color band, or use flags, dyes, or tracking systems such as nanotags, geolocators, satellite transmitters, etc. on each species. If coded flags are used to mark shorebirds, specific codes for each species should be obtained (in Canada and the U.S.) from the respective banding offices, and for other countries from the regional Pan American Shorebird Program coordinator. Status (used or unused) of each assigned code should be reported to the appropriate agency at the end of each banding season (Howes *et al.* 2016).

Many institutions require an "Animal Care Permit" or equivalent if one is handling wild animals, obtained from a university or other source, depending on your situation. A provincial or state research and/or land-use permit may be required as well, and possibly a federal permit for work carried out on federal land. Parks may have additional permit requirements, as may land owners. In Canada and the U.S., biological collections (e.g. blood or feather) from wild birds may be indicated on the banding permit. Work on species at risk has additional permit requirements from federal and/or state/provincial authorities, as well as approval from the appropriate Recovery Team. Contact your local authorities for the most up-to-date information.

4. OBJECTIVES OF STUDY

The first and most important factor to consider before capturing shorebirds is the purpose of the study. Objectives will help identify the species, season, location, and number of each species necessary, as well as the types of marking methods that will best serve the questions posed. In the past, non-unique (cohort) markers were commonly used for large scale migration studies because it was extremely difficult to create individual color band

Table 1. North American shorebird species, ageing and sexing, potential banding and handling problems, Birds of North America (BNA) references.

Species	Scientific Name	AOU Code	AOU Number	Band Size[1]	Sexing[2]	Ageing[3]	Problems[4]	BNA[5]	BNA Reference[6]
Red Phalarope	*Phalaropus fulicarius*	REPH	222.0	1A	3a,6a,7	2a,3a,10a	2y,8B	698	Tracy et al. 2002
Red-necked Phalarope	*Phalaropus lobatus*	RNPH	223.0	1B	3ab,5b,6b,7b	1b,2a	2a,8aB,9a	538	Rubega et al. 2000
Wilson's Phalarope	*Phalaropus tricolor*	WIPH	224.0	1D, 1A, 2	3ab,5ab,6b,7b	2ab,3a,10a	2?,8j	83	Colwell and Jehl 1994
American Avocet	*Recurvirostra americana*	AMAV	225.0	4, 4A	1ab,2b	1a,2a,10a	1?,3d,7d	275	Robinson et al. 1997
									Ackerman et al. 2013
Black-necked Stilt	*Himantopus mexicanus*	BNST	226.0	3A, 4, 4A	2a,3b,4b,6a	1ab,3a,10a	1?,3d,4a,7d	449	Robinson et al. 1999
American Woodcock	*Scolopax minor*	AMWO	228.0	3	2ab,3a,5b,7b	4a,7b,8b,10a	6k	100	Keppie and Whiting 1994
									McAuley et al. 2013
Wilson's Snipe	*Gallinago delicta*	WISN	230.0	3, 3B, 3A, 2	2b,4b,5b,7b	1ab	2y,5a	417	Mueller 1999
Short-billed Dowitcher	*Limnodromus griseus*	SBDO	231.0	2, 2A	2ab,6b	1ab,2ab,10a	2z,7l	564	Jehl et al. 2001
Long-billed Dowitcher	*Limnodromus scolopaceus*	LBDO	232.0	2, 2A	2ab,~6a	1a,2a,10a	2	493	Takekawa and Warnock 2000
Stilt Sandpiper	*Calidris himantopus*	STSA	233.0	1A, 1D	2a,~6ab	1ab,2ab,9b	1a,2c,7l	341	Klima and Jehl 1998, 2012
Red Knot	*Calidris canutus*	REKN	234.0	2, 2A	6ab	1ab,2ab,9c,11c	1fA,2yz,8m	563	Harrington 2001
									Baker et al. 2013
Purple Sandpiper	*Calidris maritima*	PUSA	235.0	1A, 1D, 2	~~2a	1a	2y	706	Payne and Pierce 2002
Rock Sandpiper	*Calidris ptilocnemis*	ROSA	236.0	2, 1D	2ab,6b	1a,10ab	2	686	Gill et al. 2002a
Sharp-tailed Sandpiper	*Calidris acuminata*	SHAS	238.0	1A, 1D	2c,3a,5c	1a,2a,9a,10a,11c	2y		
Pectoral Sandpiper	*Calidris melanotos*	PESA	239.0	1A, 1D, 2	3ab,5b,7b	1ab,2ab,10a	2z,7lB	348	Holmes and Pitelka 1998
									Farmer et al. 2013
White-rumped Sandpiper	*Calidris fuscicollis*	WRSA	240.0	1A, 1B	~2b,~3b,7b	1ab,2ab,9a,10a	2z,7x	29	Parmalee 1992
Baird's Sandpiper	*Calidris bairdii*	BASA	241.0	1B, 1A	~~2a	1a,2a,9a,10a	8a	661	Moskoff and Montgomerie 2002
Least Sandpiper	*Calidris minutilla*	LESA	242.0	1, 1B, 1C	2ab	1ab,2ab,9ab	2e,8ae,9a	115	Cooper 1994
									Nebel and Cooper 2008
Dunlin	*Calidris alpina*	DUNL	243.0	1A, 1B, 1D	2ab	1ab,4f	~1AC,2y,7lB	203	Warnock and Gill 1996
Semipalmated Sandpiper	*Calidris pusilla*	SESA	246.0	1B, 1	2ab	1ab,2ab,9ab	2az,8anB,9a	6	Gratto-Trevor 1992
									Hicklin and Gratto-Trevor 2010
Western Sandpiper	*Calidris mauri*	WESA	247.0	1B, 1	2ab	1a,2a,10a	2,8n	90	Wilson 1994, Franks et al. 2014
Sanderling	*Calidris alba*	SAND	248.0	1A, 1D	6a	1a,2a	~1A,2y,8m	653	MacWhirter et al. 2002
Buff-breasted Sandpiper	*Calidris subruficollis*	BBSA	262.0	1A	2b,3ab,4b,5d,7b	1a	7rB	91	Lanctot and Laredo 1994
Surfbird	*Calidris virgata*	SURF	282.0	2A, 3, 2	2b,3b,5b	1a,10a	2	266	Senner and McCaffery 1997
Marbled Godwit	*Limosa fedoa*	MAGO	249.0	4	2abg,5ab,8b	2ab,10a	1?,2,8a,9a	492	Gratto-Trevor 2000
Bar-tailed Godwit	*Limosa lapponica*	BARG	250.0	4(m)-4A(f)	2ab,5b,6ab	1ab,2ab	1fy!,2y	581	McCaffery and Gill 2001
Hudsonian Godwit	*Limosa haemastica*	HUGO	251.0	3A	2a,6a	1a,2a,9c,10a	2,7l	629	Elphick and Klima 2002
									Walker et al. 2011
Greater Yellowlegs	*Tringa melanoleuca*	GRYE	254.0	3, 3B		3a	1a!,2z,6o	355	Elphick and Tibbitts 1998
Lesser Yellowlegs	*Tringa flavipes*	LEYE	255.0	2, 2A		3a,9a	1az!,2z,6o	427	Tibbitts and Moskoff 1999, 2014
Solitary Sandpiper	*Tringa solitaria*	SOSA	256.0	1A, 1D, 2	~5b	1a,2ab,9b	2	156	Moskoff 1995, 2011
Willet	*Tringa semipalmata*	WILL	258.0	4, 4A, 3A	5b	3a,10a	2z,8ap,9a	579	Lowther et al. 2001
Wandering Tattler	*Tringa incana*	WATA	259.0	3, 2, 2A	3b	3a,5a	2	642	Gill et al. 2002b
Upland Sandpiper	*Bartramia longicauda*	UPSA	261.0	3, 2A	~~5b	5ab	8nq	580	Houston and Bowen 2001
									Houston et al. 2011
Spotted Sandpiper	*Actitis macularius*	SPSA	263.0	1B, 1A	5ab,6b	5a,9ab	3b,7d	289	Oring et al. 1997
									Reed et al. 2013

Table 1 continued. North American shorebird species, ageing and sexing, potential banding and handling problems, Birds of North America (BNA) references.

Species	Scientific Name	Code	Number	Band Size[1]	Sexing[2]	Ageing[3]	Problems[4]	BNA[5]	BNA Reference[6]
Long-billed Curlew	*Numenius americanus*	LBCU	264.0	5, 4A, 5A	2a	5a,10a	1?,2,8a	628	Dugger and Dugger 2002
Whimbrel	*Numenius phaeopus*	WHIM	265.0	4, 4A	2ab,3ab,5b	5ab	~1g,2y,7l	219	Skeel and Mallory 1996
Bristle-thighed Curlew	*Numenius tahitiensis*	BTCU	268.0	4A, 5	1b,2b,5b	4a,10a	1?,2,8o	705	Marks et al. 2002
Black-bellied Plover	*Pluvialis squatarola*	BBPL	270.0	3, 3B, 3A	6ab	5a	2y	186	Paulson 1995, Poole et al. 2016
American Golden-Plover	*Pluvialis dominica*	AMGP	272.0	3, 2A, 2	6ab	4ab	2z,7w	201	Johnson and Connors 1996, 2010a
Pacific Golden-Plover	*Pluvialis fulva*	PAGP	272.1	3, 2A, 2	6a	4ab	2y	202	Johnson and Connors 1996, 2010b
Killdeer	*Charadrius vociferus*	KILL	273.0	2, 2A, 1D	~6ab	1b,4a	7ds	517	Jackson and Jackson 2000
Semipalmated Plover	*Charadrius semipalmatus*	SEPL	274.0	1A, 1B, 1D	6ab,8b	1ab,2a,3a	2z,7s	444	Nol and Blanken 1999, 2014
Common Ringed Plover	*Charadrius hiaticula*	CRPL	275.0	1A, 1B	6h,8h	1g			
Piping Plover	*Charadrius melodus*	PIPL	277.0	1A, 1B	6abe,8abe	1a,3a,10de	2?,3,8u	2	Haig 1992, Elliott-Smith and Haig 2004
Snowy Plover	*Charadrius nivosus*	SNPL	278.0	1P	6ab	1a,3a,10a	3b,7t	154	Page et al. 1995, 2009
Wilson's Plover	*Charadrius wilsonia*	WIPL	280.0	1D, 1A, 2	6ab	1ab,2ab,3a	2?,7t	516	Corbat and Bergstrom 2000
Mountain Plover	*Charadrius montanus*	MOUP	281.0	2, 3		4a	6i	211	Knopf 1996, Knopf and Wunder 2006
Ruddy Turnstone	*Arenaria interpres*	RUTU	283.0	2A, 2, 3	3ab,6ab	1ab,6ab,10a	2hy,10A	537	Nettleship 2000
Black Turnstone	*Arenaria melanocephala*	BLTU	284.0	2A, 2	5b,6ab	1ab,6b,10ab	2	585	Handel and Gill 2001
American Oystercatcher	*Haematopus palliatus*	AMOY	286.0	5A, 5, 6	2b,5b	3a,7b,10a	2,7s	82	Nol and Humphrey 1994 Working Group AMOY et al. 2012
Black Oystercatcher	*Haematopus bachmani*	BLOY	287.0	5, 5A	1b,2ab,9f	3ab,6a,7b,8b	2,7v	155	Andres and Falxa 1995

[1]From U.S./Canada Bird Banding Manual 2017: https://www.pwrc.usgs.gov/BBL/MANUAL/speclist.cfm

[2]Sexing: 1=bill shape, 2=bill length, 3=wing length, 4=tarsus length, 5=mass, 6=breeding plumage, 7=brood patch, 8=breeding bill colour, 9=eye flecks; ~=somewhat useful; a=Prater et al. 1977, b=Birds of N.A. accounts, c=C. Minton (pers. comm.), d=R. Lanctot (pers. comm.), e=Gratto-Trevor 2011,f=Guzzetti et al. 2008, g=Ayala-Perez et al. 2013, h=Meissner et al. 2010

[3]Ageing: 1=juvenile with buff edged coverts, 2=juvenile with buff wash on breast, 3=juvenile with buff edged upperparts, 4=specific feather pattern differences, 5=juveniles with buff spots on edges of coverts, 6=juveniles with duller legs than adults, 7=eye colour differences, 8=bill colour differences, 9=some yearlings with PPW moult, 10=yearlings with very worn primaries, 11=see text (section 9.5); a=Prater et al. 1977, b=Birds of N.A. accounts, c=C. Minton (pers. comm.), d=Gratto-Trevor et al. 2011, e=Gratto-Trevor 2011, f=Choi et al. 2010; g=Meissner et al. 2010

[4]Potential problems with handling and banding: 1=prone to capture myopathy, 2=rapid wear of aluminum bands on lower leg, 3=some injuries known if band on lower leg, 4=legs of very young chicks too small for normal band sizes, 5=explosive take-offs, so secure cages, 6=tendency to desert if captured on nest, 7=some tendency to desert if captured on nest during first week of incubation, 8=virtually no tendency to desert if captured on nest after clutch complete, 9=no injuries known from bands on lower leg a=C. L. Gratto-Trevor (unpubl. data), b=Birds of N.A. accounts, c=Jehl 1969, d=L. W. Oring (pers. comm.), e=J. M. Cooper (pers. comm.), f=Minton 1993, g=Green 1978, h=Summers and Etheridge 1998, i=Graul 1979, j=M. Colwell (pers. comm.), k=McAuley et al. 1993, l=J. Jehl (pers. comm.), m=T. Piersma (pers. comm.), n=B. Sandercock (pers. comm.), o=L. Tibbitts (pers. comm.), p=M. Howe (pers. comm.), q=C. Jackson (pers. comm.), r=R. Lanctot (pers. comm.), s=E. Nol (pers. comm.), t=G. Page (pers. comm.), u=D. Amirault (pers. comm.), v=S. Hazlitt, w=J. Klima, x=R. Cartar, y=C. Minton, z=B. Harrington, A=Nellie Tsipoura, B=D. Troy, C=N. Warnock (pers. comm.)

[5]Birds of North America account number

[6]Birds of North America original reference and online update if it exists (see Literature Cited for complete reference)

combinations for thousands of birds without weighing down the bird and/or using up all potential unique color band combinations for the species. Now, flags with engraved alpha-numeric codes are common (usually 3 codes per flag, even on small species), so more unique combinations are possible with just a metal band and a flag. However, even then, assuming 25 characters (letters and numbers) in three positions, less than 16,000 combinations are possible, and can quickly be used up on commonly marked species. So ensure that you really do need to uniquely mark huge numbers of a species before using up all available unique codes for a flag color.

It is also important to know how long your markers need to last (keeping in mind that shorebirds are relatively long-lived: the oldest known Semipalmated Sandpiper was 16 years; the oldest Marbled Godwit 29). Will a dye be useful (most species of shorebirds start replacing breeding plumage during fall migration)? Do you want your birds to be reported by observers away from the banding site? If you are thinking of using some sort of tracking device (e.g., nanotags, geolocators, satellite transmitters), will it work for your species of shorebird? Is it too heavy? Will it cause injury/death? How will it be attached? Is the device there for the life of the bird or will it fall off naturally? If a device that must be recovered to collect the data, can the bird be easily recovered (e.g., a site fidelic breeder)? How many individuals do you really need to mark or track in order to answer your question?

5. TRAINING ADVISED FOR PERSONNEL

Often it is difficult to get training specifically for banding shorebirds, because few on-going programs exist, and those may be for short periods of time, once per year at distant locations. This may not be a major problem if studying an easily-recognizable species, as long as you obtain significant experience in handling and banding wild birds of a similar size and using similar capture techniques (e.g., mist nets) to those of your proposed study. In addition, you must study the appropriate literature (including this manual), and talk to others who have worked on that or similar species in the past. However, if you wish to undertake a large migration study with multiple species (especially *Calidris* sandpipers), you must obtain hands-on experience with identification, ageing, molts, banding and measurement of these shorebird species. Preferably this should be done at the appropriate season, because plumages often vary greatly among seasons and age groups.

Any trainer of shorebird banders should have extensive experience with identification of a large variety of shorebirds in the hand, using numerous methods of capture, locations, and times of year. However, it is unreasonable to expect someone doing a Master's degree on Killdeer, for example, who is capturing birds in nest traps, to have their banding expertise and knowledge evaluated on the basis of all the material in the general and specific (passerine or even shorebird) banding manuals. Nevertheless, all banders should clearly understand the responsibilities involved in handling wild birds, and have experience in handling and banding birds of similar size, plus appropriate knowledge from this manual (e.g., how to handle and mark shorebirds).

It is especially important to understand best attachment methods for your species for each different tracking device (e.g., geolocator, satellite transmitter, nanotag) you are using. This may require you obtaining training on a similar project, or importing an expert initially to show banders how to appropriately attach (and use) a device.

If you wish to become a NABC Certified Banding Assistant, Certified Bander, or Certified Trainer, requirements for each level can be found on the NABC website:
http://www.nabanding.net/shorebirds/

Shorebird Certification is a four part process:

1. Study of key materials prior to attendance at a workshop and exam
2. Attendance at a training and certification workshop
3. Pass the written exam
4. Field expertise

In order to achieve certification, applicants must demonstrate that they have achieved a certain level of field expertise. Field expertise is flexible to allow for various experience and expertise with various species, habitat, life stages and capture methods. Ideally, certified banders and trainers will have developed expertise with a variety of species and situations. Once you have completed the requirements for certification, you may apply for certification by sending your application to the North American Banding Council Certification Committee. Your application should consist of the completed NABC Shorebird Certification Requirements form document filled in and signed by your trainer(s), an account of your banding experience, the application for certification form and your certificate of participation at an NABC shorebird banding workshop.

6. HANDLING

On the whole, shorebirds are less fragile than many small passerines, but obviously care must be taken when capturing and handling these birds. Shorebirds do not undergo 'fright molt', so one will not end up with a tail in one hand and the bird in another. They tend to have soft bills and weak claws, so few species will attack each other if similarly-sized species are put together in a bag or box. Shorebirds are generally very docile birds, with most species quite tolerant of disturbance, even during the breeding season, when appropriate methods are used. However, they do have long straight wings, usually flexible bills with many pain receptors, and often long thin legs susceptible to 'leg cramp' (capture myopathy). The importance of these factors is discussed below. As with all avian species, shorebirds should be released as soon as safely possible, and should not be handled at all if you have insect repellent on your hands.

6.1. Removal from capture devices. Removing small shorebirds from mist nets is similar to removal of passerines. Many banders find it easiest to expose the breast or side first and remove legs last. However, several important differences exist between shorebirds and passerines. In general, the easiest shorebird is slightly harder to remove than a normal passerine, but the most tangled passerine is much harder to remove than the most difficult shorebird! Shorebirds seldom become extremely tangled, unless they are caught near a hole in the net or in the bottom shelf and twirl the net. Shorebird wings are long, flat, and not very flexible. Care must be taken not to bend wings at awkward angles, or create a permanent kink in the shaft of primaries. If a wing is tightly caught in the net, it may be necessary to carefully pull the remiges out through a (natural) hole in the net, then, holding the body of the bird and base of the wing, carefully slide the wing out from the netting, along the bone. A shorebird will not get the net caught behind its tongue, and seldom bites at the net (or the bander) with its bill. However, shorebird bills are often long, flexible, and full of tactile receptors, so must be carefully removed from the net. Shorebirds should not be held by the legs. Long-legged species should be removed from the net quickly, so that they do not suffer 'leg cramp' (capture myopathy). Myopathy refers to the loss of the structural or functional integrity of muscle fibres, which can be irreversible and result in leg paralysis. It also occasionally affects the wings (Green 1980). Although shorebirds do not have long claws to clutch the net, shorebird legs are often long, and not readily or safely bent at an angle, so may be awkward to remove from the net. Mist netting of shorebirds often is carried out at night, when good head lamps are essential for safe removal of birds.

Remove birds dangling in the water first, then those that appear to be strangling. Next, remove small birds next to larger birds in the net and long-legged species susceptible to capture myopathy. Finally, remove birds lower in the net before higher birds, so that they are not forced into the water or become more tangled as one pulls down the upper shelves to reach birds high in the net.

When removing a shorebird from any other trapping device, grab it quickly and firmly about the body (for small shorebirds often one can use the 'bander's grip' with its head between the index and middle fingers of one's hand, see section 6.2 below) to minimize injuries to the bird from banging against the sides of the trap, and to keep it from jumping on its eggs if they are present.

6.2. Holding. Small shorebirds should be held in the same manner as passerines, in the 'bander's grip' (upright, with the bird's head between the bander's index and middle fingers). The birds can be banded safely in this position. Shorebirds too large to be comfortably held upright in one hand can be held with both hands around the bird's body. To band these larger birds, hold them on your lap, upside down, with their head towards your body and tail and wing tips pointing away from your body. This prevents damage to the wing tips and tail feathers. Most shorebirds are extremely passive in the hand (with exceptions such as Wilson's Snipe), and seldom struggle for release if held firmly. On the rare occasions that a shorebird tries to bite you, their soft bills cannot hurt, for most species, nor can most injure you with their toenails.

It is most convenient and safest to transfer small shorebirds from one person to another by changing the handgrip to hold birds by the body, wings and tail (as an ice-cream cone), so that the person taking the bird can immediately use the proper banding grip.

6.3. Carrying and holding devices. Shorebirds often are held temporarily in boxes or cloth bags prior to banding. Cloth bags should be at least 20 cm x 15 cm for small shorebirds and proportionately larger for larger species, with no exposed threads on the inside to tangle birds, and preferably have drawstrings. They are normally made of white cotton, and **should be washed frequently**. Two to three small shorebirds may be held in small bags for short periods of time, and more small sandpipers in larger bags. Do not mix large and small species in a bag. Do not place bags with birds where they can be stepped or sat on! Birds should be put into boxes if they are to be kept longer than about 15 minutes: generally the only times shorebirds are kept in bags are instances during the breeding season when you catch chicks, or both adults at once. In some cases, it may be most convenient to place birds in boxes immediately upon removal from the capture device. Ensure that boxes or their coverings cannot blow away if outdoors (a layer of sand in the bottom of a box may help prevent the box from moving by the wind; B. Haase pers. comm.).

To reduce your chances of acquiring psittacosis (see section 9), do not inhale the contents of the bird bag or stick your head in holding cages.

For the birds' comfort, ease of removal from the holding device, and for sanitary reasons, it is often best to hold large numbers of birds in cardboard boxes with mesh or burlap on top, held down with clothes pins, or fabric tops fitted around the box with elastic cord sewn into the hem of the top. Birds kept in semi-dark conditions (e.g., boxes with burlap tops) often appear calmer than those in boxes with mesh tops (but see comments below on the usefulness of mesh box tops in species susceptible to capture myopathy). When holding large numbers of birds outside (e.g., after cannon or rocket net catches), it may be most efficient to use larger (100 x 100 cm) keeping cages to hold the birds until processing (e.g., Bainbridge 1976, Stanyard 1979, Clark 1986). Because the base of the cage is the actual ground, they do not require floor cover replacement. Birds are sorted into species or sizes, as usual.

Aggressive species such as turnstones should be kept in the dark, or in separate boxes, as they may peck at each other. Normally, for boxes covered in burlap, one clothes pin per side will be sufficient, but twelve pins per box are recommended for snipe (because of their explosive take-offs). Mesh tops will allow more airflow under warm banding conditions, but burlap often keeps birds calmer because it is dark inside the box. Paper towels may be placed at the bottom of the box and replaced regularly: when the box becomes dirty, the towels can be easily replaced. Alternatively, cheap, thin carpet can be cut to size and used as a base, although these must be washed regularly. And as noted above, outdoor folding boxes just have the ground as a base. Where cardboard boxes are not easily available, plastic or wooden boxes with holes drilled in the sides may be used, or plastic laundry baskets with newspaper in the bottom, using large clips to attach cloth tops. Both types of plastic usually stack well for transport when empty. Under some conditions, water may condense on the inside of plastic boxes and dampen birds. Birds that are damp when removed from nets or traps may not dry out quickly if kept in plastic boxes. If this happens under the conditions you work in, you should use cardboard, wooden, or cloth-sided boxes. Holes drilled into the sides of plastic or wooden boxes should be above the natural height for birds to poke their bills through, so that bills do not become caught and damaged.

Small boxes (about 30 x 30 x 30 cm) will comfortably hold four or five small shorebirds or one or two larger ones. Up to 10 small shorebirds can be placed in a larger box. Different species should be placed in separate boxes, and it may be convenient to separate age groups at this time as well, for convenience in processing. Prepared cardboard labels with species and perhaps age (adult or juvenile) can be placed on the top of each box.

Birds dyed with picric in alcohol will need to dry for 10-20 minutes before release (otherwise the dye can be rinsed off in the first water they encounter - and they often take a bath immediately after release). After dyeing, these birds should be held in low densities in cardboard boxes with mesh tops (flooring material must be replaced often), as the alcohol fumes can affect the birds if air circulation is restricted and bird densities high. If they are affected by alcohol fumes - become 'drunk' - they will recover fairly quickly if well separated in clean boxes with good air flow. Remember not to let your picric sources dry out (always keep saturated in water or alcohol), as it is explosive when dry.

Shorebirds normally lose small amounts of weight when held for short periods in captivity, with a greater percentage of weight loss soon after capture and decreasing with time held. Weight loss is greater when birds are held at higher temperatures. Castro *et al.* (1991) suggested losses of 8% per hour in temperatures above 30°C, but Wilson *et al.* (1999) found only 1.4-2.3% decreases per hour at such temperatures. Initially, most mass loss is the result of water loss, with some loss of pectoral muscle mass, lean dry mass, and fat mass within 24 hours after capture (Davidson 1984). Therefore, it is important to release birds as soon as possible after capture, especially in hot weather.

Optimally, birds should be released in habitat similar to that where they were captured. This might be in a marsh or near the edge of a wetland (but not the top of a cliff). However, care must be taken so that birds do not fall into water upon release. If birds are held in a box, the top can be removed, and birds encouraged to leave. To ensure they are healthy, it is best to encourage the birds to fly, rather than walk off, so it is often useful to release them from the palm of one's hand (not from a large height). Release them into the wind, not with it. Be aware of potential predators on release (raptors, including owls at night, crows, gulls, ravens, etc.). You may need to delay release until predators are absent.

6.4 Capture myopathy. Long-legged shorebirds (yellowlegs, godwits, Stilt Sandpipers, oystercatchers, etc.; see Table 1) are susceptible to leg-cramp (capture myopathy). They should be removed from nets or bags first, and processed as soon as possible. They must be placed in tall boxes, and care must be taken to ensure they remain standing. It is sometimes useful to place a mesh top on these boxes, rather than burlap, to encourage the birds to stand. In the hand, they should be held with legs dangling, where possible. Capture myopathy is more common when susceptible birds remain in capture devices for long periods of time, such as when large numbers are captured simultaneously (Minton 1980, 1993), and may be more common in birds of poor body condition (Stanyard 1979, Melville 1982), or those with large fat deposits (Minton 1993, B. Harrington pers. comm.). For a more detailed discussion of capture myopathy in shorebirds see Green (1978), Minton (1993), Taylor (1994), and Piersma *et al.* (1991). Treatment is long and involved, requiring many permits and veterinary experience (administration of valium and/or saturated glucose water solution), and may not be successful, so birds may need to be euthanized: focus should be on prevention, with careful capture and holding techniques, and decreased handling time for susceptible species. Removing birds from traps or nets calmly and quietly also helps in reducing capture myopathy, as does immediate banding and release of birds sitting down in holding boxes (N. Clark pers. comm.). There is no known instance of a shorebird showing capture myopathy after being captured on nest, presumably because, as birds are captured individually, they are not normally held for more than a few minutes.

Redfern and Clark (2001) summarize ways to minimize the possibility of capture myopathy in susceptible species of shorebirds, including the following points:

1. plan carefully beforehand where and how birds will be kept, processed and released, and who is responsible for doing what,
2. do not fire cannon nets into water when attempting to catch susceptible species, as it will increase extraction time, as well as time in captivity (if plumage is damp),
3. limit catch size (normally to about 50 birds of susceptible species),
4. cover, extract, and put birds into appropriate holding cages without delay,
5. keep noise to a minimum, and deal with the birds competently and quickly to reduce stress,
6. do not carry or hold the birds by their legs,
7. the birds must be able to stand in captivity (in boxes of appropriate height),
8. any bird sitting in a keeping cage should be banded and released immediately,
9. try to release all birds of susceptible species within 90 minutes of capture,
10. the release area should be near the processing/capture area, and allow birds to fly or walk off unhindered,
11. process and release susceptible species first (see Table 1) when dealing with multiple species.

6.5 Keeping shorebirds in captivity. For some experimental, breeding, or conservation purposes, it is necessary to keep shorebirds in captivity. For more details, talk to researchers who have successfully kept shorebirds in captivity, and refer to the AOU Guidelines to the Use of Wild Birds in Research (Fair *et al.* 2010; https://naturalhistory.si.edu/BIRDNET/guide/index.html).

Most problems in maintaining shorebirds in captivity are related to foot lesions caused by inappropriate substrate (Salzert and Schelshorn 1979). This can sometimes result in foot loss. Having a substrate that is bacteriologically clean is mandatory for the health of the birds; the floor must be washable. The optimal substrate would be washable but soft (D. Lank pers. comm.). One such product is called Tufflex, which can be applied to any floor configuration, in almost any thickness. It is resilient underfoot, and the substrate can be made completely slip-proof (important when raising chicks on a slope), and it stands up to years of vigorous repetitive washing (M. Rubega pers. comm.). The substrate should be washed AT LEAST once per day. Pools of water with a gentle slope are recommended, and if used, should be flushed with continually running water, if possible. Sand can be a hazard for long-term holding, as it builds up a reservoir of bacteria which infects the birds when the substrate is disturbed (M. Rubega pers. comm.). Soft walls and roofs for pens (e.g., netting) are recommended, although it may be safest to trim primaries to prevent flight if birds are to be kept for long periods of time or handled frequently.

It is important to provide water baths that continuously drain water at the surface to allow birds to keep feathers clean enough to maintain waterproofing (D. Lank, M. Rubega pers. comm.). In cases where a continuous supply of clean water is not available, where continuous draining to a sewer or other disposal route is not allowed, or where experimental needs require maintenance of a particular water composition, it is desirable to have a good recirculating water system with water sterilized (e.g., by a combination of filters and UV beams; L. W. Oring pers. comm.).

Often, captive adults are fed commercial feed sold for older pheasant chicks, ground dried shrimp, meat and fish, commercial trout feed, cooked minced eggs, boiled rice, minced fruits, carrots, catfood, commercially available oligochaetes, bloodmeal and fishmeal, and additional vitamins and minerals (Malone and Proctor 1966, Salzert and Schelshorn 1979, Vander Haegen *et al.* 1993, L. W. Oring pers. comm.). It is not advisable to feed the birds, especially young chicks, with a single food source, as it is likely to be deficient in essential nutrients. Some fat is essential, but food should not have a greasy surface, or the birds are likely to get 'dirty' and their plumage lose its waterproofing ability; egg yolk is a useful source of fat (M. Rubega pers. comm.). Young chicks must learn to recognize and peck at food items that do not move, so 'bouncing' bits of food items (such as egg and egg yolk put through a garlic press) at young chicks helps train them (D. Lank pers. comm.).

Chicks should not be isolated (keep at least two chicks in a pen). Adults of some species may need to be isolated at some times of the year (e.g., Solitary and Green sandpipers in early fall; L. W. Oring pers. comm.), although other species such as Sanderling, Red Knot, and Semipalmated Sandpipers appear to adjust more quickly to captivity and accept a pellet diet better when they are kept in a group of birds (N. Tsipoura pers. comm.). It is important to simulate the natural light regime so that molt proceeds normally (L. W. Oring pers. comm.).

7. CAPTURE METHODS

Capture methods vary according to location, season, species, and objectives of the study. General types, and some variations, are described below. Much more detail and many more types are described in Bub (1991).

7.1. Migrants, wintering, or foraging shorebirds.

7.1.1. Mist nets. Mist nets are commonly used to capture migrant or wintering shorebirds. Although nets used to capture shorebirds are often the same as those used for passerines (3.25 cm/1.25 in. mesh primarily for smaller shorebirds, approximately 3.9 cm/1.50 in. mesh for larger species, normally 12 m (42 foot) or 18 m (59 foot) long, 8 foot high (2 m), 4 panel, black), several differences in capture techniques exist. The text below will emphasize conditions specific (or more common) in shorebird mist netting, as use of mist nets in general is discussed in the general banding manual (NABC 2001).

Often, shorebird nets are strung together (using a common pole between nets) in sets of five in a straight line, perpendicular to the coast or through a wetland. A 'line' of nets may consist of up to four sets of five nets. Nets are set up in areas where flocks are known to feed, or return to roost. Sites are usually not well protected from wind, so shelf strings may need to be adjusted to create 'bags' in panels, and nets should be closed if birds begin to get cold or cut by the net. If nets are left in the same position for several days, guy ropes must be sufficient (normally two per pole attached to heavy pegs such as rebar or welding rods) to hold up a set of nets in high winds and water (often including tides). Catching is usually over water, so poles must be tall enough so that lower panels will not be under water, even when large numbers of birds are captured in that panel. Drowning of birds is a major potential problem when capturing shorebirds, so this risk must be considered and mitigated. In tidal situations, it is particularly important to ensure that net panels are not too low. Tide height may vary considerably with storms offshore, so can be unpredictable, and nets should be especially well monitored near high tide. An extra insurance measure is to place a support under the middle of each net (use M-shaped wire support, or tie center of net to a short pole; G. Appleton and J. Gill pers. comm.).

Poles may be made of different materials: 305 cm (10') EMT metal conduit is convenient, with 1.3 cm diameter (0.5 in.) lighter, but less sturdy than 2.0 cm diameter (0.75 in.). A stick or thin pole with a large nail driven through one end makes a useful 'furling stick' to lower upper shelf loops in order to remove birds high in the net, or to adjust tautness of the net shelves. Nets should not be left unattended in areas where visitors might open nets. At locations where visitors are rare, nets temporarily not in use can be furled instead of removed, with shelf-strings securely tied together at intervals (flagging tape works very well and is reusable). It is important to immediately repair tears in the net so that birds do not become excessively tangled when the net is open, and that torn portions of net do not flap open and catch birds while the net is closed.

Because standard black mist nets are normally highly visible on mudflats or wetland edges during the day, most shorebird mist netting is carried out during the night, or at dawn and dusk when birds are more active, but cannot see the nets well. Many can be captured when dawn coincides with high tide; it is important to have sufficient experienced personnel to quickly remove birds from nets in the dark, and adequate numbers of boxes to hold birds for banding. If netting in darkness, head lamps (and good batteries) will be essential for each person. In order not to deter other birds from flying into the nets, lights should be used sparingly, but enough to insure the safety of the birds and allow them to be extracted promptly. In some cases (e.g., large numbers of birds moving consistently about), normal black mist nets can catch large numbers of small sandpipers during the day. Monofilament mist nets are harder to see and may be more effective in capturing small shorebirds during the day, especially in marshes. These nets tend to cut shorebirds. Even in moderate wind conditions, birds are difficult to remove for less experienced banders, and the nets degrade rapidly because of exposure to weather and rough handling by inexperienced banders. Nevertheless, if carefully used, monofilament nets can be a safe and useful way to capture shorebirds during the day. Sand-colored mist nets also may allow capture of shorebirds during the day in similarly colored substrate. Two panel nets have been used effectively to capture dunlin and dowitchers over water with decoys (N. Warnock pers. comm.).

Juveniles, and adults during spring migration (especially Semipalmated and Western sandpipers) may make distress calls when in the net. This not only attracts other shorebirds, but also may attract predators such as gulls, hawks or owls. If this happens, nets must be checked more often, and closed if necessary. A tape lure of breeding Curlew Sandpipers was used successfully to catch wintering Curlew Sandpipers, although a greater percentage of light-weight birds were mist-netted when using the tape (Figuerola and Gustamante 1995). The use of taped Semipalmated Sandpiper distress calls was not successful during spring migration in Saskatchewan (pers. obs.), nor Long-billed Dowitcher alarm calls elsewhere (N. Warnock pers. comm.). However, oystercatcher/knot roost calls (broadcast from a tape recorder set in the middle of a set of nets) often have been used successfully to attract a mixture of shorebird species (*Calidris* and *Tringa*) into nets in Britain during the winter; and roost calls of *C.* sandpipers used to call *Calidris* sandpipers into mist nets at Delaware Bay during spring migration (Clark and Austin 2005). In recent years at James Bay, roosting and foraging calls were successfully used to mist net shorebirds (C. Friis, pers. comm.). Western and Semipalmated sandpiper distress calls improved captures of those species in Ecuador (Haase 2002). Clark and Austin (2005) found that the clarity of the recording appears to be more important than the species making the calls in terms of the effectiveness of the sound lure.

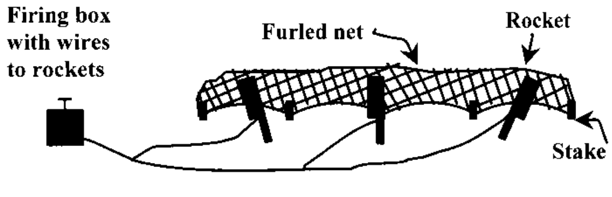
Specific conditions may require variations on the traditional theme of straight lines of nets on a mudflat or into a wetland. Nets may be arranged in a box, '**v**', '**c**', etc. In some situations birds may be flushed into nets. For example, at the Bay of Fundy, where birds roosted on shore at high tide, one or two nets were set up parallel to the shore just below or at the high tide mark, and the roosting birds were gently moved so that they flew in front of the nets, between the nets and the upper shore. At that time, a person hiding well behind the nets on shore jumped up and ran towards the nets, so that the birds flew towards the water and into the nets (maximum number captured at once in two nets was 268 small shorebirds).

If birds consistently move along a narrow corridor (e.g., along a lake edge, or between two ends of a wetland), conditions may be suitable to use a mist net as a 'flick net': holding a net near the ground between two persons or on a cord, and flicking it up into position when birds fly past (e.g., Otnes 1990). Johns (1963) described a method of capturing phalaropes by releasing a net held horizontally 2 feet above the water when birds swan underneath. Birds had to be removed immediately to prevent drowning. Peyton and Shields (1979) explain a variant of that method. Koopman and Hulster (1979) describe use of a 'Wilsternet' (i.e., the net is pulled up and over birds in flight) with decoys.

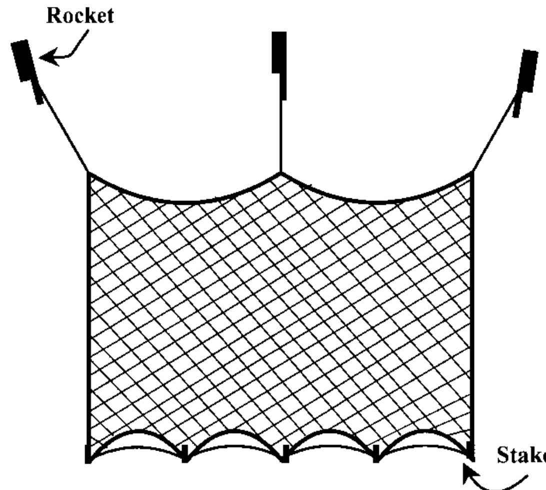
Birds captured in mist nets may represent a biased sample. For example, juveniles (e.g., Pienkowski and Dick 1976, Goss-Custard *et al.* 1981, pers. obs.), birds not in active wing molt (Pienkowski and Dick 1976), and probably birds lighter or heavier than average (less able to maneuver) are more likely to be captured than adults, molting birds, or average-weight birds, respectively.

7.1.2. Cannon or rocket nets. When shorebird flocks roost at a predictable site, birds may be captured in cannon or rocket nets by personnel extremely experienced with this potentially dangerous technique, and with all appropriate permits. Both cannon and rocket nets involve a net that is attached to the substrate along one edge, with projectiles attached to the other edge. The net is furled along the tethered edge. When the projectiles are fired, they carry the leading edge of the net over the roosting birds (Figure 1). For cannon nets, the cannons contain explosives as well as projectiles attached to the leading edge of the net. The cannons are placed at an appropriate angle near the furled net. When the cannons are fired, the projectiles shoot out to open the net. For rocket nets, the explosive is contained inside the rockets, which are themselves attached to the leading edge of the net and positioned at an appropriate angle. When the rockets are fired, the rockets become the projectiles and carry the net over the roosting birds. Nets normally contain three to five projectiles, which are wired together so that they fire simultaneously. Often they are attached to a battery-operated firing box, or they may be fired remotely with a radio system. The furled net can be disguised with a thin layer of vegetation.

Figure 1. Rocket net.



Rocket net before firing



Rocket net after firing

These techniques require considerable training in the safe use of explosives and use of the rockets/cannons and net, both for human safety and the safety of the birds. Anyone intending to use rocket or cannon nets should first obtain practical experience in their use under different conditions with experienced users (e.g., Wash Wader Ringing Group in Britain). Special permits are required to use these nets, and often for transport and safe storage of the explosives. Birds must not be on top of the furled net, nor in the air in front of the net before it is fired, or they will be injured or killed. The net should not be fired far into water, particularly into an incoming tide, or birds may be drowned, or smothered when the leading edge is partially furled onto dry ground. Cannons or rockets must be set at appropriate angles to fire the net over the roosting birds (not through them), but not so high that the birds could escape before the net settles. Cannons can be set to more exact angles than rockets, and projectiles may be safer (rockets tend to speed up as the net extends, cannon projectiles start fast and tend to slow down; C. D. T. Minton pers. comm.). Charges must be sufficient to open the net to its full extent, yet not pull away the moorings of the tethered edge. Charges must fire simultaneously, and projectiles or rockets must be firmly attached to the net and their attachments constantly checked for wear. The exact extent of the net must be known, so that it does not fire far into water, or capture too large a flock of shorebirds to handle safely. If the net is set to fire a few meters into the water, sufficient crew must be present to IMMEDIATELY push the net and birds onto dry land, without clumping the birds (so they do not smother).

Once the net is fired, placing a layer of burlap over the net (on dry land) will help keep birds calm until they are removed from the net. Birds are removed from under the leading edge, which is furled as you move to the back of the net. For species susceptible to capture myopathy, it is important not to capture more than can be removed quickly from the net by available personnel, and processed immediately. Under appropriate circumstances (consistent roosting patterns, trained and careful personnel), this is a very efficient and safe technique to quickly capture large numbers of birds that may be wary of mist nets. It has, however, the potential to kill or injure large numbers of birds very quickly if carried out by inexperienced or careless banders. Certain weights of netting and mesh sizes have advantages over others, and, as noted, cannon nets may be safer than rocket nets. Much more detail on cannon netting in particular can be found in the BTO cannon-netting guide (Appleton 1992), and in Bub (1991).

7.1.3. Pull or drop nets. Drop nets, where a cord is pulled from a distance and a net is dropped over feeding birds, have been mentioned earlier (Peyton and Shields 1979, Johns 1963). They can be very effective in capturing small numbers of birds in winter or migration. A portable drop net is described in detail in Doherty (2009), made of a 5 m x 11.5 m rectangular fish net, fishing weights, blocks, black parachute cord through and along the edge of the net, with a control line of braided nylon cord, and four 2 m long metal fence posts as anchors. When the control cord is released, the suspended net drops onto the foraging birds underneath. The fish net material lasts much longer than previous versions made from mistnets.

In some areas, pull or ‘clap’ nets are commonly used to capture shorebirds. Light fishnets (approx. 3-5 cm mesh) are used, with an arrangement of pivoting poles and tension ropes that release the net to flop over the capture area when the pull string is tugged. Many different variations exist, some of which are described in Bub (1991). This type of net is useful when birds roost in predictable locations on dry land. A type of pull net using launching stakes, that has been used very successfully on roosting shorebirds in the Bay of Fundy, is the Fundy Pull Trap (see Hicklin *et al.* 1989 for complete instructions and diagrams). Equipment includes a white monofilament herring net (3.7 m x 5-8 m, #12 gauge, 5.1 cm mesh), a light-duty steel conduit pole (3.1 m long, 1.3 cm diameter) attached to the leading edge of the net to pull the net open, two 1 m long poles of the same type of conduit used for launching stakes (driven 0.5 m into the ground about 2 m apart just in front of the net at a 30-45 degree angle), about 24 m (depending on the size of the net) of 1 cm sash chord woven into all sides of the net to weight down the sides of the net when open, and 20 m or more of 2 mm diameter pull chord. A loop is made in the center of a 6 m length of the pull chord. The ends of this 6 m length are then attached to each end of the leading edge pole. The remaining pull chord is attached to the center loop of the 6 m length, and run back to where the person who will pull the chord is waiting. The net is furled so that when the chord is pulled, the leading edge pole rides up over the launching stakes, and pulls the net open and over the roosting birds in front of the net. The back edge of the net is weighed down with stones. A very small percentage of birds were injured by the leading edge pole, but unless the net is pulled into water, other injuries or losses should be minimal, and extraction was simpler than from mist nets.

7.1.4. Walk-in traps. Walk-in traps are commonly used to capture shorebirds at staging sites (e.g., Serventy *et al.* 1962). Often, these traps require less experience than mist-nets, as they are less dangerous to the birds, and they can be used in a variety of weather conditions when mist-nets are not safe (e.g., wind). A wide variety of walk-in traps exist (see Bub 1991); most are made of wire, and consist of wire fences or 'leads', leading to the trap which has several 'one-way' entrances. These traps are not normally baited, but are situated in areas where birds commonly feed, such as marshes or mudflats. Foraging shorebirds encounter a lead, and follow it along to the trap entrance, then enter the trap and cannot easily escape. Meissner (1998; Figure 2) describes traps commonly used for shorebirds, constructed of rust-proof wire frames (40 cm high) and thick fishing net ($\geq$ 1 mm rope, mesh 1.8-1.9 cm): netting resulting in fewer injuries to trapped birds than wire. These traps can be made in sections and wired together so that they fold up for easier transportation and more convenient repair of damaged netting. Funnel entrances are relatively deep (initially 40 cm high, decreasing to 21 cm inside the trap), and not placed in a line, so that fewer shorebirds can escape. Multiple traps can be joined by leads. The height of wire netting leads should be about 15-23 cm, and the funnel gaps only about 2.5-6.0 cm, since the birds force their way into the trap (Lessells and Leslie 1977). Leads also may be constructed of soft mesh (e.g., from fish netting; J. Klima pers. comm.).

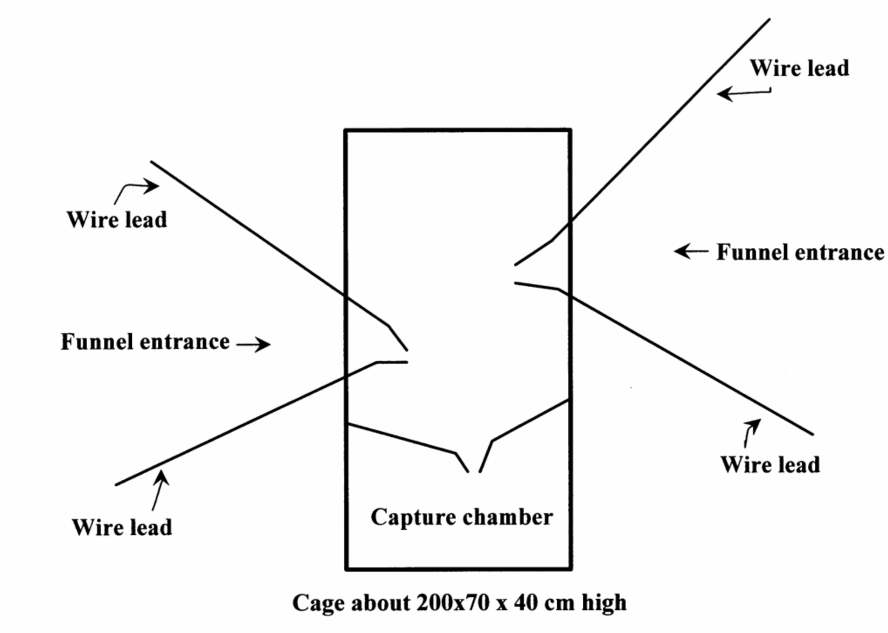
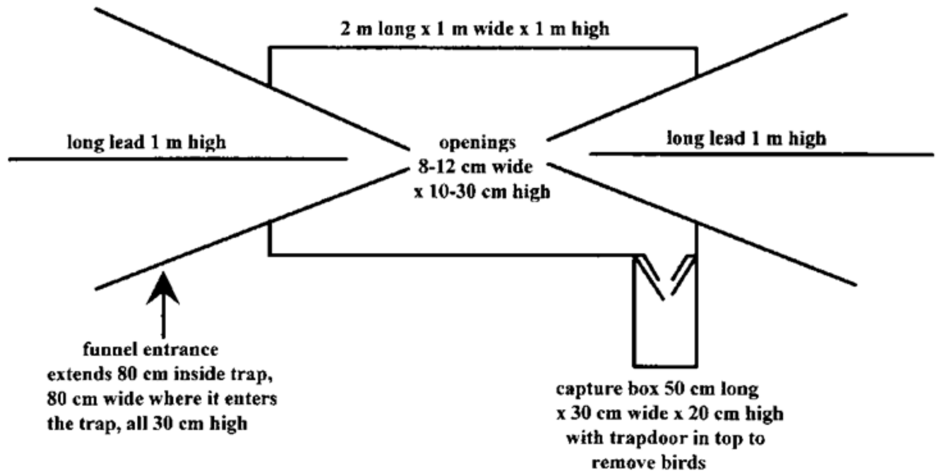


Figure 2. Foraging walk-in trap 1 (Meissner 1998).

Figure 3. Foraging walk-in trap 2 (Guy Jarry).



Meissner (1998) notes that in areas with clear shorelines, v-shaped fences are most effective, while in muddy flat areas a single line of fences can be useful. The floor of the capture chamber must be dry, or covered in sand and/or cut grass. Traps should be checked every 1-2 hours. In tidal areas, the trap must either be placed above the tide line, or moved when the water is rising. If water rises higher than usual due to high winds or storm tides, traps must be removed quickly. If raptors or mammals begin to prey on captured birds, trapping must be terminated, and the traps may need to be moved. Traps should be kept clean of blowing or floating debris (e.g., seaweed). Walk-in traps usually are most effective for smaller shorebird species. Figure 3 illustrates an alternative design for a walk-in trap (Guy Jarry pers. comm.). Lindstrom *et al.* (2005) describe a portable walk-in trap of 120 x 41 x 32 cm designed for use in field expeditions, which can be folded flat for easy transportation. It weighs less than 2 kg and is made in sections (metal frames with fishing net), which are attached together with zip-ties. The netted roof is attached by an elastic chord.

7.1.5. Hand nets. In some circumstances, hand nets can be a useful capture method. The net should be approximately 1 m diameter, with 36-50 mm mesh. The handle should be lightweight and 2-3 m long (e.g., an extendable pole, such as from a golf ball retriever, may be used). Often a hand net is used for night-lighting shorebirds. A bright light is used to dazzle roosting birds, which are then caught with the hand net (e.g., Potts and Sordahl 1979, Tree 1982). Night-lighting works best on dark nights, and a background noise is useful to cover the sounds made by stalking the birds. Hand nets also can be used to capture certain shorebirds during the day, for example pre-laying pairs of phalaropes swimming in shallow water (J. D. Reynolds, pers. comm.). This technique requires steady nerves and practice, but can be a useful capture method.

7.1.6. Noose mats. Some species of shorebirds (e.g., Piping Plovers, Snowy Plovers) have been captured with noose mats during the nonbreeding season or near nests (Mehl *et al.* 2003). These consist of numerous small monofilament nooses attached to a surface. The carpets are set up near the nest or in areas where the birds feed. When the birds walk over the carpet, their feet catch in a noose that tightens.

These traps must be monitored at all times, and birds removed as quickly as possible. No injuries to birds have been reported. The traps are time-consuming to construct and re-set, but very effective in some situations (no vegetation, predictable areas where the birds walk). The use of strategically placed barriers such as beach debris or small logs can direct birds towards a mat. The type used to capture wintering Piping Plovers in Texas (K. R. Mehl pers. comm.) consisted of 0.6 cm (0.25 in.) hardware cloth (sturdy wire mesh with small square holes versus the larger hexagonal holes of chicken-wire) with monofilament nooses (10 lb test clear fishing line; others prefer to use 6 lb test) tied at approximately 2.5 cm intervals throughout the length and width of the hardware cloth. Pliers were used to bend ends of the wire under to reduce sharp points that might injure birds. The strips of hardware cloth used were approximately 0.3 m x 0.75 m, but this can vary. The 10 lb test monofilament fishing line creates a noose that stands upright but is still hard for the birds to see. Nooses made of fishing lines of lesser strength tend to blow over easily in the wind, resulting in unsuccessful trapping attempts. Nooses which stand about mid to upper chest on the bird work best, as smaller nooses result in birds walking over the line without entanglement. (See Appendix 2 or Mehl *et al.* 2003 for instructions on tying nooses). Leaving a small 3-5 mm tab of monofilament at the slip knot of the noose (the 'tail' in Appendix 2) allows an easy method of disentangling the birds by pulling on this tab to loosen the slip knot. Lead lines are often used to direct foraging birds to the noose mats, and normally consist of chicken wire fencing approximately 0.3 m in height and about 1 m in length. Thin metal rods wound through the chicken wire at 0.3 m intervals and extending into the substrate can be used to anchor the lead line into the substrate, and small metal hoops can be used to anchor the noose mat to the substrate.

7.1.7. Net guns. In some instances a net fired from a gun propelled with either gunpowder or compressed CO_2 gas has been used to target specific individuals or small numbers of shorebirds (e.g., Johnson *et al.* 2011, Edwards and Gilchrist 2011, Buidin *et al.* 2015). Edward and Gilchrist (2011) used a compressed gas propelled net gun (Super Talon Net Gun), which weighed just over 1 kg. This model uses single-use CO_2 cartridges and has removable heads that hold nets, allowing for used heads to be swapped quickly with preloaded ones. Approximate reload time with a preloaded net head is one minute. Nets supplied with this model are ~3 m with a mesh size of approximately 10 cm, which is too large to capture small shorebirds. Therefore, Edward and Gilchrist (2011) constructed nets from standard passerine mist nets. They had 100% capture success at 3 m, declining to 10% at 5 m, but success was species dependent. They noted it was essential to fire downwind, rather than against any wind (and successfully captured birds firing downwind with winds up to 50 km/h). They also advised against repacking nets into the gun heads in the field, as debris and errors in repacking resulted in misfires.

Gunpowder propelled nets often have relatively high mortality rates compared to gas propelled net guns (Lehman *et al.* 2011), mainly from projectiles hitting birds. Buidin *et al.* (2015) described a technique using a portable gun-powder propelled net gun (Coda Enterprises, Mesa, Arizona, USA, www.codaenterprises.com) where they had no mortality when capturing Red Knot. This was primarily attributed to practice-firing to understand how projectiles are fired, to ensure that when fired in the field no birds were in the direct line of fire of any projectile. Buidin *et al.* (2015) noted that the gunpowder propelled net can be fired at a greater distance than a gas propelled net, even using medium strength cartridges (here, the effective range was 4-6 m). A CODA net gun was also used to capture Purple Sandpipers in New Brunswick and Newfoundland (J. Paquet, pers. comm.). Flocks of roosting Purple Sandpipers, primarily on rocky headlands and shoals, were approached with a zodiac boat to within 5-10 m. If the flock did not flush, the gun was fired only if the net would land on rock versus water. Capture attempts from the shore were more difficult, as the net would usually have landed in water if fired.

An unusual variant is a crossbow used to pull a net over small flocks of roosting shorebirds (Martins *et al.* 2014). The authors note that the technique is portable, easily set up, has minimal disturbance of birds near the capture area, and no explosive materials are needed. The crossbow was fixed firmly to the ground behind the capture area, using wooden poles and a board, and the net placed on the ground (in a plastic gutter) in front of the crossbow.

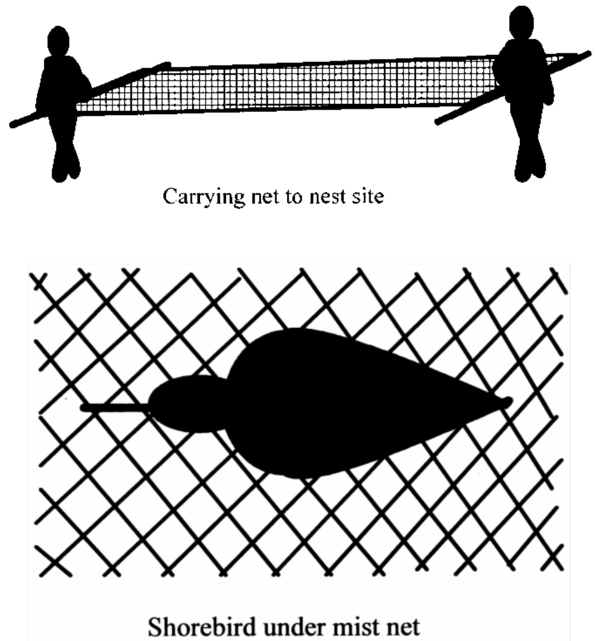
7.2. Shorebirds at nests. Many species of shorebirds are quite easy to capture at their nests, and few will desert nests after marking and release, if captured on completed clutches (see Table 1, and review in Kania 1992 for European species). Many shorebirds will desert nests (and are much harder to capture), if caught on the nest during the laying period. Some species, especially plovers, may desert if captured during the first week of incubation. In colonial species, such as American Avocets and Black-necked Stilts, trapping of more than two or three birds in a colony per day may result in desertion of the entire colony (L. W. Oring and J. A. Robinson pers. comm.). Avocets and stilts seem particularly prone to desertion, at least in some areas (N. Warnock, pers comm.). To prevent desertion in all species, it is often useful to delay capture of the second adult at a nest for several days after the first is captured. The rate of desertion may depend on the trapping method used, the length of time the bird is held before release (due to application of nanotags, geolocators or satellite transmitters, time taken to capture, etc.), and may vary among areas (e.g., is higher among some single parent incubators at very high latitudes compared to the same species slightly farther south; T. Piersma pers. comm.). The trapping method used should be the most efficient technique that minimally disturbs birds and their eggs, and depends on species and habitat. Vegetation around nests should be disturbed as little as possible, so that predators are not attracted to the nest site. If only one sex incubates, obviously only that sex will be captured on completed clutches, so that must be considered during study design (Table 1). Traps with moving parts may not be useful in heavy vegetation or if the nest is under a bush (which is common for many species). Species (or individuals) reluctant to enter a typical walk-in trap may be caught easily in a pull-trap or monofilament trigger trap. If you need to carry traps for long distances, the weight of the trap will be a major concern. In any instance where one is flushing shorebirds from nests, an increased risk of egg predation may occur, especially if birds do not quickly return to nests once released or flushed. This should be considered when deciding on the appropriate amount of disturbance in an area.

Normally, shorebirds eggs can withstand fairly cold temperatures until the embryo becomes more developed. Chicks are highly vulnerable for the first few days after hatch. Regardless, it is often difficult to capture adults on chicks, as parents normally try to call chicks away from the nest trap, rather than go in themselves, but see Appendix 1 and section 7.2.5. Do not attempt to capture birds on a nest under conditions of extreme cold, rain, or snow. In extremely hot weather, where nests have little shade, eggs should be removed from the nest before the trap is placed and held in a cooler until the bird is captured and released. Temporarily, artificial eggs of painted plaster or wood can be placed in the nest cup. In most species, eggs are rarely damaged during capture; occasionally an egg may be dented slightly by the bird flushing, or jumping on the nest in the trap. Normally the egg still will hatch. Denting is more likely to happen late in incubation when eggshells are thinner. Concern about egg-breakage is reduced if eggs are temporarily removed and replaced with artificial eggs before capture (unless using a mist net dropped on the nest).

In species that flush when a person is very close to the nest, mist nets are an excellent method of capture. It is often useful to use a mist net (see 7.2.1) placed on the nest as a first attempt, then immediately put down a nest trap if the mist net attempt was not successful. In species that flush when a person is far from the nest, some sort of nest trap must be used (or an upright mist net near the nest, or noose mat). Appendix 1 notes methods used for capturing different shorebird species at nests and with broods.

7.2.1. Mist nets. Mist nets can be used in several ways to capture shorebirds at nests. The most efficient and common method is to carry the net on two poles (preferably aluminum for lightness) open and taut between two persons (Figure 4). These persons stride briskly up to the nest area, and quickly place the net on top of the incubating bird, trying to have the nest (and bird) in the center of the net. One person then runs to the front of the net to hold down the front edge, and the other to the back to do the same. The bird is then removed from under the net.

Figure 4. Use of horizontal mist net to capture birds on a nest.



Care must be taken not to crush the eggs underfoot. Sometimes the bird remains sitting on the nest and can be carefully picked up off the eggs. This technique only works on birds that flush at close distances and under conditions of low vegetative cover so that the net is not lifted off the ground (e.g., Upland Sandpipers, Dorio *et al.* 1978; Long-billed Curlews, Marbled Godwits and some western Willets, Gratto-Trevor 2001). It is extremely useful to place an obscure mark a specific distance and direction from the nest, to indicate when to put down the net over the nest (normally one cannot see the bird on the nest until after the net is placed over it). For example, one might place a pin flag (wire stem with a small plastic 'flag' on top, used by surveyors) 15 m from the nest, and a pin flag with almost all of the flagging removed 4 paces from the nest in line with (and between) the first flag and the nest. The net normally used is any 2.4 m (8 foot) long mist net with 4 panels. Mesh size and thickness of the netting varies according to the size of the bird being captured: 32-36 mm mesh for small species. Larger birds can be captured with a small mesh net, but the net (being dropped on the ground and trampled) will suffer considerable wear, depending on the terrain, and the larger birds will more easily be able to escape from under the net rather than be caught in it. It is important to fix all holes in the net, but because the technique does not depend on invisibility of the net, repairs need only be functional and complete, not inconspicuous. This technique is less useful in a strong wind, as it whistles through the net when one is walking (one reason to keep it taut), blows the front or back edge out of place when setting the net, and birds may be more skittish under windy conditions. Obviously it is not possible to remove eggs before flushing the bird, but denting the eggs is rare, even with large species. This is an exceedingly efficient and safe technique: if it works for your species and location, and you have an associate, use it.

Another alternative to a nest trap for capturing more skittish birds on a nest is an upright mist net placed near the nest. The net is set with a third pole in the center, and the net is bent around the center pole, partially encircling the nest area (Figure 5). The bird is allowed to resume incubation, then the researcher dashes up, directly towards the nest, in an attempt to flush the bird into the mist net. This technique may be useful for small birds (use an appropriate mesh size) that are trap-shy (e.g., Spotted Sandpipers, L.W. Oring pers. comm.).

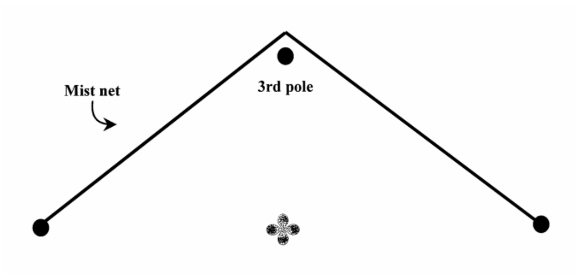


Figure 5. Use of upright mist net to capture birds on a nest.

7.2.2. Hand net. Hand nets may be used to capture certain shorebirds that sit tightly on nests (e.g., Willets in coastal Virginia, Howe 1982; woodcock females and broods, Ammann 1981). The net must be larger than the bird (approximately 1 m in diameter). Use an appropriate mesh size and weight for the type of shorebird (36-50 mm mesh); part of a mist net may be sewn onto a wire hoop, or a fish net might be used for larger species. The handle should be light weight and 2-3 m long. An extendable pole (such as from a golf ball retriever) may be used. The pole is extended and the person walks briskly towards the nest at an angle (to pass to the side of the nest at a distance less than the length of the net handle). At the appropriate moment, the net is quickly placed over the bird. It is important not to be tentative in placing the net, but even more important not to injure the bird or its eggs with the rim of the net. This technique requires steady nerves and practice, but works well if only one researcher is available, for some shorebird species that sit tight. It is important to mark the nest precisely with some inconspicuous marker such as a twist-tie, in addition to a more remote, more conspicuous marker. This enables you to place the net precisely over the bird with minimal risk of hitting the bird with the net frame (M. Howe pers. comm.).

7.2.3. Nest trap. The most common methods for capturing shorebirds on the nest use specially designed traps fixed in place over or adjacent to the nest. Nest traps vary enormously. However, certain types of traps will work better in some conditions and with some species than others. Passive traps involve no moving parts. Active traps have doors or nets sprung by the motion of the bird walking into the trap, or by an observer who springs the trap from a distance when they observe the bird in the trap. With any metal trap it is important to ensure that no exposed or pointed edges of wire remain inside the trap to injure the bird when it is attempting to escape. Traps should not be left unattended for more than 20 or 30 minutes. For most species it is not necessary to be able to see this type of trap at all times, as the birds normally continue to incubate until the trap is approached. Predators might be attracted to the trap, although I know of no instance where a bird has been killed by a predator while in a nest trap.

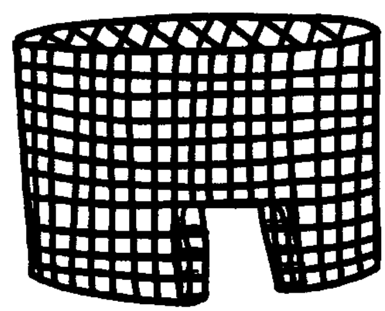
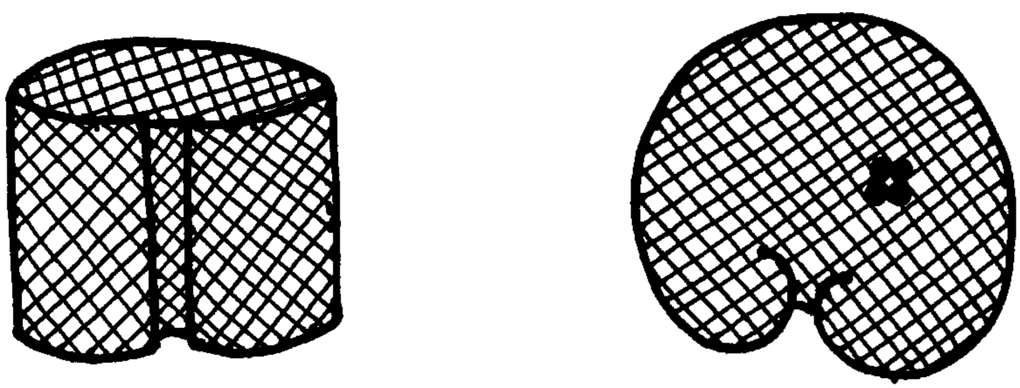


Figure 6. Passive walk-in nest trap of rigid mesh with small door.

Passive nest traps are often made inexpensively from wire mesh. Most are circular in shape. Trap sides may be rigid with small square holes (hardware cloth with 0.6 cm/0.25 inch square mesh) with a small opening cut into the mesh (the ‘doors’ bent inside), and a top of similar mesh or mist-netting (Figure 6). Ensure that no sharp edges protrude from loose ends of the mesh. These may be covered with wax or silicon caulking to avoid injury to birds.

Alternatively, the trap can be made entirely of flexible chicken-wire (hexagonal holes, 3.2 cm/1.25 in. mesh) with a larger ‘key-hole’ design opening (Figure 7). Again, ensure the traps do not have sharp edges protruding from any part of the trap to avoid injuries. One benefit of a chicken-wire trap is that it is flexible and can be bent to accommodate almost any terrain, including bushes and rocks near the nest. In either type, the width of the door can be adjusted to the size or shyness of the bird. Often the trap is held in position with pegs: three thin steel (‘skewer’) tent pegs work extremely well, with one placed by each side of the door and one at the back. Normally, the size of the entire trap is dependent on the size of the species of interest (e.g., a Semipalmated Sandpiper trap may be 25 cm and a Willet trap 60 cm in diameter and height). Placement of the trap is important: often it is useful to position the trap so that the nest is not directly in front of the door, but it must not be so off-center that birds ignore the door and try

Figure 7. Passive walk-in nest trap of chicken-wire (view from side and above).



to get to the nest from the back or side. In some species (e.g., Red-necked Phalaropes) a trail from the nest indicates the entry direction of preference for the bird, and the trap door should accommodate this. Once the trap is placed, the bander must leave the immediate area, and be far enough away that the bird’s behavior is normal (i.e., the bird will comfortably return to the nest and enter the trap). This distance is usually less for a small species than a large one. Usually, it is helpful to remain fairly motionless and silent until the bird is in the trap. You must be able to get back to the trap quickly; obviously with an ATV you can move more quickly than on foot.

Because no moving parts exist, only the configuration of the trap and shape of the door prevents the bird from walking out of the trap. However, once the bird enters the trap (usually in 10-30 minutes), it normally starts incubating immediately, and rarely leaves the nest until the bander approaches. The bander should approach the trap rapidly in the direction of the door, to prevent the bird from flushing towards the door. If the bird does escape, the door is probably too wide, and should be made more narrow. Generally, shorebirds are most difficult to capture in traps early in incubation; catching becomes progressively easier as hatching time approaches.

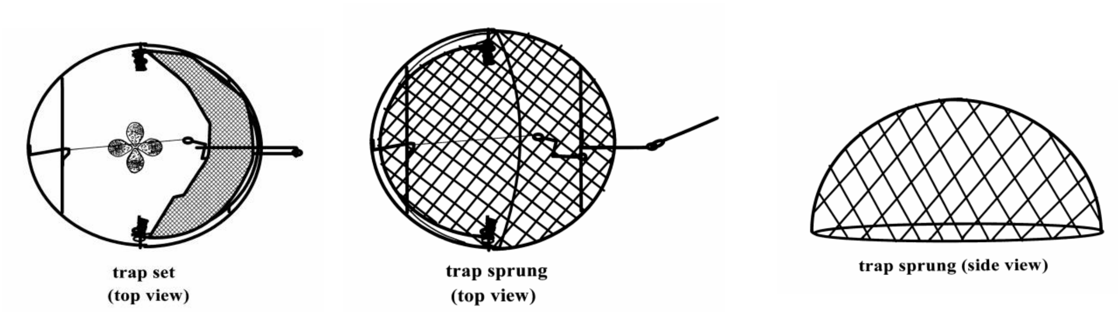
Birds can easily be extracted from most traps by putting a hand in the opening and grabbing small birds in the bander’s grip, and larger birds in both hands. Yalden and Pierce-Higgins (2002) describe another type of simple walk-in nest trap.

A common active nest trap is a variant of a potter-trap, in which, when the bird steps on a treadle or trips a line as it enters the trap or sits on the nest, the door shuts behind it (e.g., Parr 1981). This type of trap ensures that the bird cannot escape (but birds rarely escape from a properly set passive trap). Care must be taken to have the treadle or tripwire appropriately sensitive, and this type of trap may not be useful where rocks or vegetation hinder the dropping of the door. Because the bird often jumps up when the door closes, the trap must be kept under close observation at all times. Often it is useful to set the trap with the nest closer to the door than to any of the other three sides of the trap, so that the bird is more likely to go through the door rather than ignore the entrance and push at the sides of the trap.

Other nest traps, including some bownets (see below), rely on the observer to pull a cord once the bird is incubating, and the cord pulls the trap or netting over the incubating bird, or causes a door to close (e.g., Ferns and Green 1975, Koopman and

Hulscher 1976, Graul 1979, Hill and Talent 1990, Conway and Smith 2000). The simplest type is a 'fall-door' trap (such as a box-mesh trap or circular mesh trap without an entrance, which is propped up on a stick over the nest, with a cord attached to the stick. When the bird incubates, the cord is pulled and the trap falls over the nest and bird. An advantage of these traps is that the bird may more readily incubate if no trap walls are in sight, but again, the trap must be under constant observation, and may not work properly if rocks or vegetation impede the trap mechanism or placement. The mechanism must work quickly enough that the bird cannot escape the trap as it closes.

Figure 8. Bownet for nesting shorebirds.



One type of bownet trap uses a monofilament line tripped by the incubating bird, and consists of a flat wire frame at ground level with springs that pop netting over the incubating bird (Figure 8 and Appendix 3; similar bownets are described in Bub 1991, p. 178). This sort of trap has evolved over the last 30 or more years, but this specific one was described by L. W. Oring and S. M. Haig (pers. comm.). This type of trap is useful, as are many of the traps described in the paragraph above, for wary birds that will not enter other types of walk-in traps. As with any of the traps with moving parts, rocks or vegetation around the nest may cause the trap to malfunction, and the trap should be watched constantly. It works exceedingly well for plovers nesting in sandy locations. The monofilament should be clear and thin (6 lb test) so that the birds cannot see it; it should be low enough that the bird cannot duck under it; and it should pass directly over the center of the clutch (which should be in the center of the trap). If birds are wary of the ground level frame, it can be painted the color of the substrate, and the netting dyed to match the substrate color as well. Bownets can be semicircular, rather than a full circle, but the capture method is the same.

Both bownets and Potter-type traps can be used with a remote firing mechanism such as the 'bownet remote trigger' available from Modern Falconry (https://www.modernfalconry.com). This system consists of a black box (which can be spray-painted 'sand' or another color) about 15 cm x 8 cm x 8 cm that has an on/off switch and a thin lever. This unit is placed near the back of the trap (outside the trap), and the lever is used to hold the monofilament line. A small remote unit has a button one pushes when the bird is in place, which moves the lever, releasing the monofilament and causing the trap to spring. The system works well, but is not totally reliable (usually due to battery issues or poor connections).

7.2.4. Noose mat. Noose mats can be used to catch some shorebirds near nests, on small islands, pilings, etc. (e.g., Snowy Plovers). These consist of numerous small monofilament nooses attached to a surface. The mats are set up near the nest, and when the birds walk over the carpet, their feet catch in a noose, which tightens above their foot.

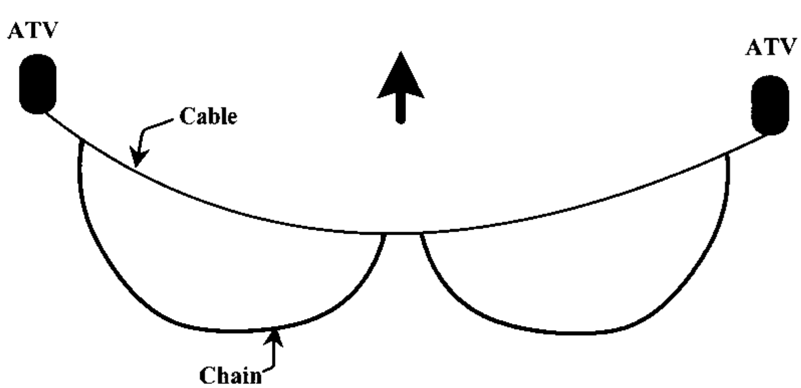
These traps must be monitored at all times, and birds removed as quickly as possible. No injuries to birds have been reported (G. Page pers. comm.). The traps are time-consuming to construct and re-set, but very effective in some situations (no vegetation, predictable areas where the birds walk). More detailed instructions on making and using noose carpets are described in section 7.1.6, Appendix 2, and Mehl *et al.* 2003. McGowan and Simons (2005) describe use of a remote controlled mechanical decoy to lure territorial oystercatcher adults to a leg-hold noose-mat trap.

7.2.5. Capturing adults on broods. Sometimes adult shorebirds can be captured on broods. This is usually easiest when chicks are young and parents most protective, so care must be taken not to let chicks get too cold or too hot when parents are unable to brood them, and not to trample chicks underfoot when capturing their parents. One method is to find chicks and place them in a bird bag (or small mesh bag), which is then placed in or under a mist net set upright in the area. This has worked relatively well for phalaropes and small *Calidris* species, but not for larger species such as Willets (pers. obs.). A similar method is to capture a chick or use a tape player with chick distress calls, and, with a person at each end of a horizontal mist net, swing up the net when the parent flies by. This has been effective in capturing small *Calidris* species, Buff-breasted Sandpipers, Black Oystercatchers, and Bristle-thighed Curlews (R. Lanctot pers. comm.; N. Warnock and R. Gill pers. comm.). Black-necked Stilts (but not American Avocets) were successfully captured by placing young in clear plastic containers with air holes, under a bownet. Adults were captured when they attempted to brood the chicks (N. Warnock pers. comm.).

8. NESTS.

8.1. Finding Nests. Obviously, in order to capture a shorebird on a nest, one must first find the nest. Simple methods such as watching the behavior of a bird, waiting for a change-over at the nest, or walking around waiting for a bird to flush are unlikely to damage the bird or the nest (unless one steps on the nest or greatly disturbs laying birds in an area). Behavioral methods work best for birds that flush fairly readily when the searcher is relatively near their nest, and that return to nests quickly after disturbance. This is true for many shorebirds. Birds that sit tightly, especially when they nest in low densities, are considerably more difficult to find (and those that flush at long distances and do not return to the nest are virtually impossible!).

Figure 9. Cable chain drag.



Nests of birds that sit tightly may be found by using radio transmitters (if you are fortunate enough to mark birds off nest or before incubation, and have them nest in the area). Otherwise, rope drags (for birds nesting in relatively high densities) or cable/chain drags can be used to find nests.

Rope drags involve two people dragging a rope between them in a systematic fashion. The length of the rope varies from 25 to 65 m (often about 30 m). Braided polypropylene rope of approximately 1.3 cm (0.5 in.) thickness is commonly used. Thinner rope is lighter, and easier to get good up and down rope movement (which is important for flushing birds) but snags on surface irregularities and vegetation. With thicker rope it is very difficult to get movement 25 m out. With a longer rope, it is useful to have a three person team: one on each end and the third watching the center of the rope. Ropes may be shorter for a two person crew, and may have noise makers such as tin cans or bells attached (although these may catch on vegetation). Rope drags often have been used to find shorebird nests in the Arctic. Birds are flushed by the feel and sound of the drag rope. This technique is unlikely to cause damage to birds or eggs, but is very tiring. It is most effective for fairly tight-sitting birds nesting relatively densely (B. Dale, T. Gunnarsson, R. Lanctot, T. Piersma, D. Troy pers. comm.). A variant, in areas with large rocks or bushes, is a rope with plastic streamers attached to it. The rope is 'dragged' at a height of about 1 metre and the streamers touch the ground (E. Pierce and L. W. Oring pers. comm.).

If nests are very widely distributed and birds sit tightly, a common waterfowl nest searching technique, the chain or cable chain drag, may be used. A cable chain is a length of 1 cm thick (3/8 in.) galvanized aviation cable attached between two vehicles such as jeeps or ATVs, that has swags of 0.6 cm thick (0.25 in.) chain attached to the cable on swivels (often two swags of about 900 cm or 30' each; Figure 9). The chain drag is simply a length of heavy chain (about 0.8 cm or 5/16 in. thick) attached between two vehicles. The chain or cable is usually 30 m (100 feet) in length, but may be up to 60 m (200 feet). The vehicles are driven slowly (approximately 11 km/hr) in a systematic fashion through the study area, and birds flush before, or most often after, the chain or cable passes over the nest and bird. Very large areas can be efficiently and safely searched in this manner. Care must be taken to keep the vehicles a consistent distance apart (or the chain will wrap around the axles of the vehicles), to keep an eye on the other vehicle at all times (if one vehicle stops abruptly, the other will be dragged by the chain), to ensure the chain does not catch on obstructions such as large rocks, and to follow the appropriate lines so that no areas are missed. It is very important to watch the area behind the chain as well as in front of it, as most birds flush only after the chain has passed over them. This technique works best where there is little (e.g., bushes, rocks) to catch on the chain, and is safest for the drivers in areas without steep hills. ATVs should preferably be four-wheel drive, and have a reinforced extension to the hitch so the chain or cable is not caught in the tires during turns. See Higgins *et al.* (1977) and Klett *et al.* (1986) for more details on the technique and construction of cable drags. With cable or chain drags, there is a slight possibility that a nest could be driven over with the ATV, but since nests are usually very sparsely distributed, this is a very rare event. A slight possibility exists that birds may be injured by the chain, but again, this seems to be very rare. Eggs are occasionally broken by the chain or flushing bird, and this hazard apparently varies considerably among species. Only 0.4% (3/843) of Willet eggs were broken by chain or cable drags in six years of field work in southern Alberta, while 6% (30/503) of Marbled Godwit eggs were destroyed (Gratto-Trevor 2001). This may be due to differences in the depth of nests, or mass of the flushing birds, and probably varies among habitats (data were from an area of low vegetation in mixed grass prairie). Significantly more eggs were broken in this study when using a 200 foot chain than a 100 foot cable or chain. Ironically, 6 of the 9 godwit eggs broken during 100 foot drags were from the same female (in three different nests), so individual differences in flushing or nest shape may have an effect. If all evidence of broken eggs is removed immediately from the nest cup (no matter how eggs were broken), most shorebirds will continue to incubate if left with two or more eggs. Normally, one egg clutches are soon deserted. Cable or chain drags with ATVs sound like destructive techniques, but if carefully carried out, are very safe and effective methods of finding widely dispersed nests of tightly incubating shorebirds in flat habitats with low vegetation.

8.2. Marking and Checking Nests. Methods for marking nests vary considerably, from no marks at all (where nests are relatively obvious and location is easily described or can be re-found from large scale maps/aerial photographs, accurate GPS coordinates, and/or photographs of the nest site), to obscure piles of stones, thin willow stakes, painted wooden stakes, small plastic flags, or PIT tags. PIT tags are passive integrated transponder tags that have been used to 'invisibly' mark shorebird nests (Booms and McCaffery 2007). Use whichever method is least obvious to predators and of least disturbance to the birds, while allowing one to easily re-find the nest. This will vary considerably among environments and species, as well as capture techniques. For example, use of mist nets or hand nets at the nest requires knowing its precise location, in order to accurately and quickly lay the net down on the incubating bird. For mist nets, it is useful to place a pin flag with almost all of the flag removed, 4 paces from the nest, in line with a more obvious marker farther away. For hand nets, an obscure marker such as a twist tie should be placed at the nest, since the net must be very accurately placed.

In order to minimize human-induced egg predation (or possibly desertion, in colonial species), visits to nests should be minimized as much as possible while still allowing for capture or identification of adults and checks for nest success or failure.

It is probably useful to float and measure eggs at some distance from the nest. Flotation is used to determine the approximate time the eggs have been incubated, in order to estimate initiation and hatch dates of nests found during incubation (Hays and LeCroy 1971). Eggs are normally too heavily marked to use 'candling' to age them, as is used for waterfowl eggs. Flotation charts are generally unique to a species. Check the literature or persons who have conducted breeding studies of that species to see if a chart exists for your species. Liebezeit *et al.* (2007) created a generalized regression equation that can be applied to all shorebird species, although they recommended developing site- and species specific regression models where possible. They noted results were most accurate if eggs are floated early in incubation, and when both continuous egg angle and float height data are collected if eggs are floated later in incubation. If incubation is inconsistent (for example, in uni-parental incubating species), estimates may be less accurate. Alberico (1995) discusses whether egg floating affects hatchability.

8.3. Predator Nest Exclosures. Sometimes it is considered useful to put exclosures around a nest to increase nest success. Usually, this is done either because the researcher is interested in chicks or behavior of adults after hatch, or because nest predation rates are high and productivity of the species is a conservation concern. Most predator exclosures are made of wire and netting, and many different designs and sizes exist (e.g., Nol and Brooks 1982, Rimmer and Deblinger 1990, Melvin *et al.* 1992, Johnson and Oring 2002). Desertion of nests after exclosures have been placed has been a problem in many areas (e.g., Vaske *et al.* 1994), and exclosures have sometimes resulted in predation of the incubating adult (e.g., Johnson and Oring 2002, Murphy *et al.* 2003). Roche *et al.* (2010a) determined that in most instances of nest desertion by Great Lakes Piping Plovers at exclosed nests, one member of the pair was dead. Generally, the exclosure must be quick to set up in order to prevent cooling/heating of eggs, or desertion of adults. Adults must accept the exclosure, and readily enter it to incubate. The exclosure must not allow predators to get in through the mesh (e.g., weasels), or dig under the exclosure. Not only can eggs be lost, but incubating adults may be killed if the exclosure slows their escape. Predators may be attracted to the exclosure, as the nest and adult(s) are now more obvious. Raptors may use the exclosure as a convenient perch from which to attack the adult as it leaves the exclosure. Large mammals such as cattle may be attracted to the exclosure and use it as a rubbing post, which will likely damage the exclosure, and may cause the birds to desert. Exclosures may work well in an area for several years until a predator learns to exploit them. This may happen more often when exclosures are common in an area. Therefore, even after the need for exclosures in an area is determined and an appropriate design selected, the usefulness and design of exclosures in an area must continue to be well monitored.

9.0 PROCESSING.

9.1. Species identification. This section describes very briefly the major differences among common North American shorebirds in the hand. Much more detailed information can be found in the following references, from which most of these descriptions were taken: Birds of North America accounts (see Table 1 and Literature Cited), Prater *et al.* (1977), Cramp and Simmons (1983), Marchant *et al.* (1986), and Pyle (2008). Additionally, a field guide to birds in your study area region will provide general species descriptions.

All three species of phalaropes occur in North America: Red Phalaropes primarily in the mid Arctic or off-shore; Red-necked Phalaropes in the low to mid Arctic, migrating through the interior, and off-shore; and Wilson's Phalaropes primarily in the interior plains. Breeding plumages of the three species are distinctive: Red Phalarope with a white face and red body; Red-necked with a red neck; Wilson's with black and chestnut on the neck (breeding plumages are duller in males of all three species). All species have lobed toes, although this is least distinct in the most terrestrial species, Wilson's Phalarope. Wilson's lacks the white wing-bars present in the other phalaropes, and is the only species with a white rump. Both Red and Red-necked have white wing-bars, but the very fine bill and slim body of the Red-necked differs from the thicker bill and body of the Red Phalarope.

American Avocets and Black-necked Stilts are very distinctive in all plumages. Avocets have a long thin recurved (upturned) bill while stilt bills are thin and straight. Downy young can be distinguished by the presence of a hallux (fourth, or hind toe) in avocets that is absent in Black-necked Stilts.

American Woodcock have a distinctive head shape with large eyes set far back. By their white lower back, dowitchers can be distinguished from Wilson's Snipe. Long- and Short-billed dowitchers often are difficult to tell apart (see Prater *et al.* 1977, Takekawa and Warnock 2000, Jehl *et al.* 2001). Bill length overlaps considerably between species. Tertials and scapulars of juveniles differ: a distinct black pattern on tertials of Short-billeds that is absent in Long-billeds, and dark scapulars with a small (usually scalloped) chestnut edge in Long-billeds versus a rather mottled paler design in Short-billeds. Adults are more difficult: some subtle differences in breeding plumage exist (see references above), and tail feathers of Long-billeds are more consistently barred with more brown than white, while those of Short-billeds are variable, but sometimes more white than brown. It is very difficult, if not currently impossible, to differentiate most Short- versus Long-billed dowitchers in winter plumage, even in the hand. Stilt Sandpipers are superficially similar to dowitchers, but lack the white lower back and have a white rump instead, and are overall a much slimmer bird with a shorter and more delicate slightly decurved bill. In breeding plumage, Stilt Sandpipers have many fine horizontal stripes on their underparts and a chestnut cheek patch; underparts of dowitchers have more irregular streaks and spotting.

The *Calidris* sandpipers, especially the smaller species ('peeps') are quite difficult to identify in the field. Breeding and winter plumages are often very different. However, with the exception of Semipalmated versus Western sandpipers, it is not difficult to differentiate species in the hand, especially when Palearctic species are ignored (the chance of capturing any in North America is very low in most areas). Purple Sandpipers are chunky birds with dull yellow legs, yellow at the base of the bill, and white wing-bars and white trailing edges of the secondaries. Their Pacific counterpart is the Rock Sandpiper, and the two species can be very difficult to tell apart. Rock Sandpipers have greenish legs and white on the outer webs of the inner primaries. Surfbirds are also similar to Purple Sandpipers, but are much larger, with a shortish plover-like bill, long narrow white wing-bars, and a striking tail pattern with white on the rump and base of the tail, and black at the tip.

Pectoral Sandpipers are relatively large, with a very distinct pectoral band, and yellowish or greenish legs. Sharp-tailed Sandpipers are very similar to Pectorals, but always lack the sharp border on the lower breast, often appear to have a ‘cap’, have a prominent eye-ring, and a wedge-shaped tail (in contrast to a more irregularly shaped tail in Pectorals). White-rumped Sandpipers are the only calidridine with a white rump except Stilt Sandpipers, and the two species could never be mistaken for each other. In breeding plumage, White-rumped bills have a small orange spot near their base, and in all plumages, the wings extend slightly beyond the tail. Red Knot are large, chunky calidridine sandpipers (of about 135 g), with dark legs, much like a huge Semipalmated Sandpiper. Sanderling have large white wing-stripes and are the only North American calidridine lacking the hallux (hind toe). Dunlin are highly distinctive in breeding plumage, with a reddish back and black belly. Their relatively large size, long decurved bills, and dark legs differentiate them from other calidridines in winter or juvenal plumage. Semipalmated and Western sandpipers are the only calidridines with semipalmated toes (partial webbing). These species are similar in overall size and winter or juvenal plumage. Both have dark legs. Bill length overlaps between the species (Semipalmated 15-24 mm, Western 20-29 mm). Semipalmated Sandpipers normally have a distinct ‘bump’ (expansion) at the tip of the bill, and Western bills are often longer and droop slightly at the tip, but considerable overlap exists. Least Sandpipers have yellowish legs, thin sharp bills, and relatively sharp (pointed) heads, and tend to be darker than Semipalmated Sandpipers in all plumages (e.g., dark brown versus gray; brighter chestnut on juveniles). Baird’s Sandpipers have longer wings than the previous three species, as well as thin sharp bills, dark legs, a relatively distinct pectoral band, and streaking on the head.

Three of the four species of godwits breed in North America: Hudsonian, Marbled and Bar-tailed. All have long, slightly recurved (upturned) bills. Hudsonians have conspicuous wing-stripes, black under their wings, and a white rump with a black-tipped tail. Marbled Godwits have a uniform appearance, cinnamon underwings and lack of a pattern on the upper tail.

Lesser and Greater yellowlegs differ from other, superficially similar, North American shorebirds in having long yellow legs, long necks, relatively long straight bills, black spotting on the breast, square white rump-patches, and no wing-bars. Although the two yellowlegs species can be mistaken for each other in the field, in the hand they are very different in size (Lessers are about half the mass of Greaters). Willets are larger than Greater Yellowlegs and have pale (but not yellow) legs, thicker bills, and huge white wing-stripes. Solitary Sandpipers are smaller than yellowlegs, the legs are not bright yellow, and they have a complete white eye-ring. Spotted Sandpipers are superficially similar to Solitary Sandpipers, but have a pale eye-stripe and white wing-bars.

Wandering Tattlers are medium-sized west coast tringids, with short yellow legs and long wings and tails.

Upland Sandpipers are distinctive in shape (vaguely chicken-like with their small ‘dovelike’ heads on narrow necks and large bodies). They are most similar to Buff-breasted Sandpipers, although Buff-Breasted Sandpipers are smaller, with more compact sandpiper-like proportions. Buff-breasts also have shorter bills and a more buffy than striped coloration, compared to Uplands.

The four large curlew species of North America all have relatively long decurved (down-turned) bills. Long-billed Curlews are the largest, with a streaked crown (but no crown-stripe), and overall cinnamon color, similar to Marbled Godwits. Whimbrel are smaller, with a dark crown with distinct large pale crown-stripe, and dark stripe through the eye. Bristle-thighed Curlews have a dark crown and pale crown-stripe, with a bright cinnamon rump and upper tail. Diagnostic in the hand are feathers on the rear flanks and thighs that are elongated to form shiny bristles (Prater *et al.* 1977). Eskimo Curlews are the smallest (about two-thirds the size of a Whimbrel), with no distinct crown-stripe, but with cinnamon wing-linings, a faint stripe through each eye, and uniformly dark primaries (compared to barred primaries of Whimbrel) (Gill *et al.* 1998). The Eskimo Curlew is very rare (likely extinct).

Black-bellied Plovers can be differentiated from all other North American plovers by having a hallux (hind toe). They also differ from golden-plovers by having black axillars under the wings. American and Pacific golden-plovers are difficult to separate. Best separation is by wing length but some overlap exists (American flattened wing chord usually >180 mm; Pacific usually <175 mm), and see Marchant *et al.* (1986: p. 392). Mountain Plovers are approximately the size of Killdeer, but have longer legs, so superficially resemble American Golden-Plovers, but lack the black breast bands of other plovers.

Killdeer are distinctive in having two dark breast bands and a rufous/orange rump. Wilson’s Plovers are larger than the other ringed plovers in the Americas, have larger all-black bills, and flesh-colored legs. Piping, Ringed, Snowy, and

Semipalmated plovers are all small, with a single or incomplete black breast band. Semipalmated is very similar to Ringed Plover, but has clear palmations (partial webbing) between all three front toes (i.e. two webs), while Ringed has clear palmations only between the two outer toes (1 web). The other plovers lack palmations. Piping Plovers differ from the other species in having a white patch across their upper-tail coverts. The breast band is never complete in Snowy Plovers.

Surfbirds appear superficially similar to turnstones, and all have white wing-bars and white rumps, contrasting with dark upper parts, but Surfbirds lack the white back pattern of the turnstones. Surfbirds have yellowish legs and yellow at the base of the lower bill. Ruddy Turnstones have a white chin and throat in all plumages and bi-lobed dark breast markings. Black Turnstones always have black on their chin and throat, and fairly uniform dark feathers across the breast.

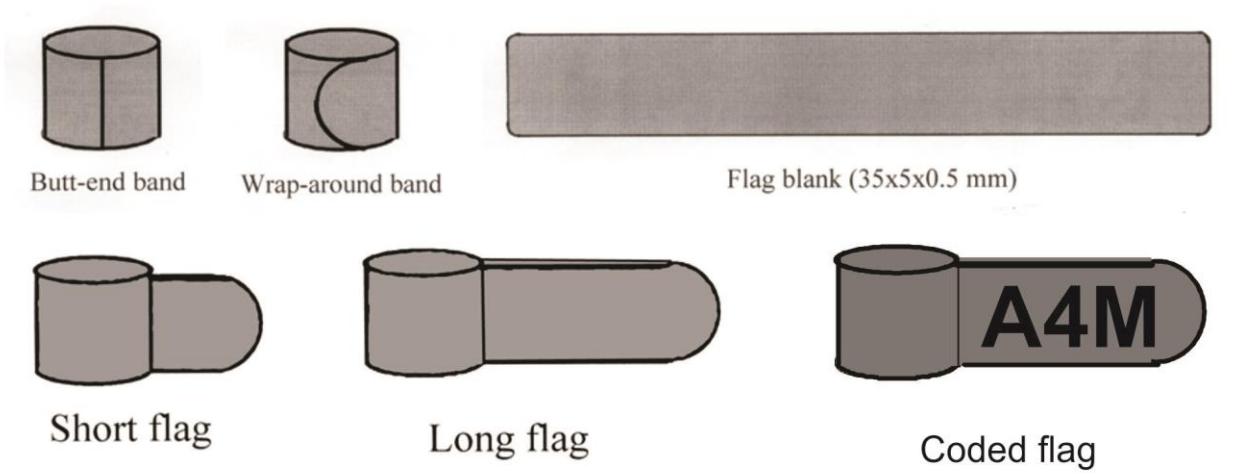
We have two species of North American oystercatchers: Black and American. Black Oystercatchers are completely blackish-brown in plumage, in contrast to the white wing-stripes, rump and underparts of American Oystercatchers.

9.2. Metal bands. Due to salt water corrosion and abrasion, aluminum bands last only a short time on many shorebirds, especially when the band is placed on the lower part of the leg (Jehl 1969, R.I.G. Morrison pers. comm., pers. obs.). For example, most of the approximately 10,000 Semipalmated Sandpipers banded with aluminum bands during migration at James Bay in 1976 either had lost the metal band or it was unreadable less than two years later. Even a celluloid color band may last longer than an aluminum band on some species. For such reasons, some other countries do not use aluminum bands at all, and in Canada and the U.S. many shorebird banders use stainless steel and incoloy metal bands for shorebirds, available from the U.S. and Canadian banding offices. Normally these stainless steel and incoloy bands last the life of the bird, which can be considerable in some shorebirds. They are often more difficult for inexperienced banders to completely close, and cannot (or should not) be removed from the bird if the band is overlapped, because the risk of breaking the bird's leg usually is greater than the risk of leaving on the band. If stainless steel or incoloy bands are unavailable, or the bander feels more confident with aluminum, then aluminum bands will last considerably longer if placed on the upper part of the leg (tibiotarsus). It is likely that shorebirds foraging on mudflats, and highly aquatic species such as phalaropes, suffer heavier wear to aluminum bands than species foraging on sand or wintering in the interior. Even incoloy or stainless steel bands may wear quickly on species such as Ruddy Turnstones and Purple Sandpipers, which inhabit rocky coastlines, so it may be more sensible to place any metal bands on the upper legs of such species (Clapham 1978, Summers and Etheridge 1998).

In most shorebird species, it is not a problem for the bird if metal or color bands are placed on the lower leg (e.g., Semipalmated Sandpipers, Gratto-Trevor 1994). However, apparently a problem developed with Black-necked Stilts and American Avocets banded on the lower leg in Nevada, because bands caught on the 'ankle' (base of the toes) and crippled the bird (L. W. Oring pers. comm.). This has not been noted as a problem in other areas and other shorebird species. Three percent (7) of Spotted Sandpipers banded on the lower leg lost a leg, which was presumed to have been because of the metal band in 6/7 cases (Reed and Oring 1993). Problems with metal bands have been reported in two other North American species. A special band size (1P) was created for Snowy Plovers after 1-3% of birds banded on the lower leg with size 1B aluminum bands were found to have lost the leg with the metal band, apparently caused by sand caking between the band and the leg (Page *et al.* 1995). Use of 1P bands on the lower leg has reduced leg injuries to 0.2% of banded birds (G. Page pers. comm.). Amat (1999) noted that 1.9% of Snowy Plovers in Spain that were resighted in subsequent years had injuries (especially foot loss) caused by the metal band on the lower leg. No injuries resulted when the metal was placed on the upper leg. All band injuries should be reported to the Bird Banding Office.

In the 1990s, leg injuries and foot losses were noted for Piping Plovers in some locations (about 6% overall, of those reencountered), especially on the U.S. Atlantic coast, the Great Lakes and Nebraska, but not North Dakota or Manitoba (Lingle and Sidle 1989, Lingle and Sidle 1993, Lingle *et al.* 1999). One suggestion was that sand had collected on the inside of the (usually metal) band, causing leg injury, and that the extent of injuries might vary according to sand grain size in different areas of the species' range. Although some injuries might have been caused by 1A or 1B aluminum bands on the lower leg, which were often used in conjunction with other bands, there may have been other causes of injury, including full-length flags on the lower leg, and large (size 2 or larger) color bands. Tall (9.1 mm) coded metal bands on the lower legs of Piping Plovers in Eastern Canada resulted in foot loss in 7% of birds reencountered, compared to less than 1% injuries in birds marked with stainless steel, incoloy, short anodized metal bands, or plastic color bands on lower legs

Figure 10. Types of bands.



(Amirault *et al.* 2006). Even with the use of shorter, rounded edge flags on an upper leg, 1A aluminum on the other upper leg, and only 1A color bands on lower legs, 6% (of 47 Atlantic breeding Piping Plovers seen in a later season) lost a foot (Gratto-Trevor pers. comm.). In contrast, in Saskatchewan only 1% (of 650 Piping Plovers seen in a subsequent season) banded in a similar fashion (with the addition of a metal on one upper leg) had leg injuries in subsequent years (Gratto-Trevor and Abbott 2011). In no instance was the upper leg metal (1A aluminum) or upper leg short flag known to have caused any problems, and in Saskatchewan any band issues appeared to result from birds (rarely) attempting and failing to remove lower leg color bands, when the color band hung up on the foot and cut off the blood supply. So there may be more likely to be leg problems in Piping Plovers on the east coast, compared to the west. Use of normal height metal bands on the upper leg (or no metal at all) and coded flags on the upper leg have greatly reduced leg problems caused by bands in the Atlantic breeding population, although different weights and lengths of coded flags may make a difference.

For several species (e.g., Black-necked Stilts, Bar-tailed Godwits), recommended band sizes are different for males and females. In these species, if sex cannot be determined, the larger size must be used unless the band can pass from upper to lower leg or over the foot. If the larger band size is too large in fully grown young or adults, the smaller size can be used. However, if the large size is too large for an unfledged young, no band should be placed on the bird, in case the leg continues to grow. A metal band of appropriate size can be safely put on shorebird young as soon as the chick is hatched, with a few exceptions. Legs of Black-necked Stilt chicks are too thin for bands until several days of age, unless one puts a small strip of tape over the band and leg to hold it on for a few days. By the time the tape falls off, the leg is large enough for the band (J. A. Robinson pers. comm.). Chicks of Black Oystercatchers must be more than 100 g before their legs are wide enough for leg bands (S. Hazlitt pers. comm.). Legs of some freshly hatched Killdeer appear to be too thin for size 2 metal bands, but bands will stay on when chicks are 3-4 days old (L. W. Oring pers. comm.).

9.3. Marking. Because only two species of shorebirds are hunted in North America and very few shorebirds are recaptured by others, researchers must mark shorebirds with more than just metal bands in order to get reports of their birds from other areas and trace their migration routes. Shorebirds are usually marked with color bands and/or colored 'flags' (color bands with a tab of varying length that sticks out from the leg, Figure 10). Flags may be plain or coded (with letters/numbers engraved on each side). **It is not possible to over-emphasize the importance of considering the purpose of your study when deciding how to mark shorebirds.** If your chosen methods or marking schemes are not visible, deteriorate too quickly, or overlap with those of others studying the same species, then either your study or someone else’s may be useless. If you unnecessarily give individual color band combinations to large numbers of birds of a species, you have eliminated considerable potential for others to usefully mark the same species. Shorebirds often live for many years, and many migrate tremendous distances. If your birds potentially migrate outside of the Americas, it is important for you to coordinate your banding scheme with researchers in those areas (see Howes *et al.* 2016), as well as with the Pan American Shorebird Banding Program (https://www.canada.ca/en/environment-climate-change/services/bird-banding/pan-american-shorebird-program.html), and appropriate banding office for your permit. The Canadian Banding Office and U.S. Banding Lab now coordinate coded flags for shorebirds marked in Canada or the United States. Shorebird marking coordinators exist for numerous areas, e.g., Europe or the East-Atlantic flyway (http://www.waderstudygroup.org/projects/colour-marking/), East Asian-Australasian Flyway (http://awsg.org.au/wader-flagging/).

Resighting rates of shorebirds, particularly small species, increase with the visibility of the marker. Recoveries or resightings of dyed birds are considerably greater than for birds only color banded, and those with flags very much greater than those marked only with a metal band (Lank 1979, Handel and Gill 1983, Minton 1996). However, since increased visibility may also result in higher predation rates (Lank 1979), this must be taken into account when designing marking schemes. Electronic marking schemes can also have a survival effect, depending on size of the bird, weight of the device and attachment, and method of attachment (see section 9.3.4).

9.3.1. Color banding.

9.3.1.1. Choosing a color marking scheme. With the increased use of coded flags on shorebirds, it is much less common to color band shorebirds with a cohort scheme, even in large migration projects. Most projects now use unique markers for that species, where individual birds can be identified without being recaptured. This is usually important in breeding, behavioral, survival and even movement studies. Often these unique markers are coded flags.

Without a considerable amount of coordination among banders, it would soon be impossible to distinguish the shorebirds marked by one person from those of another. Therefore, in the mid 1980s, the Pan American Shorebird Program (PASP) was created to define a different flag color scheme (one or two specific colors of flags) for each country in the Americas (Myers *et al.* 1983), and this has been revised to a one flag system for different countries or regions in the Western Hemisphere (Appendix 4: https://www.canada.ca/en/environment-climate-change/services/bird-banding/pan-american-shorebird-program.html; the entire PASP manual can be downloaded from the North American Banding Council Shorebird webpage under PASP, in English or French: http://www.nabanding.net/shorebirds/). Smaller countries are grouped together into regions with one regional color flag, and may use a specific color band with the flag to represent the particular country within the region. For example, Canada is the only country using a white flag, so has no assigned country color band to use with the flag, while French Guiana is now assigned a dark blue band over a black flag, for country and region respectively (Howes *et al.* 2016). Coded flags or color band combinations from different banders are organized within each country. If a species does not exist in a particular country or region, PASP may allow use of those flags on that species in a different country. For example, Piping Plovers are almost entirely found only in the United States, Canada, Mexico, and the Caribbean. Therefore, white, green, black, grey, yellow, orange, red, and light and dark blue have all been used on this species in Canada and the U.S. Appendices B through F in the PASP Shorebird Marking Protocol (Howes *et al.* 2016) lists the level of coordination necessary for each shorebird species occurring in the Western Hemisphere, ranging from coordination within North or South America only, to coordination with international flyways. Shorebird color marking schemes in Canada and the U.S. are coordinated by PASP (Email: ec.bbo.ec@canada.ca) and the banding offices of both countries, while other species or regional coordinators exist for some species or areas (e.g., Appendix G in Howes *et al.* 2016). It is strongly recommended that you follow the PASP protocol, including what characters to use for alpha-numeric flags, and how to describe a banded shorebird.

When deciding on a color-banding scheme, several factors should be considered. It is usually necessary to place a consistent number of bands on one's birds, at least in a specific age group and species. This serves two purposes: it allows coordination of banding schemes, and makes accurate resighting of one's own birds easier by knowing when one has missed reading a band (or the bird has lost a band). In some cases (particularly when banding very young chicks), it may be useful to give adults individual color band combinations, and nestlings only a metal or a single color band. Nestlings normally return to breeding areas at far lower rates than adults, so individual combinations are not 'wasted', and being much lighter in mass than adults, it is conceivable that nestlings are more affected by the weight of additional bands (although see Bart *et al.* 2001 and Roche *et al.* 2010b). The number of color bands used should be the minimum number necessary to provide the essential information, and if using only color bands and not coded flags, will often depend on the number of birds expected to be marked during the study, and the number of banders marking that species.

With few exceptions, only UV-stable color bands or flags should be used on shorebirds. Celluloid bands (as used on passerines) discolor very rapidly and become brittle and fall off most shorebirds within one or two years. Unfortunately, a limited selection of useful UV-stable colors is available for bands or flags: none is striped or patterned. The usual colors are: red, orange, yellow, light green, dark green, light blue, dark blue, gray, black, and white. White, light green, and light blue color bands are almost impossible to tell apart under any conditions, so if possible your scheme should use only one of the three, unless one is a flag and one a normal color band. Grey flags are difficult to tell apart from white in the field. It is useful to know that white color bands often discolor to beige or pale yellow, dark blue and yellow sometimes fade greatly within several years, red may change to brown (or in some circumstances, change quickly to pale pink), orange may fade to a pink color. In some local environments, bands may become coated with brownish or yellowish/orange-brown stains from the sediment (Robinson and Oring 1997, Minton 2000, Thorup 2000, pers. obs.). However, most researchers report that the majority of UV-stable color bands are clearly identifiable after 6-8 years or more (Thorup 2000, Ward 2000, N. Warnock pers. comm., pers. obs.; but see Robinson and Oring 1997). Colors probably fade fastest under conditions of extreme sun and salinity/alkalinity (Robinson and Oring 1997).

The interior diameter of color bands or flags used should be very similar to the interior diameter of the appropriate USFWS/CWS metal band (Appendix 6). Normally, bands can be put on either the upper or lower legs of shorebirds. However, under a few circumstances it is not advisable, for the safety of the bird, to put color or metal bands on the lower legs (see Table 1). If you are using aluminum bands, they should, for most species, be placed on the upper leg (to last longer). Flags should always be placed on the upper leg, for bird safety and for increased visibility.

Engraved alpha-numeric color bands have been used on some species of shorebirds (American Oystercatcher, Red Knot, Piping Plovers; B. Winn, K. Clark pers. comm. 2003).

To avoid confusion and loss of data to the bander, do not remove or exchange flags or bands on recaptured birds from other projects without prior agreement. This is true for all markers you may encounter on birds, including geolocators. However, if a marker is causing injury to the bird, remove the marker and report all changes to the bander and/or banding office.

9.3.1.2. Obtaining UV-stable color bands or coded flags. Most North American shorebird banders obtain UV-stable plain color bands and plain flag blanks from A. C. Hughes Ltd., 1 High Street, Hampton Hill, Middlesex TW12 1NA United Kingdom (http://www.ringco.co.uk/) or Avinet (https://www.avinet.com/). UV-stable bands can be made of salbex, darvic, or acetal. Acetal colors appear to last as well as darvic, but the bands may not be formed as well.

Sources of coded flags can be more problematic. **It is necessary to plan well ahead of time to obtain small coded flags. If you are banding in Canada or the U.S., remember to obtain a list of which flag codes you can use on each species from the banding offices. If you are banding elsewhere, determine what agency is coordinating coded flags in your area.** The PASP protocol (Howes *et al.* 2016) strongly recommends that regional color flags be engraved using a specific set of field-readable characters to identify individual birds and allow for international resightings. They note that, as shown by Meissner and Bzoma (2011), engraved color flags can reduce reporting error of resighted birds (compared to color band combinations) and increase the number of accurate resightings. However, under some circumstances color bands are easier to read than coded flags, so it is important to adapt your marking scheme depending on habitat, how closely one can approach the marked birds, and what question you are examining. Clark *et al.* (2005) experimented with various sizes and types of font, and determined which letters and numbers were easiest to tell apart in the field. Using this information, the PASP protocol (Howes *et al.* 2016) recommends that color flags be engraved with a three character code using only the following 29 sans-serif characters:

15 letters: A C E H J K L M N P T U V X Y (in Arial font)

10 numbers: 1 2 3 4 5 6 7 8 9 0 (in Century Gothic font)

4 optional symbols: + = @ % (in Arial font)

This set of 15 letters, 10 numbers and 4 optional symbols allows for 24,389 individual birds per species to be marked with a unique three-character code per flag color. For small species, or where a much smaller number of birds need to be marked over time, a two character code can be used to create a shorter, lighter flag. If all 29 characters above are used, only 841 unique flags (per flag color) can be created with 2 characters per flag.

Some suppliers use a single sheet of material to create flags, with engraved characters filled in with long-lasting paint, while others use material made of two different colored sheets of material engraved down to the second color. The latter are often heavier than flags made of a single sheet (although single sheets in some colors may be as thick as flags made of two sheets fused together). Flags may come fully formed, or flat (see section 9.3.1.4 for how to form flags). See Howes *et al.* (2016) for sources of engraved flags, and also contact Christian Friis for more current information (Email: christian.friis@canada.ca). Also check with other banders who have ordered flags from specific suppliers, to verify quality of flags, customer service, and timing of delivery of ordered flags from those suppliers.

9.3.1.3. Applying color bands. Color bands for smaller species (size 1B to 3) are usually 'butt-end' bands, similar to metal bands, while those for species size 3A and larger are usually 'wrap-around' bands (see Figure 10). Butt-end bands are applied with a thin metal 'shoehorn' applicator (normally obtained from the color band supplier): a smaller size for bands up to 1A, and a larger size for size 2 bands. The band is placed on the applicator with the opening of the band towards the depression in the shoehorn, and the band is slid up the applicator until the band is sufficiently open to fit on the leg. The applicator is laid against the leg, and the band is slid off the small end of the applicator onto the bird's leg. It is important to stretch these bands no more than is necessary to put them on the leg, and to ensure that the color band is completely closed when on the leg. It may be necessary to click the edges of the band under each other with one's fingers to ensure that the band is completely closed. Wrap-around bands are twirled carefully onto the bird's leg, ensuring that the leg is not injured and the bands are not opened more than necessary. Again, these bands may be tightened with the fingers after they are on the bird. Ensure that the bands rotate freely around the leg, but are not so loose that they can pass over the 'knee' joint or 'ankle'. It is usually not necessary to seal UV-stable color bands, as they normally last for numerous years. However, birds such as oystercatchers or plovers may attempt to remove bands on the lower legs so it may be advisable to seal bands on those species. Some researchers have used heat (from a small portable butane welder such as Pyropen from Cooper Tools, or a heated screwdriver) or glue (Clear PVC Solvent Cement, often applied with the tip of a small screwdriver or a toothpick) to seal the bands on the bird. For oystercatchers in the U.S. and Australia, it was necessary to seal both the outer cm and inner end of the spiral in wrap-around bands, to prevent relaxation and opening up of the band, and reduce sand or grit from collecting in the band interior (Minton 2000, B. Winn pers. comm.).

9.3.1.4. Forming and applying flags. Obtain UV-stable flag blanks (35 X 5 X 0.5 mm, Figure 10) from A. C. Hughes or elsewhere. Uncoded flag blanks may be cut in half for small birds such as Semipalmated Sandpipers to make short flags, left uncut for long flags, or cut to any length in between. Cut one third off the flag blank to make short flags for medium sized birds, and use the full blank for large species. Obviously, coded flat flags are not shortened, particularly if they are three-character codes.

Find nails or other objects of the same diameter as the desired size of bands, bend the flag blank (cut or full) around the nail so that the ends are even (especially important for coded flags!), and pinch the flag tabs with pliers as close to the nail as possible. Especially with coded flags use smooth tip pliers (no grooves); otherwise the code may be difficult to read. If the material is stiff, like Salbex, warming it in hot water first helps to soften the material, avoiding breaking the flag. While holding the flag and nail with pliers, immerse the flag in extremely hot (boiling) water for about 15 seconds (possibly longer for thicker flags). Remove from hot water and immediately immerse in very cold (ice) water (still using pliers) for about 15 seconds. Remove the flag from the nail: flag tabs should be tightly closed and even, and the body well rounded (not oval or tear-drop shaped) - if not, try again! Nail clippers can be used to make both sides of the flag even (without losing any part of the codes), and to round off any sharp corners, or fine sandpaper works very well. Use a color band applicator to place the flag on the bird or use one's nails to open the flag slightly. Open the flag as little as necessary, so that the flag is not stretched (otherwise, remove and reshape later). For short uncoded flags on small species it is not necessary to seal flags (assuming the tabs are tightly closed); otherwise (including all coded flags), flag tabs should be shut with glue (solvent) or heat (small solder iron or hot screwdriver or pliers). The 'glue' recommended is clear PVC solvent cement (preferably in a tube, e.g., UPVC Solvent cement,, produced by Marley Extrusions Ltd., Lenham, Maidstone, Kent, UK tel 0622 858888 or fax 0622 858725; Jessop *et al.* 1998, C. D. T. Minton pers. comm.), although clear PVC cement bought at hardware stores in North America works very well. Glue is applied to the tabs of very slightly-opened flags with an object such as the tip of a small screwdriver or a toothpick. With pliers, hold the flag tabs closed for about 20 seconds until the glue is set, then carefully remove pliers to prevent the flag from opening. All excess glue should be wiped clean and care taken to ensure no glue gets on the bird.

9.3.1.5. Standard protocol for recording color markers on a banded shorebird. Recording color band schemes and colors has long been extremely inconsistent in the shorebird world, varying enormously among projects. This often makes interpretation of resightings difficult, leads to mistakes, and makes inputting data into banding office or other multi-project resighting input, storage, and recovery systems problematic. For example, the color light green has been commonly listed as 'L', 'g', 'P', or 'M' and so on; black can be 'L' or 'K', gray can be 'A' or 'E', etc. The variations are almost endless. A group of researchers helped to create a standard protocol for recording color marking as part of the updated Pan American Shorebird Plan protocol (Howes *et al.* 2016), and this is described below. Please use it! Obviously you may record resightings in the field using your own notation, but the PASP protocol format is the only format accepted when submitting data (banding, recaptures, and resightings) to either reportband.gov or bandedbirds.org.

Combinations should always be read from the bird's upper left leg, to bottom left leg, to upper right leg, to bottom right leg.

Black = bk
White = w
Red = r
Orange = o
Yellow = y
Dark Green = dg
Light Green = lg
Dark Blue = db
Light Blue = lb
Pink = lp
Dark Pink = dp
Purple = pu
Purple-Brown = pr
Brown = bn
Grey = gy
Metal Band = m

Geolocator (on leg) = GEO
Satellite (on leg) = SAT
unknown character on code = Q
unknown color or bands on particular portion or sub-portion of leg = U

Comma (,) separates markers on the same part of the leg
Vertical bar (|) separates upper versus lower leg
Colon (:) separates left versus right leg
Forward slash (/) separates colors on split bands
Single dash (-) means no bands or flags present in that part of the leg
U = this part of leg not seen in resighting so bands unknown

Colored Flag (where x = color) = Fx
Bi-Colored Flag (where x = color) = Fx/x
Tri-Colored Flag (where x = color) = Fx/x/x
Engraved Band (where # = alpha or numeric code) = Ex(###)
Engraved (coded) Flag (where # = alpha or numeric code) = FEx(###)

So, a shorebird with a metal on its upper left leg, red over grey color bands lower left, coded black flag L2P on its upper right, and nothing lower right would be written as:
m | r, gy : FEbk(L2P) | -

A shorebird with a plain (not coded) white flag over an orange band upper left, light green over dark green lower left, metal upper right, and yellow over dark blue band lower right would be written as:
Fw, o | lg, dg : m | y, db

A shorebird banded with geolocator mounted on a dark green (uncoded) flag above a red color band on the upper left, a metal band on the lower left, a red over a yellow over a dark blue color band on the upper right, and nothing on the lower right would be written as:
FdgGEO, r | m : r, y, db | -

A shorebird banded with a dark green engraved flag (2NP) over a red band on the upper left, nothing on bottom left, metal band on the upper right, and a yellow over a dark green over an orange color band on the lower right would be written as:
FEdg(2NP), r | - : m | y, dg, o

A shorebird resighted with a dark blue coded flag (CU6) upper left, nothing lower left, and right leg not seen (standing on the left leg with right tucked up) would be reported as:
FEdb(CU6) | - : U | U

If members of the public encounter the occasional marked shorebird, they should be encouraged to write out the combination in words, as above, rather than using the shorthand codes (and hopefully provide a photograph of the bird). If they submit large numbers of resightings, then they should be encouraged to use the shorthand codes as described above, instead of other, usually confusing shorthand (e.g., what does 'L' mean?).

9.3.2. Patagial tags. Patagial tags (numbered tags placed around the humerus between the wing and the body) are not currently used for shorebird studies, and are not recommended. Two previous studies demonstrated a much lower survival of shorebirds marked with patagial tags compared to those marked with leg bands (breeding Willets: Howe 1980; migrant Semipalmated Sandpipers: Lank 1979).

9.3.3. Color dyes. Color dyes are sometimes used to identify marked birds from a considerable distance. This may be useful if birds are often seen in large flocks during migration or wintering. If all the birds marked in a location are given the same pattern (e.g., upper breast in yellow/orange dye), it allows one to more easily determine migration routes used that season, or identifies marked individuals to concentrate on for reading color bands. Alternatively, dyes may be applied in a 'cohort' pattern (so that age group or banding location can be identified from the pattern), or in unusual cases (e.g., breeding studies) individual combinations of dyes (so individuals can be identified even when legs cannot be seen clearly).

Although color dyes often result in many more shorebirds being seen during migration, as compared to birds given only color bands, they also may make birds more obvious to predators, so the decision to use them should not be undertaken lightly. The number of useful dyes is limited, so only a limited number of studies can use dyes at one time. The length of time the dyes are visible varies considerably: most last only a few weeks, so the study must take this into account. The maximum length of time a dye will last is until the feathers are molted: for shorebirds this is usually during the winter, but body molt may be initiated during fall migration. The dye used cannot degrade flight or insulation properties of the feathers. Dyes are usefully only put on light-colored plumage. They are put in a water or alcohol base (an alcohol base can make the dye in a feather last much longer), and painted on the bird, often with a small paintbrush, so that the feathers are covered but not drenched. Dyes commonly used include Malachite Green, Rhodamine B (pink), and picric acid (initially yellow but weathers in a few days to orange).

The only dye that permanently marks feathers is a supersaturated solution of picric acid in 95% ethanol (picric crystals are added to the alcohol until some crystals precipitate in suspension). Birds must be held for approximately 15 minutes until the dye dries on the bird; otherwise the birds can wash off the dye. Picric chemically binds to feathers, so the orange dye remains until the feather is molted. Alcohol fumes can affect the birds, so care must be taken to hold freshly dyed birds in conditions of good air circulation (e.g., in clean boxes with mesh tops and low bird densities). Normally birds affected by fumes will recover if moved to areas of better air circulation. **Concentrations of picric acid are explosive when dry so crystals are shipped in water, and must be kept wet in water or alcohol** (in fact, picric acid was used as munitions in World War II). If care is taken to ensure that stored picric is not allowed to dry out, it is a safe and extremely effective feather dye (although the use of picric acid is 'strongly discouraged' in Gaunt and Oring 1999, due to its explosiveness when dry and its potential toxicity).

Rhodomine B (pink) is more colorfast if it is diluted in propanol 2-o1 instead of alcohol. However, it is EXTREMELY important to place birds in a very well ventilated container to dry (e.g., mesh sided cage outside where there is airflow) or they will become drunk and take up to 24 hours to recover from the fumes (N. Clark pers. comm.).

Florescent powder has been used to track woodcock broods (Steketee and Robinson 1995). The chicks, when rubbed with powder, left trails of florescent powder for several hours after marking. Chick survival was not affected by application of the powder.

9.3.4. Electronic Tracking of Individuals. Currently, there are a number of systems to remotely track bird movements, and the technology is changing rapidly. Each system has its own set of advantages and disadvantages in terms of spatial and temporal resolution of bird locations, costs, potential effects on birds, and methods of data acquisition. Some are briefly described below, but banders wishing to use tracking techniques should find the latest information on systems, usage, and attachments, and if necessary, get experience in the attachment and use of specific units. Questions that you should ask yourself ahead of a tracking study include: is the unit safe for your species in terms of weight and attachment method, do you need to recapture the bird to download the data, how will the unit be attached, have you factored in the cost of obtaining and analyzing the downloaded data as well as the cost of capture and the unit itself, how many units do you need to apply to obtain sufficient data to answer your question, and will the data provided be accurate enough for answering your question?

In general, transmitters should be < 3% of the bird's mass (Fair *et al.* 2010), although attachment method may be more of a concern than weight to particular species (Porter and Smith 2013). Transmitter weight will depend on desired battery life, and method of transmitter attachment to the bird, as well as the weight of the transmitter itself. Length of the antenna is usually fixed for particular units and is often quite long (e.g., 231 mm for 5 g satellite tags). Method of attachment will vary depending on size, shape, and habits of the species involved. For the safety of the bird, the attachment should optimally be designed to remain securely on the bird for the duration of the study or life of the battery, and then quickly fall off; although this is not possible in all cases (or even desirable if one needs to recapture the bird to download the data). Attachment method, particularly harnesses, must take into account weight changes of the bird during the annual cycle, as these can be substantial in many shorebirds.

Numerous attachment methods exist, although those with a harness around the wings are not likely to be appropriate for shorebirds, as the harness may interfere with flight (but see Chan *et al.* 2016). For shorebirds, VHF radios are commonly glued to the lower back of the bird (Warnock and Warnock 1993), placed on the back with a harness over the legs (Sanzenbacher *et al.* 2000), or, in a few instances of large shorebirds with long legs, attached to a metal leg band carried by the bird (Plissner *et al.* 2000). Geolocators and other small data loggers are often attached to a leg flag (e.g., Minton *et al.* 2010, Niles *et al.* 2010); the larger satellite transmitters often with a leg harness (e.g., Watts *et al.* 2008, Hillig *et al.* 2012, Olson *et al.* 2014), although Battley *et al.* (2012) implanted 25 g transmitters in Bar-tailed Godwits. When attaching a transmitter with glue, feathers are usually clipped to achieve proper adhesion to the skin. These will normally remain on the bird for a few days to months depending on the age of the bird, and timing of molt.

Radio transmitters: radio telemetry is still one of the few options for obtaining fairly accurate location data on small birds for weeks or months at a time (Ponchon *et al.* 2013, Loring *et al.* 2017). Combined with automated data collection towers this system provides an array of tracking options. Automated radio telemetry (digital VHF) stations consist of one or more antennas attached to a tower and connected to a data-logging radio receiver, and for shorebirds have been used to study such topics as local movements during various times of the annual cycle, and long distance movements during migration (Green *et al.* 2002, Leyrer *et al.* 2006, Verkuil *et al.* 2010, Sherfy *et al.* 2012, Loring *et al.* 2017). Multiple individuals can be tracked on a single frequency, using very light, digitally-coded VHF transmitters that can be attached to even the smallest shorebirds (e.g. Taylor *et al.* 2017). Several recent papers have used digital VHF transmitters to examine length of stay at sites (Loring *et al.* 2017; Mann *et al.* 2017. Nanotags are very small digitally coded radio transmitters (currently 0.2 to 4.3 g, manufactured by Lotek Wireless: http://www.lotek.com/), lasting 10 days to several years, depending on size and transmitter burst rate. They are often glued to the lower back of shorebirds (feathers are clipped and tags glued to the stubble; e.g., Mann *et al.* 2017), and see: https://beta.motus.org/data/download/tag_deployment_methods.pdf for more information on this and other attachment methods. These transmitters are compatible with the Motus network of automated receivers described below.

Taylor *et al.* (2017) describe a recent international collaborative network, the Motus Wildlife Tracking System (Motus: https://motus.org), which uses coordinated automated radio-telemetry arrays to study movements of birds, bats, and insects, at up to hemispheric scales. Motus systems use a single radio frequency and act as a clearinghouse to coordinate, disseminate, and archive detections and associated metadata of all collaborators in a central repository. As the number of automated receiver stations expands across regions, the value of the Motus network in examining migration routes and so on will continue to increase. See the Motus website (https://motus.org) for more information on Motus, including how to deploy tags and receivers. The usefulness of the system depends on your research question, as well as tags, attachment methods, and receivers used (e.g., some receiver tower setups are more effective than others, birds on the ground may not be picked up by a nearby tower, and some birds may be able to pull off the tag by pulling at the antenna), so examine your options carefully.

Geolocators: Long-distance movements of shorebirds have been studied with light level geolocators recording time-stamped periodic ambient light levels. This allows estimation of daily sunrise and sunset times, which can be converted to latitude and longitude estimates (Clark *et al.* 2010). Advantages of light-level geolocators are their low weight (<1 g), that they can last more than a full migration, their relatively low cost (compared to satellite transmitters), and their lack of an external antenna, which can simplify attachment method (Porter and Smith 2013). However, location accuracy is usually in the tens of km to >100 km (less accurate for latitude than longitude, and least accurate near the equinoxes and the equator) and data analysis is not simple; Porter and Smith (2013) describe techniques to improve accuracy of location estimates when analyzing geolocator data, and as they note, many geolocators measure conductivity as well, which can also be used to improve location data. Often the most difficult aspect of using geolocators in tracking studies is that birds need to be recaptured to download data.

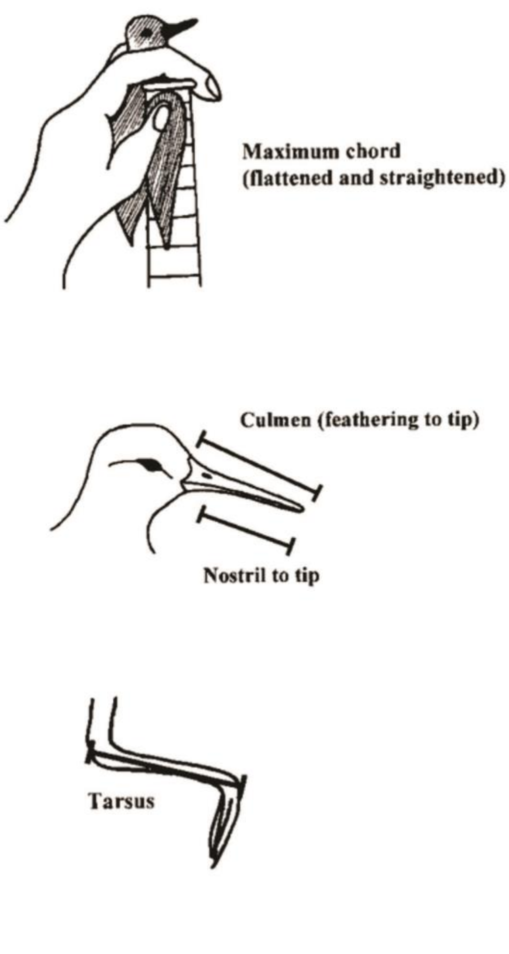
Geolocators are usually glued to a leg band: for example, to double-wraparound Darvic leg bands on Bar-tailed Godwits (Conklin and Battley 2010), and to plastic flags on Ruddy Turnstones, Red Knot, and Semipalmated Sandpipers (Minton *et al.* 2010, Niles *et al.* 2010, Brown *et al.* 2017). Others have used leg loop harnesses, with varying success. Minton *et al.* (2010) found that harnesses were not well retained and detrimentally affected Ruddy Turnstone that had gained considerable mass before spring migration, while Lislevand and Hahn (2013) had high return rates with flexible leg loop harnesses for Temminck's Stint. A number of studies have examined the effect of geolocators on survival of birds in general (e.g., Bridge *et al.* 2013, Costantini and Moller 2013), with some showing negative effects on survival and others no effect. For shorebirds, several studies have shown no effects (e.g., Lislevand and Hahn 2013, Pakanen *et al.* 2015), but others have noted negative survival (and sometimes nesting success) in several small shorebird species (Weiser *et al.* 2016, Brown *et al.* 2017), including Semipalmated Sandpipers. Results were variable by year and site. Several authors have suggested that for leg band-mounted geolocators, the use of a color band under the tag as a 'spacer' reduces joint abrasion and may increase survival (e.g., Clark *et al.* 2010, Pakanen *et al.* 2015, Brown *et al.* 2017). The geolocator, attachments, and bands used should be as light as possible, preferably weighing in total less than 2.5% of body mass (Weiser *et al.* 2016).

Satellite transmitters: The most accurate satellite based Global Positioning System (GPS) technologies can now be used to track shorebirds because these GPS dataloggers weigh as little as 1 g (www.lotek.com). However, these dataloggers must be recovered to download the data (like the geolocators), thus are only useful when the probability for recapturing an individual is high (e.g., at a nest site). A disadvantage of the small GPS dataloggers is that only a limited number (e.g., 30) of locations can be stored (although the unit can be programmed to determine when these locations are collected). In cases where the probability of retrieving a datalogger is low, the relatively new Pinpoint GPS Argos tracking devices (3.5 – 4.0 g) pairs the Lotek's GPS capabilities with the Argos system so that location data are downloaded remotely and at regular intervals (pass prediction) removing the obstacle of recapturing the bird. The Pinpoint tags offer opportunities to track small species in somewhat realtime with high accuracy.

Relatively accurate locations (up to 250 m accuracy but realistically generally within 20 km; Douglas *et al.* 2012) can be obtained from Platform Transmitter Terminals (PTTs), which estimate locations using the Doppler effect and relay data to an online server, so the units do not need to be recovered to obtain the data. Units are becoming lighter, and now there are 5 g and 2.5 g satellite transmitters (e.g., Microwave Telemetry, Inc. www.microwavetelemetry.com). However, units are expensive (currently over $3400 and 4500 USD, respectively each), as are monthly data fees (maximum $63 USD per month per unit, but usually between $25 and $50 per month unit). Options such as solar versus battery operated, pattern of data collection, and so on will depend on the source of the unit, weight, and species. Currently, only solar PTTs are light enough for shorebirds. The lightest units are solar with a rechargeable battery. For the solar panel to operate effectively, with optimal location quality, body feathers must be clipped in the back attachment area. Hillig *et al.* (2012) suggest a method to prevent shading by feathers. For shorebirds, it is usually a leg-loop backpack attachment, usually with Teflon ribbon (sometimes neoprene) straps around the legs: at this time it is not known how well the stretchable neoprene straps last (e.g., Gill *et al.* 2008, Watts *et al.* 2008, Olson *et al.* 2014).

9.4. Measurements. Shorebirds are often measured differently than passerines (Figure 11). The most common measurements are wing, bill, and tarsus length (measured in mm), and mass (measured in g). Wing length is normally taken with the wing flattened and straightened, measured from the bend in the wing to the tip. This measurement is usually more consistent than 'natural chord', as used on passerines, and differences among banders are easily standardized (Pienkowski and Minton 1973). Wing length is often used as a measure of structural size within a species, and is measured with a wing rule (ruler with a 'stop' at the zero point; note that rulers with an offset 'stop' can be used only by a right-hander or a left-hander, depending on the direction of the offset). Wing length in an individual bird will vary according to time since the previous molt, and perhaps age (Pienkowski and Minton 1973, N. Clark pers. comm.). Bill length is normally culmen, from the midline anterior edge of feathering to the tip of the bill. Culmen is not as accurate a measurement as bill length from the anterior or rear of the nostril to the tip of the bill, because feather wear or loss at the base of the bill sometimes makes it difficult to determine where the culmen measurement should start (Pienkowski 1976, Prater *et al.* 1977). Normally one can tell where the edge of feathering was or should be, and measures from there. Often only culmen measurements exist when making comparisons with other studies, as historically, nostril to bill tip measurements seldom were made. In many species, bill length is a useful indication of sex. Within a population, females often have, on average, longer bills than males. Total head length (tip of the bill to the back of the head) is sometimes used. It is apparently more repeatable than many types of bill measurements, and may be better than bill length alone in separating sexes of some species, but cannot be used on museum specimens (N. Clark, C. D. T. Minton pers. comm.). Bill width has been used to attempt to separate populations of Semipalmated Sandpipers (Harrington and Morrison 1979), and is measured at the smallest part of the bill posterior to the terminal ‘bump’ in this species. Bill and tarsus length are usually measured with calipers. Because bills of most shorebirds are very sensitive, the bill is usually held lightly with the fingers, with the calipers resting on one’s fingers and not the bird’s bill. Metal digital calipers are normally the most accurate, as errors in reading are uncommon (if the calipers are properly zeroed after being turned on), but they may malfunction if used under wet conditions in the field, and batteries may run out. Many dial or vernier calipers can be misread if care is not taken, and inexpensive plastic calipers may not be accurate. Tarsus length is measured from the base of the toes to the mid-point of the ankle joint (see Figure 11), and also is sometimes used to indicate structural size within species. This is a difficult measurement to repeat among banders, or even for a single person. A

Figure 11. Common shorebird measurements (after Prater *et al.* 1977).

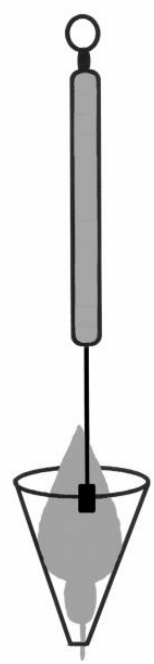


variant involves the foot (tarsus plus toes; from the back of the ankle to the tip of the flesh of the longest toe, excluding the nail; N. Clark pers. comm.).

Mass or weight can be measured with a hanging Pesola-type scale (widely used in the field) or a digital electric or battery balance (often used in more permanent banding station situations). Digital battery balances are usually more accurate than Pesola-type scales. Birds may be placed on the scale in tubes (e.g., toilet roll tubes, other cardboard tubes, or PVC tubes, of an appropriate diameter and cut to length). The tube (and bird) is laid horizontally on the scale. To prevent the tube from rolling, it can be flattened on one side. Bags also may be placed on the scale, but are less efficient than tubes, and their weight when empty should be verified more often.

If a Pesola-type scale is used, it should be held by the top ring or hook and allowed to dangle freely, while being protected from the wind. The bird can be placed in a weighed cloth bird bag, or preferably in an appropriately sized and weighed plastic cone (Figure 12) with the bill protruding from the bottom. Both sides of the bag should be firmly attached to the teeth of the clip at the bottom of the scale (pinch teeth together), so that the bird cannot escape the cone, and the cone cannot become unclipped and fall. It is very easy to release shorebirds from plastic cones, by sliding them out into the palm of the hand until one can hold them in the banding grip. Any weighing container (cloth bag or cone) should be checked periodically when empty to verify its mass.

Figure 12. Shorebird in weighing cone with Pesola-type weighing balance.



Mass/weight is normally used as an estimate of body condition and fat level, particularly during migration. In Willets during the breeding season (and probably some other species), it is a much better indicator of sex than wing, bill, or tarsus length (C. Gratto-Trevor unpubl. data). When large numbers of birds are captured at once (migration studies), time since capture should be noted next to the mass measured, as shorebirds lose mass after capture (Lloyd *et al.* 1979, Schick 1983, Davidson 1984, Castro *et al.* 1991, Warnock *et al.* 1997, Wilson *et al.* 1999).

Amount of fat deposition may be 'scored' by observing the yellowish fat masses present in the furculum (where the throat joins the body) and abdomen. See the general North American Banders' Study Guide for details of scoring (North American Banding Council 2001). Because it is based on a continuum, often considerable variation in scores exists among banders. Meissner (2009) describes a classification scheme for scoring subcutaneous fat deposits of shorebirds.

Machines measuring total-body electrical conductivity (TOBEC) have been used as a noninvasive technique to estimate body composition (including lean weight and fat content) in live shorebirds (e.g., Castro *et al.* 1990, Skagen *et al.* 1993, Lyons and Haig 1995). However, the device must be calibrated for each species by taking TOBEC measurements from some individuals, and then accurately measuring body composition by sacrificing those birds and doing solvent extraction on them. In these studies, lean mass could be predicted with much more accuracy than lipid mass. Lyons and Haig (1995) noted that TOBEC measurements provided little improvement in predicting fat mass compared to conventional body mass and size variable equations. This technique also has been used on eggs, and lean mass was more accurately predicted than egg lipid mass. Factors such as egg temperature and the position of the egg in the storage chamber significantly affected the TOBEC index obtained (Williams *et al.* 1997).

Dietz *et al.* (1999) used ultrasonographic imaging to measure size of the pectoral muscles and stomach in several species of shorebirds. They concluded that the technique is best suited to measure rapidly changing organ sizes over short time periods.

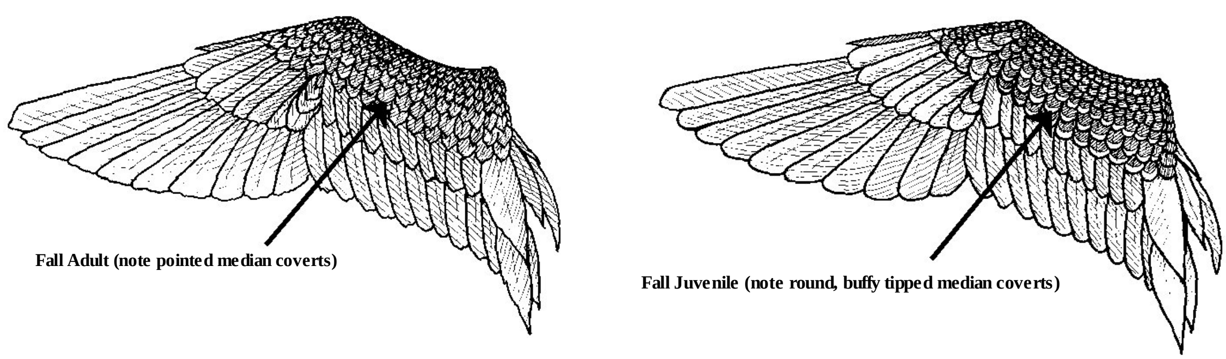
For any bird banded, visible abnormalities, such as healed injuries to legs, deformed bills, or excessive feather lice loads, should be noted, and reported to the banding office.

9.5. Ageing. Skulling cannot be used to age shorebirds (C. L. Gratto-Trevor unpubl. data). However, during fall migration and early wintering, simple plumage differences between adults and juveniles allow ageing of most species (Table 1). Most North American shorebirds undergo a complete molt once a year, usually on the wintering grounds. A few species, primarily those that winter relatively far north, begin molting flight feathers during migration, or even on the breeding grounds (e.g., Dunlin, which start flight feather molt during incubation and continue molt at migration staging sites; both species of dowitchers, which initiate flight feather molt during migration, at least in the Canadian Prairies; and American Avocets and Black-necked Stilts, which apparently start wing molt during late incubation/brood care, at least in southern Canada; Purple Sandpipers, Wilson's Snipe, and American Woodcock also may start wing molt at the breeding site, as will some late-incubating Piping Plovers (probably yearlings)). Most species have a prealternate molt of body feathers into breeding plumage in early spring, and replace body feathers into basic (winter) plumage starting during migration. Adults normally have a mix of worn and new body feathers into the late autumn. Primary molt and condition of median coverts are often important in determining age of shorebirds. As adults complete their winter plumage, the birds are progressively more difficult to age in winter, but with some knowledge of the timing of flight feather molt in particular, most birds can be aged as adults or young of the year throughout much of the winter. Juveniles arrive in the south later than adults, start flight feather molt later, and often replace fewer (or no) flight feathers compared to adults. Their feathers are structurally weaker than those of adults and wear at faster rates (N. Warnock pers. comm.). In many species, yearlings may not undergo complete migrations (they remain south or short-stop south of the breeding grounds) and so often start flight feather molt earlier than older birds (in the autumn/early winter). Prater *et al.* (1977) describe plumage differences in shorebird ages and sexes in detail: more general descriptions are noted below and in Table 1. Pyle (2008) also describes molt patterns and aging methods for shorebirds. Brock (1990) has useful descriptions for several species, and molting patterns of Palearctic shorebirds are well described in Barter and Davidson (1990). Cramp and Simmons (1983), and Marchant *et al.* (1986) provide useful descriptions of different plumages.

Primaries of juvenile shorebirds tend to be more pointed and narrow than those of adults (Prater *et al.* 1977), which may be of use when adults and juveniles are captured in mixed flocks and can be compared in the hand (e.g., Redshank and Bar-tailed Godwits; G. Appleton pers. comm.; *Tringa* sandpipers; N. Clark pers. comm.).

In *Calidris* sandpipers, juvenile plumage is easily distinguished from that of adults during fall migration. Median wing coverts (Figure 13 and Appendix 7; Prater *et al.* 1977) in juveniles at this time are rounded, with a pale buffy edge. In adults, light edges have worn off, and the feathers are pointed. Any recently replaced median coverts are rounded, as in juveniles, but the pale edge is more white than buffy, and normally a mix of old and new feathers is present. During winter, it becomes progressively more difficult to separate adults from juveniles. However, because adults of most shorebirds migrate some weeks earlier than most juveniles, they normally begin molt earlier, so that by November most adults have undergone some flight feather molt, while many juveniles have not. As well, juveniles often retain some buffy-edged inner median wing coverts until November or December, and the innermost median coverts, normally covered by the scapulars, retain their buffy tips until the next molt, at 12-18 months of age. Red Knot juveniles can be distinguished past November, even after buffy fringes have worn away, but the diagnostic dark brown/black subterminal fringes remain on wing coverts most of their first year. In addition, legs of juvenile knot are normally significantly greener than those of adults (C. D. T. Minton pers. comm.). While buff-fringed coverts in Sharp-tailed Sandpipers may be present in both adults and juveniles, juveniles can be distinguished by their ginger-brown crown and legs that are more yellow/green than those of adults (C. D. T. Minton pers. comm.).

Figure 13. ***Calidris*** **sandpipers: juvenile versus adult median coverts.**



The breast plumage of adults of many species often shows patterns of stripes or spots, but that of juveniles is usually a soft buffy wash, and the difference is distinctive. These and other methods of distinguishing adult from juvenile shorebirds are summarized in Table 1.

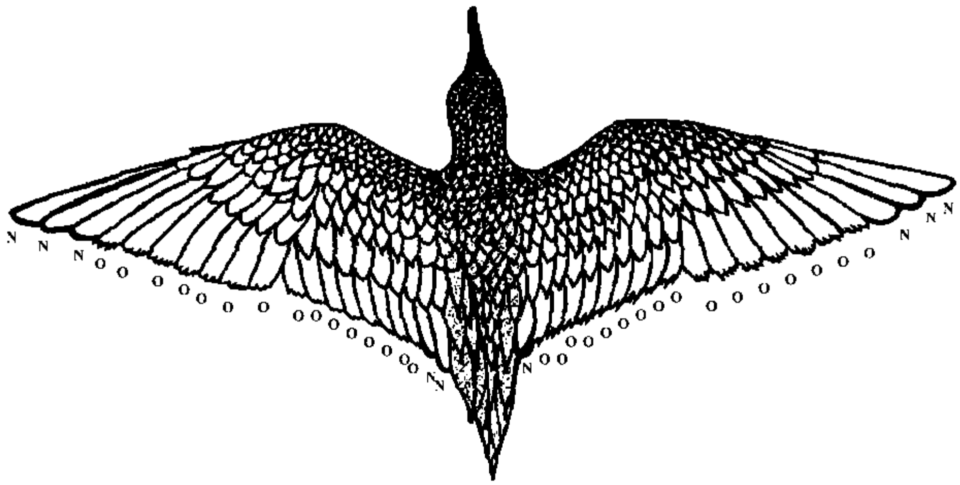
At times of the year and instances where plumage methods are not reliable, Franks *et al.* (2009) were able to accurately age Western, Semipalmated, and Least sandpipers using the large expected differences in isotope values of flight feathers grown at Arctic versus non-Arctic latitudes.

Some yearlings (SY birds) of several species can be identified in the hand by a partial molt, including Semipalmated Sandpipers, Least Sandpipers, Stilt Sandpipers, Lesser Yellowlegs, Red Knot, and a few Hudsonian Godwits (Table 1).

Shorebirds normally molt all flight feathers during the 'winter'. However, juveniles will have undergone only one migration with those feathers (north to south), while adults have had two migrations (south to north and back south), so flight feathers of juveniles are often less worn. Juveniles of some species do not molt flight feathers at all, so feathers may be very worn as yearlings (Table 1), and in other species all feathers are molted, similar to adults.

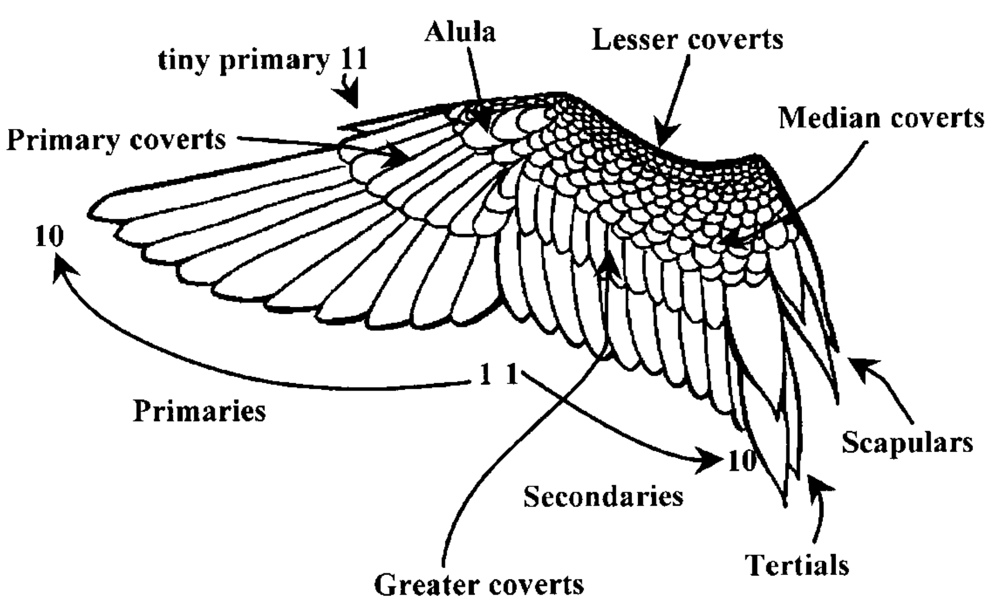
There may be considerable variation among subspecies or populations as well (e.g., Meissner *et al.* 2010). In a few species, such as those noted above, most or all juveniles molt the most important (outer) primaries only, as well as inner secondaries. These birds may be identified as yearlings (between at least May and September) by the contrast between fresher outer primaries and more worn inner primaries (Figure 14 and Appendix 7). If all feathers had been molted the previous winter, outer primaries, which suffer the most wear, would be more worn than inner primaries. Note that the percentage of juveniles in these species with this Partial Postjuvenal Wing (PPW) molt can be variable among populations and years (e.g., Prater *et al.* 1977, Gratto and Morrison 1981, Nicoll and Kemp 1983). Individuals without the partial molt usually have not molted any primaries, but some undergo a complete molt. A convenient method of describing PPW molt scores is to define all primaries and secondaries as new (N: replaced previous winter) or old (O: not replaced previous winter). This can be noted as follows, reading from left to right across the back of the bird (the tiny outermost 11^{th} primary is ignored; Figure 14 and Appendix 7): $N^3O^7O^8N^2/N^1O^9O^7N^3$ (outer three primaries on the left wing had been replaced, so look new, inner seven primaries left wing old, outer eight secondaries old, inner two secondaries new, slash represents body, innermost secondary on right wing new, outer nine secondaries on right wing old, inner seven primaries on right wing old, outer three primaries right wing new). Occasionally, the pattern of replacement is more complicated (e.g., $N^3O^1N^2O^4O^8N^2/N^2O^2N^1O^5O^5N^1O^1N^3$).

Figure 14. Partial Post-juvenile Wing (PPW) Molt (spring to fall yearling, noted as: $N^3O^7O^8N^2/N^1O^9O^7N^3$).



9.6. Molt. As noted above, it is useful to examine birds for body and flight feather molt. This can indicate age as well as provide information on timing and extent of molt, which is poorly known for most shorebirds. To describe body molt the bird is normally divided into three regions: head, upperparts, underparts. The extent of replaced feathers can be coded from 0 (all old), 2 (a few new feathers), 3 (about half replaced), 4 (most replaced), to 5 (all new) (Ginn and Melville 1983). For birds in active flight feather molt, feather molt scores are usually more complicated, with the condition of every primary (feathers attached to the hand), secondary (feathers attached to the forearm), tertial and tail feather described, as well as clumps of other feathers (greater coverts, lesser coverts, scapulars, alula). Their condition is noted as follows: 0 (old feather), 1 (feather missing or completely in pin), 2 (just emerging from sheath to one-third grown), 3 (one to two-thirds grown), 4 (more than two-thirds grown but still with waxy sheath at base), 5 (new feather fully developed, and without waxy sheath; Ginn and Melville 1983). Each primary and secondary has a number. In Britain and North America, primary feathers are numbered from the middle of the wing out: primary one is in the middle of the wing, and ten is outermost (except for the tiny 11th primary). In other European countries, and some South American countries, primary one is outermost, and numbers increase to the center of the wing. In all systems, secondary one is in the middle of the wing, and the 10th is next to the tertials (Figure 15). Instead of describing every feather, one could describe the condition of primaries and secondaries only (e.g., $0^4 1^2 2^1 3^1 4^1 5^1 3^1 2^1 1^1 0^7/0^6 1^1 2^1 3^1 4^1 5^1 4^1 3^1 2^1 1^2 0^4$: outer four primaries on left wing - no. 7-10 - all old, 6th and 5th primaries missing, 4th primary just out of pin, 3th half

Figure 15. Labeled shorebird wing.



grown, 2nd almost grown, 1st fully grown and without sheath; 1st secondary on left wing almost two-thirds grown, 2nd secondary one-third grown, 3rd in pin, 4-10th old; body; secondary 5-10 on right wing old, 4th secondary missing, 3rd one-fifth grown, 2nd half grown, 1st almost grown; 1st primary on right wing fully grown and without feather sheath, 2nd three-fourths grown, 3rd half grown, 4th just emerging from sheath, 5th in pin, 6th missing, 7-10 all old).

9.7. Sex determination. For a few shorebird species, the sex of birds can be determined in the hand during the nonbreeding season, but in most it is only possible during the breeding season, and even then it is difficult or impossible for some species (Table 1). If plumage differences exist, they are likely to be present only during the breeding season. Often, they are subtle, and only obvious when both members of a pair are observed at the same time. Except for phalaropes and jacanas, males usually are brighter in plumage than females (e.g., darker black neck and headband in some plovers), although females in most species tend to be larger in size than males. Bill color may indicate sex in some species during the breeding season (e.g., orange tip on bill in male Marbled Godwits). Bill shape may differ between sexes (e.g., longer straighter bill in female American Avocets, shorter more curved bill in males). In Black Oystercatchers, presence of eye-flecks were used to determine sex with 94% accuracy (females had full eye flecks and males either slight or no eye flecks; Guzzetti *et al.* 2008).

If only one sex incubates, incubation patches during the appropriate season will identify the incubating sex (remember that not all birds without incubation patches will be the nonincubating sex). Even when species are monomorphic in plumage, sexes in some can be determined by size (e.g., wing length longer in male Pectoral Sandpipers). Bill length is commonly the most sexually dimorphic measurement in sandpipers, with female bill length normally averaging longer than males (Table 1). Other measurements may provide more information in other species. For example, mass is a much better determinant of sex in breeding populations of Willets than wing, tarsus, or bill length (Gratto-Trevor unpublished data). Vent size during the breeding season is useful in monomorphic species where both sexes incubate.

Overlap in size measurements between the sexes varies among species, and is often least within specific breeding populations. For example, while the sex of >90% of Semipalmated Sandpipers can be accurately determined by measurements in a single breeding study site (Gratto and Cooke 1987), where eastern and western breeders mix during migration, accuracy of assigning sexes by measurements alone would normally be less (e.g., Harrington and Taylor 1982). As well, the degree of overlap between sexes in measurements may vary from one breeding site to another.

Sex can be determined in any species and in chicks by DNA analysis, using various methods, as reviewed in Dos Remedios *et al.* (2010). Small tissue samples are required from each bird (see feather and blood sampling below) and known sex samples are often necessary to verify accuracy of sexing for previously untested species (Halverson 1997).

9.8. Feather and blood sampling. Often it is necessary to collect feather or blood samples for DNA, isotope, sexing, disease or hormone studies. If carefully carried out, adverse effects on shorebird behavior and survival are rare (Colwell *et al.* 1988, Gratto-Trevor 2001). Check with experts on current techniques for sample collection and storage and ensure your sampling regime will be useful in answering your scientific question. DNA samples can sometimes be obtained from feather samples. This may require pulling a (or several) contour feathers, or cutting off as much as possible of the shaft of a larger feather (e.g., 10th [innermost] secondary on each wing). Especially for smaller species, check with experts that your sample(s) will be adequate to provide DNA. Ensure feather removal does not impair flight. Care should be taken not to touch the feather shaft, and the feathers can be stored in a labeled paper envelope. Feather sampling for isotope analysis is similar (K. Hobson pers. comm.).

Bird red blood cells are nucleated, so very useful for DNA analysis. Methods used to handle the birds before blood sampling, and the treatment of the collected blood afterwards can vary with the purpose of the blood collection. So check appropriate methods first, and ensure the samples are collected and stored appropriately. Any personnel collecting blood samples needs to be properly trained in blood sampling techniques and have the appropriate Animal Care approval and permits in place. Blood samples are normally collected from the brachial vein in the wing of shorebirds, sometimes a leg vein or even the jugular (e.g., Lanctot 1994). In unfledged young where the brachial vein is not well formed, it is often easier to obtain blood from a leg vein. Drawing blood from the jugular requires more training and expertise than obtaining samples from a wing or leg vein. Heart puncture may result in injury or death, especially in small species, and should only be carried out by an expert trained in the laboratory (Gaunt and Oring 1999). Vacuum tubes often are ineffectual in collecting blood from shorebirds, particularly from small species, and difficulties may be encountered with syringes, but verify current techniques with experts.

To collect blood from the brachial vein (or leg vein), use as small amount as necessary of clean uncontaminated water to move feathers away from the vein (do not overwet). Locate the brachial vein, and poke the needle (without a syringe) into the brachial vein, then withdraw the needle and allow blood to drip into microhematocrit capillary tube(s) – check whether you should be using heparinized or nonheparinized tubes. Note that blood flows more freely in warmer weather: this may affect amount of blood that can be collected under colder conditions, or blood clotting in warmer conditions. When each tube is ¾ full (or desired amount if less), blood can be put into a collection tube (preferably by an assistant); or it can be directly dripped onto an FTA-type card if that is appropriate for your analysis. If the puncture site is still bleeding after sampling is concluded, apply slight pressure on the site with a small amount of cotton for 30 seconds or more, to promote blood clotting at the puncture site. If still bleeding, continue to apply pressure: add a small amount of cornstarch or flour if necessary to help in clotting. If birds seem to be bleeding too heavily, use a smaller gauge needle. Injuries such as haematomas can occur if the vein area is repeatedly pierced to increase blood flow, but usually the punctured area returns to normal within a couple of days. Shorebirds are generally very calm birds, but occasionally a bird is encountered that appears highly stressed (excessive panting, saliva dripping from the mouth) and physically agitated before any manipulations have commenced. It is recommended that these birds be released without further handling.

Amount of blood collected varies with size of the species as well as the collection technique: DNA samples generally require much less blood than hormone samples, and plasma (for hormone samples) generally makes up only about 50% of total blood volume. While DNA analyses often require only one small capillary tube of blood (about 50 µl) or less, multiple hormone analyses may require as much as 10 tubes (500 µl) per bird. Maximum blood volume to be collected in a single draw (one time only) can be calculated as 1% of body mass (i.e., it is acceptable to collect up to 500µl of whole blood from a 50g bird; 100 µl of whole blood (2-3 capillary tubes) per 10 g bird) (Gaunt and Oring 1999).

10. HEALTH OF BANDER (SHOREBIRD DISEASES)

Shorebirds are prone to several diseases. Some are discussed very briefly below, along with their potential to affect humans. In order for swifter diagnosis of any of these diseases in humans, it is important to mention to your physician that you have been working with birds.

Avian botulism is a paralytic, often fatal disease of birds. It results from ingestion of a toxin produced by a bacterium (*Clostridium botulinum*). Type C botulism is common in shorebirds, and deaths occur yearly. Humans are considered relatively resistant to botulism type C toxin (Locke and Friend 1987).

Avian cholera is a highly infectious disease among birds, caused by the bacterium *Pasteurella multocida.* It often results in the death of the infected bird. However, only a few reports of infected shorebirds occur yearly, generally involving individuals or small numbers of birds. Avian cholera is not considered a high risk disease for humans (Friend 1987).

Chlamydiosis, or psittacosis (ornithosis), is caused by intracellular parasites (*Chlamydia psittaci*) considered to be a link between viruses and bacteria. This disease has been reported for several species of shorebirds, but appears to occur infrequently in North American species. Psittacosis can be a serious human health problem, particularly to those working with birds, especially in areas with dry bird feces (Locke 1987).

Encephalitis has been known to be contracted by humans handling shorebirds, particularly those from Russia. The possibility should be mentioned to your doctor if difficulties arise in diagnosis (C. D. T. Minton pers. comm.).

West Nile virus is a mosquito-borne flavivirus. Birds are the primary vertebrate reservoir hosts. This virus was first found in North America in 1999, and since then has spread rapidly throughout much of North America. Corvids are most often found dead and dying from this virus, although over 200 species of birds have tested positive for it, including several species of shorebirds (CDC 2016; F. A. Leighton pers. comm.). Killdeer were experimentally infected with West Nile by infected mosquitoes. Little is known about oral or contact transmission among birds, although some transmission occurred among cage-mates (including gulls) in the absence of mosquitoes (Komar *et al.* 2003). Humans are most often exposed to West Nile virus from infected mosquitoes. However, since some virus is shed in the feces of infected birds, there is potential for transmission from handling wild birds. About 80% of infected humans will suffer no disease, and most of the rest will have some mild form of illness from which they will recover completely. A few will develop clinical neurologic disease (e.g., encephalitis and meningitis). Recommendations to avoid exposure include using mosquito repellant (but don't have this anywhere on yourself where it would touch a bird such as the palms of your hands), wearing long sleeves and pants to avoid mosquito bites, and cleaning one's hands with antiseptic (not antibacterial or antimicrobial) wipes after handling a bird (F. A. Leighton pers. comm.). In order to prevent transmission from one bird to another, wipe one's hands with antiseptic wipes between each bird, and preferably clean bird bags after each use.

Wild aquatic birds are considered the reservoir for all subtypes of Avian Influenza (influenza A viruses), and there is some possibility of evolution into highly pathogenic avian influenza (HPAI) viruses in poultry and pandemic influenza viruses in humans. However, currently the incidence of even low pathogenic avian influenza viruses in the Americas appears to be low in shorebirds, even in Alaska, with its avian migratory connections to Asia (Ip *et al.* 2006). Although to date, no humans appear to have been infected from the HPAI viruses found in North America, USDA (2016) advises people handling live or dead wild birds to take appropriate precautions, including wearing protective clothing when handling sick, dead, or potentially diseased wildlife (USDA 2016). In general, keep field equipment clean and take appropriate sanitary precautions (e.g., washing hands in soap and water, cleaning bird bags frequently). Do not go from the field to a poultry operation after banding wild birds without cleaning up and changing clothing (check with current regulations).

11. DATA MANAGEMENT

The importance of having specific questions in mind when planning research has already been noted. The research plan will identify the species to be studied, sample sizes necessary, the types of trapping and marking techniques to be used, the measurements to be taken, etc. Numerous types of data forms exist. Depending on the site conditions, data may be collected directly into a computer, directly onto data sheets, or into a field book and then (as soon as possible) onto data sheets or a computer. Data are entered for each bird: band number, species, age, sex (if known), date, time, location (and nest site if applicable), trapping method, exact marking scheme, measurements, and known injuries or abnormalities, etc. 'Bandit' (from the U.S. and Canadian banding offices) is software specifically for banding data entry and management and can be used to enter these sorts of data. Banding information must be reported to the Canadian or U.S. banding office as soon as possible after the field season, in a prescribed format.

As noted earlier, color band coordination of North America shorebirds is through the Pan American Shorebird Program (Email: ec.bbo.ec@canada.ca). Information about this program can be found at: https://www.canada.ca/en/environment-climate-change/services/bird-banding/pan-american-shorebird-program.html, and the entire PASP manual can be downloaded from the North American Banding Council Shorebird webpage under PASP, in English or French: http://www.nabanding.net/shorebirds/.

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APPENDIX 1. METHODS TO CAPTURE SHOREBIRDS AT NESTS AND WITH BROODS

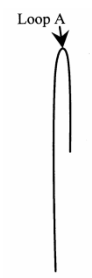
Species	Nest Trapping Methods Used	Adults Captured on Broods
Red Phalarope	passive and active nest traps, mist net	upright mist net
Red-necked Phalarope	passive and active nest traps, mist net, handnet	upright mist net
Wilson's Phalarope	passive nest trap, mist net	upright mist net
American Avocet	bownet, passive and active nest traps	
Black-necked Stilt	bownet, passive and active nest traps	bownet
American Woodcock	hand net	
Wilson Snipe	passive nest trap	
Short-billed Dowitcher	passive and active nest traps, mist net	
Long-billed Dowitcher	active nest trap	
Stilt Sandpiper	passive and active nest traps, mist net	flicked mist net
Red Knot	bownet, mist net	
Purple Sandpiper	passive and active nest traps	
Rock Sandpiper	bownet, passive nest trap	
Sharp-tailed Sandpiper	bownet, passive and active nest traps	
Pectoral Sandpiper	passive and active nest traps (F), flicked mist net (M)	upright mist net
White-rumped Sandpiper	passive nest trap	upright mist net
Baird's Sandpiper	passive nest trap, mist net	upright mist net
Least Sandpiper	passive nest trap	upright mist net
Dunlin	passive and active nest traps	upright mist net
Semipalmated Sandpiper	passive and active nest traps	upright or flicked mist net
Western Sandpiper	passive nest trap	flicked mist net
Sanderling	passive nest trap	
Marbled Godwit	mist net	
Bar-tailed Godwit	mist net, bownet	
Hudsonian Godwit	mist net	
Greater Yellowlegs	mist net	upright mistnet and chick tape
Lesser Yellowlegs	mist net	upright mistnet and chick tape
Solitary Sandpiper		upright mistnet and chick tape
Willet	mist net, passive nest trap, hand net	
Wandering Tattler	mist net	
Upland Sandpiper	mist net	
Buff-breasted Sandpiper	passive and active nest traps	flicked mist net
Spotted Sandpiper	passive nest trap, flushed into mist net	
Long-billed Curlew	mist net	
Whimbrel	passive nest trap	
Bristle-thighed Curlew	mist net	
Black-bellied Plover	bownet, active nest trap	
American Golden-Plover	bownet, potter trap, active nest trap	
Pacific Golden-Plover	bownet	
Killdeer	bownet, passive nest trap	
Semipalmated Plover	passive nest trap	
Piping Plover	bownet, passive nest trap potter trap	
Snowy Plover	noose mat, bownet	
Wilson's Plover	bownet	
Mountain Plover	active nest trap	
Ruddy Turnstone	bownet	
Black Turnstone	bownet, passive nest trap	
American Oystercatcher	noose mat	
Black Oystercatcher	passive walk-in trap	flicked mist net

APPENDIX 2. CONSTRUCTING NOOSE MATS
(by G. W. Page)

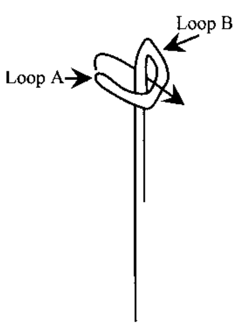
These directions are for making a noose mat to capture shorebirds foraging or at the nest. See text for more details regarding use.

You will need:

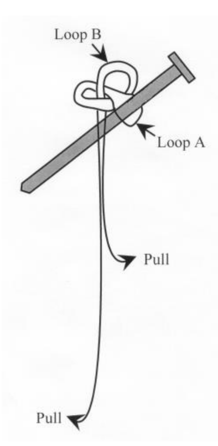
- 3 pieces of hardware cloth (0.6-1.2 cm or 1/4 to ½ inch mesh square wire netting), each 10 cm x 90 cm (4 inches x 36 inches)
- spool of clear monofilament fishing line (6 or 10 lb test)
- a 1.5 mm diameter nail
- glue (e.g. 'shoegoo/goop')
- 3 (or more) thin steel pegs or bent nails (small tent size)



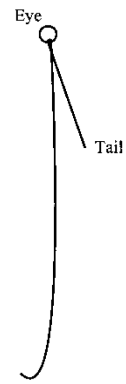
1. Take a 15 cm (6 inch) piece of the monofilament line and fold over to create loop A.



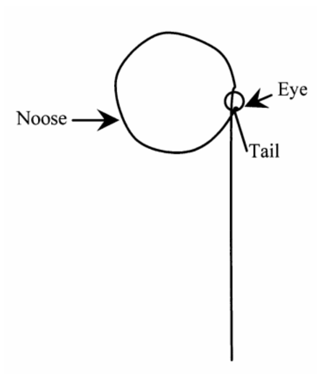
2. Bring loop A over the top to create loop B.



3. Take loop A and push from behind through loop B. Slip loop A over a 1.5 mm diameter nail. Pull on either end of the monofilament line until the knot is tight on the nail. Add additional nooses to the nail (instructions 1-3). Hold all under boiling water for 15 seconds to set the knot.

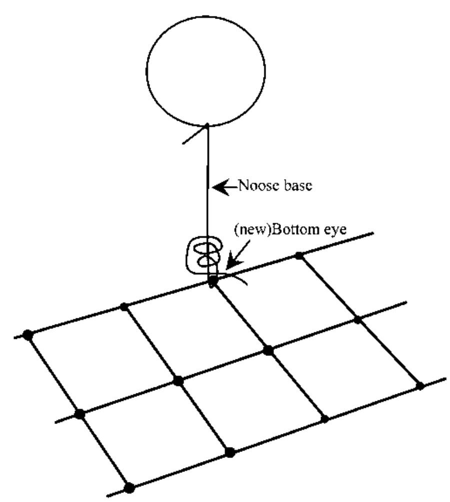


4. Remove noose from nail. Cut tail to ½ inch length.



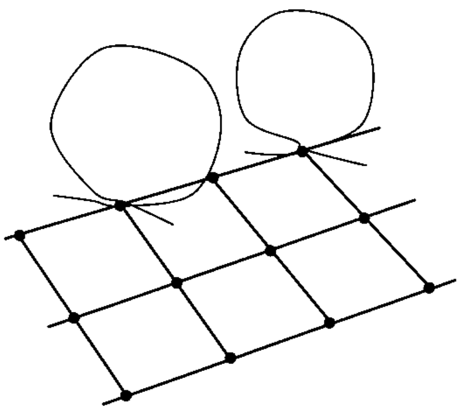
5. Thread the long end of the monofilament line through the 'eye' to create a noose.

6. Take the long end of the noose and thread it under a corner of the hardware cloth (1/2 inch mesh wire). Wrap the end around the base of the



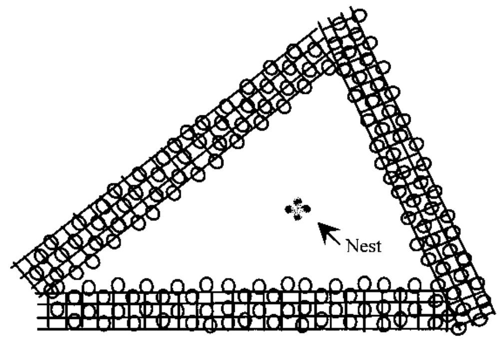
noose two or three times. Thread the end through the 'bottom eye'. Pull the end and the noose to tighten the knot around the hardwire cloth (wire).

7. Open the noose to its full size (should be about 4 cm or 1.5 inches in diameter when fully open). Make certain the noose stands as perpendicular as possible to the hardware cloth (wire). Manipulate the knot until it does stand upright. Repeat to produce nooses every other corner or so.



8. Glue the knot on the hardware cloth (wire). Be careful not to glue the noose so it will not slip shut.

Traps may be placed in a row and foraging birds then chased over it, or three traps may be placed around a nest. It is especially important to peg down traps near a nest so that they are not dragged over the eggs. Overlap traps slightly at the corners (using 1 peg per corner) so that birds are 'forced' over the trap to get to the nest.



APPENDIX 3. CONSTRUCTION OF A BOWNET SHOREBIRD NEST TRAP

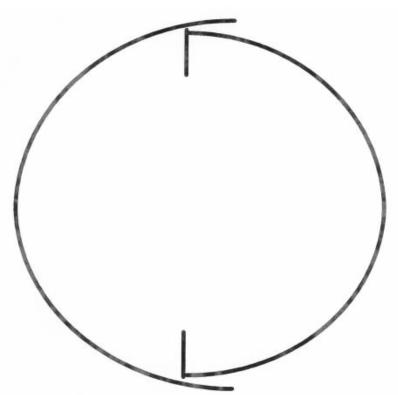
(this specific version designed by L. W. Oring and S. M. Haig; diagrams and instructions below by C. L. Gratto-Trevor)

These directions are for a trap appropriate to capture small plovers (about 50 cm diameter and 25 cm high). For larger shorebirds (e.g. avocets or stilts), you will need to increase the dimensions greatly (to make a trap approximately 100 cm diameter and 50 cm high).

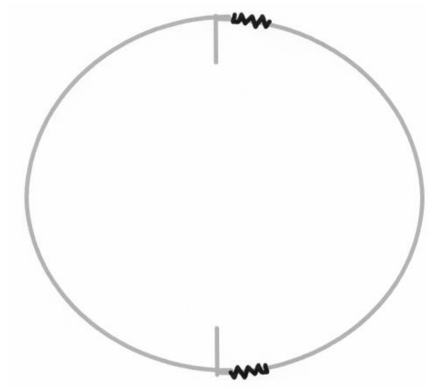
You will need:

- wire cutters, several pairs of pliers, scissors
- spool of very thin wire (25-28 gauge, craft or beading wire
- at least one tube of glue such as 'shoegoo'/ 'household goop'
- very thick and strong thread, or twine (something strong that won't separate into threads)
- piece of 6 lb test clear monofilament fishing line of ~40 cm (but will need extra to replace line when it breaks)
- duct tape (to hold pieces together before adding thin wire and 'goop')
- 2 springs about 4 cm long that thread in opposite directions
- a piece of netting (about 2.5 cm mesh, white colored if to be used on sand substrate) about 80 cm X 80 cm
- about 400 cm of approx. 4 mm thick wire
- about 150 cm of approx. 2 mm thick wire

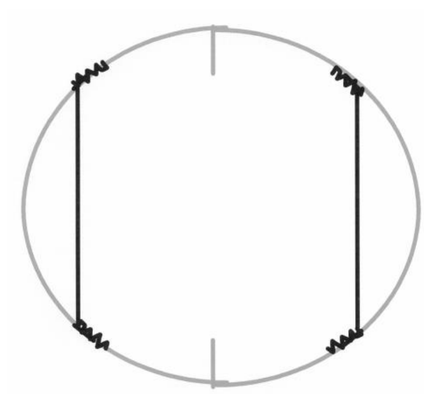
1. Cut 2 pieces of 4 mm thick wire ~93 cm long each. Bend into semicircles. On one piece, bend 10 cm at each end into center of circle.



2. Fasten the two semicircles together (unbent piece will overlap other piece) with duct tape, then very thin wire and glue (e.g. 'goop').



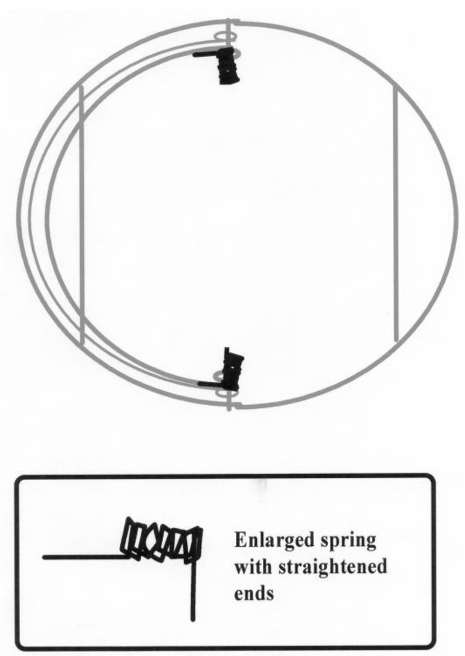
3. Add straight support pieces to front and back: cut two 4 mm thick pieces of wire about 38 cm long each. Bend 4 mm of each end to fit curve of frame, and attach with duct tape, thin wire and glue to front and back of frame.



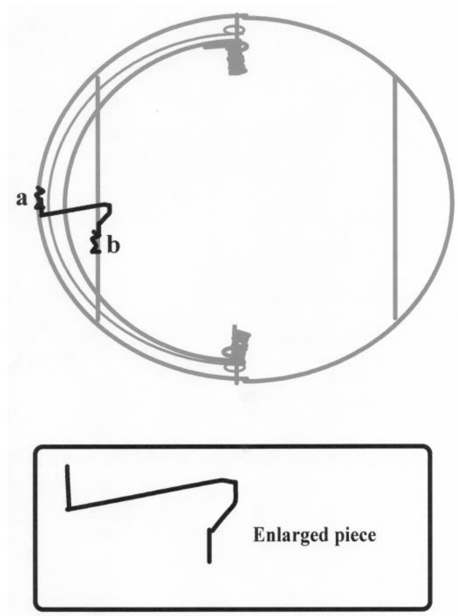
4. Cut 1 semicircle of 2 mm thick wire about 79 cm and bend ends into 'eyes' around center posts.

5. Cut 1 semicircle of 4 mm thick wire about 79 cm and bend ends into ‘eyes’ around center posts (just to inside of step 4 semicircle - more towards interior of circle).

6. Add 2 springs that thread in opposite directions, to center posts. First flatten about 3 cm of each end of each spring, and bend one end at right angles to the other end. Bend 4 cm of center posts up to hold in springs. Attach one end of each spring (with wire and glue) to the thicker wire (step 5) semicircle where it attaches to the center posts, and attach the other ends of the springs to the bits of the center posts now bent upright. Springs need to be orientated so that each tightens when the thick step 5 semicircle they are attached to is bent towards the back of the trap (to the right in diagram below).

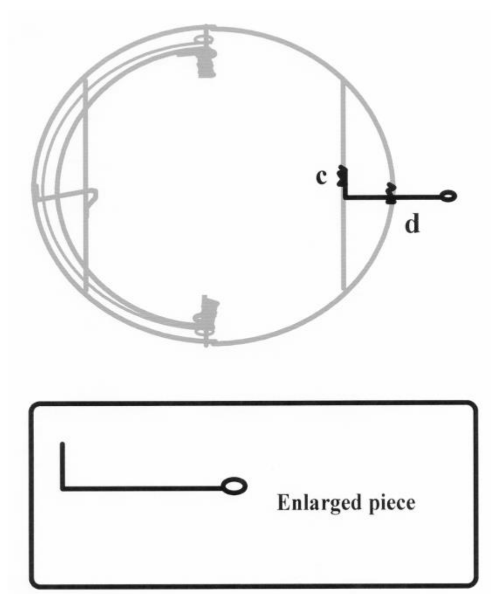


7. Cut one piece of 2 mm thick wire about 18 cm long. Bend the piece so the outer 4 cm is bent to the left, and attach it to the center of the front piece of the frame (a), then the next 8 cm of the piece is bent slightly upwards (maximum height of ~2.3 cm), then abruptly downwards and in to form a forward pointing lump, and the last 3 cm of the piece is bent to the right and attached



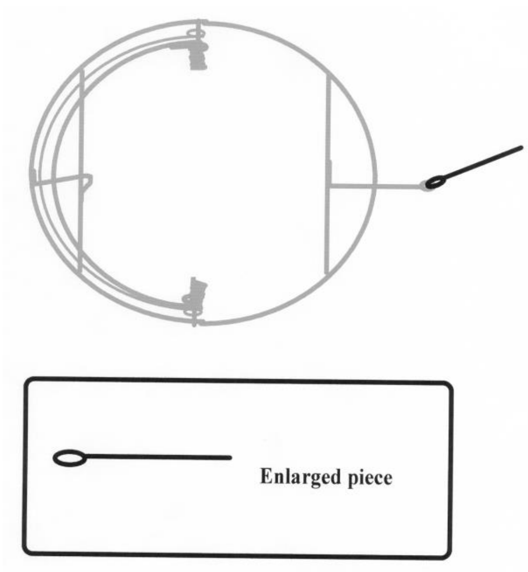
to the center of the straight front reinforcement wire (b). This creates a support sticking up about 2.3 cm to attach the monofilament line to. This piece should be of an appropriate height so the monofilament line is barely above the top of the eggs when it passes over them.

8. Cut one piece of 2 mm thick wire about 16

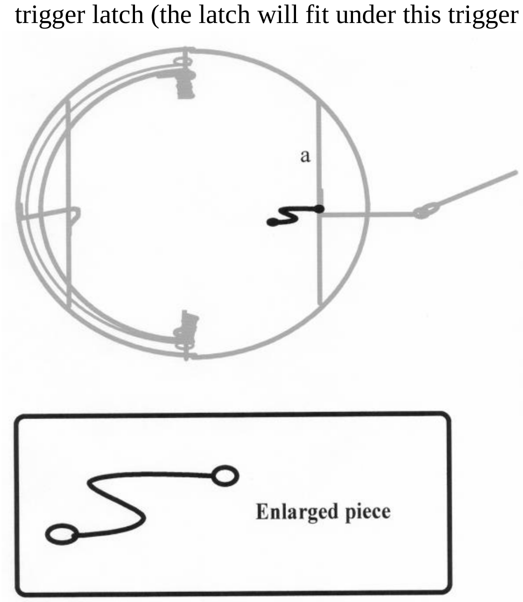


cm long. Bend 3 cm of one end to the left and attach it to the center of the back straight support wire (c). Bend the opposite end 3 cm into an 'eye'. Attach with wire and glue where the piece touches the middle back of the frame (d).

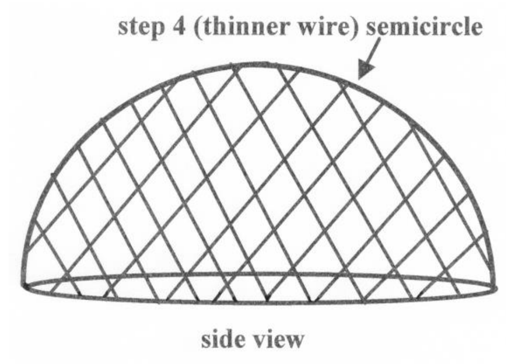
9. Cut one piece of 2 mm thick wire about 14 cm long. Bend one end into an 'eye' through the previous 'eye' in the piece of step 8. This is the trigger latch - its length can be adjusted later.



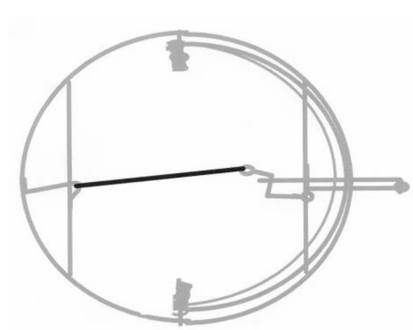
10. Cut one piece of 2 mm thick wire about 6 cm long. Bend to form the trigger: bend one end loosely in an 'eye' around the back straight support wire (a) so it can slide easily to the center, and bend the other end into a small 'eye' to attach the monofilament line to. Bend the piece in the center to form a 'catch' for the trigger latch (the latch will fit under this trigger piece - barely). When the two semicircles are pulled back against the springs to the back of the trap (to the right), the trigger latch should fit under the bend in the trigger. The length of the trigger latch can be fixed later, once the netting and monofilament are on the trap.



11. Sew the netting on the trap with a needle or twisted piece of wire, using the heavy thread or twine. Attach the net to the back half of the trap frame and to the (thicker wire) spring-loaded semicircle of step 5. The thinner wire (non spring) semicircle of step 4 should be sewn in to form the top of the 'tent' of the sprung trap. Add glue ('goop') to all knots and loose bits of netting. Netting should be loose enough so that the leading edge (spring-loaded semicircle) sits on the front frame and not in the air (i.e. doesn't allow birds to escape once the trap is sprung). Netting should be tight enough around the spring area so that it does not catch in the center posts that stick up, when the net is fired. One can 'gather' up the netting out of the way of the posts later, with a few stitches.



12. Attach clear monofilament fishing line (6 lb test) from the front piece that sticks up (step 7) to the trigger 'eye', so that when the leading net edge is forced towards the back, and the trigger latch is set under the trigger, only a small push on the monofilament will spring the trap. The length of the trigger latch and the monofilament line can be adjusted to make as hair-trigger an effect as desirable.



APPENDIX 4. PAN AMERICAN SHOREBIRD PROGRAM (PASP)

COUNTRY and REGIONAL FLAG and BAND COLORS

(from Howes *et al.* 2016, Appendix A)

REGION	FLAG COLOR	COUNTRY	BAND COLOR
Canada	White	Canada	-
		St. Pierre et Miquelon	-
United States	Dark Green Light Green	United States	-
Mexico	Purple-red	Mexico	-
Central America	Gray	Belize	Light Green
		Costa Rica	Black
		El Salvador	Dark Blue
		Guatemala	Orange
		Honduras	Grey
		Nicaragua	Dark Green
		Panama	White
Caribbean	Pink	Bermuda	Dark Blue
		Cuba	Dark Green
		Dominican Republic	White
		Guadeloupe	Light Green
		Haiti	Red
		Jamaica	Black
		Martinique	Orange
South America	Black	Colombia	Yellow
		French Guiana	Red
		Guyana	White
		Suriname	Light Green
		Venezuela	Black
	Yellow	Bolivia	Dark Blue
		Ecuador	Red
		Peru	Yellow
	Dark Blue	Brazil	Dark Blue
		Paraguay	Orange
	Orange	Argentina	White
		Uruguay	Dark Blue
	Chile	Red	-

APPENDIX 5. HOW TO READ A SHOREBIRD COLOR BAND COMBINATION

Describe each band: type (metal, color band, flag), colors (as exact as possible - light green, dark blue), and location on bird (bird's left or right leg, upper or lower leg, above or below other bands). Note if you are unsure of any bands or if you did not see all parts of both legs clearly.

⇐bands of Piping Plover to left would be described as: Metal upper left, orange color band lower left; plain black flag upper right, black over light green color bands lower right. From left to right on the bird):

m | o : Fbk | bk,lg

Bands of Semipalmated Sandpiper to right⇒
would be described as: White flag with code ELA over yellow color band upper left, nothing lower left; orange color band upper right, metal lower right. From left to right on the bird):

FEw(ELA),y | - : o | m

Note species, location of sighting, date and any other information (behavior, other birds)

Email shorebird color band sightings to:
https://www.pwrc.usgs.gov/BBL/bblretrv/ or http://www.bandedbirds.org/ or search the internet for specific species such as Piping Plovers or American Oystercatchers, etc.

APPENDIX 6. SIZES OF SHOREBIRD METAL (U.S./CANADA) BANDS

from

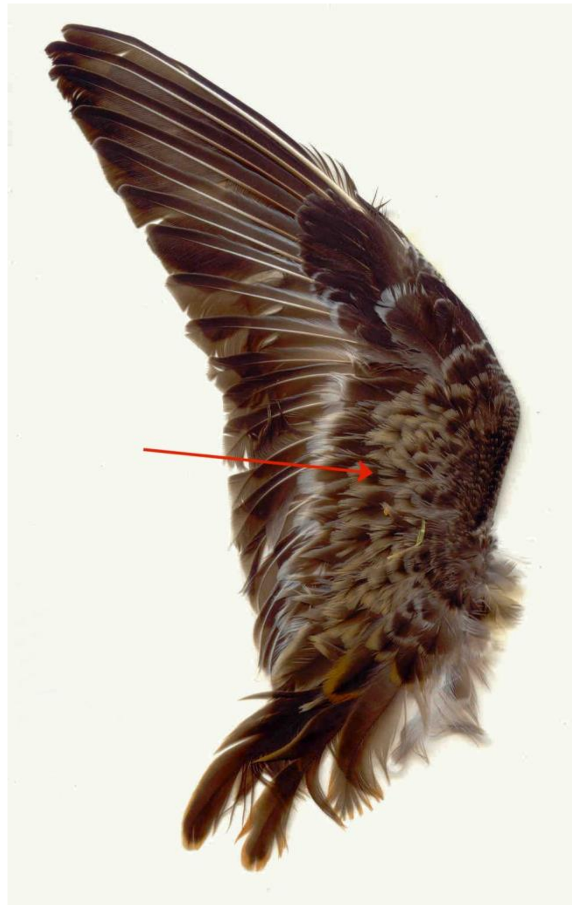
https://www.pwrc.usgs.gov/BBL/MANUAL/SIZES.cfm

July 2017

Band Size	Interior Diameter (mm)	Height (mm)
1	2.39	5.5
1B	2.77	5.5
1A	3.18	5.5
1D	3.50	5.0
1P*	2.84	5.5
2	3.96	6.7
2A	4.20	6.7
3	4.78	6.7
3B	5.16	6.7
3A	5.56	6.7
4	6.35	9.5
4A	7.14	9.5
5	7.95	9.5
5A	8.74	9.5
6	9.53	9.5

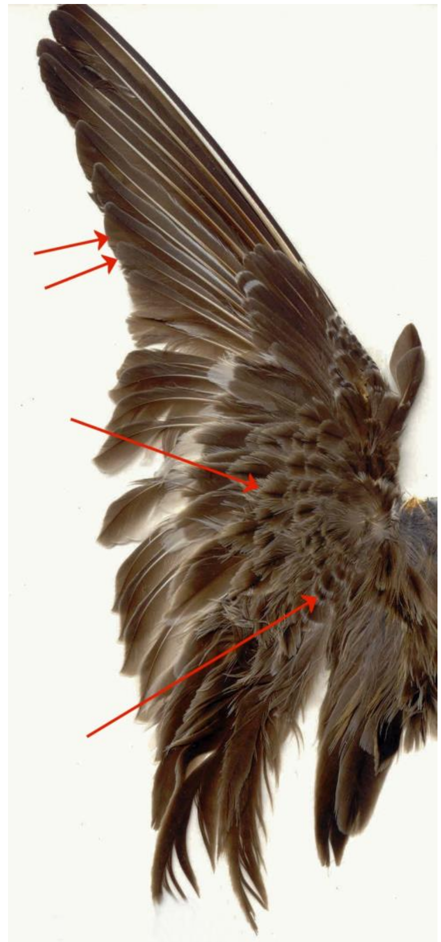
*1P to be used for Snowy Plover only

APPENDIX 7. AGING *CALIDRIS* SANDPIPERS
(photos of Semipalmated Sandpiper wings by C. L. Gratto-Trevor)



1. Fall Juvenile - note rounded median coverts (at arrow) with buffy colored tips.

2. Fall Yearling - note: top arrow - new (replaced previous winter) primary [outer 3 primaries are 'new']; 2nd arrow - old (not replaced previous winter - juvenile feather) [inner 7 primaries are 'old'; 6 outer secondaries 'old', 4 inner secondaries 'new']. Bird has Partial Postjuvenile Wing (PPW) Molt, which would be written as (assuming left wing is the same, which is not always true, reading across bird's back from left to right wing): $N^3O^7O^6N^4/N^4O^6O^7N^3$. 3rd arrow - pointed (worn) median coverts; 4th arrow - rounded innermost median coverts in yearling. Yearlings (SY) undergo a complete 2nd prebasic molt in late fall/early winter on the wintering grounds, and then cannot be separated from other adults.



3. Fall Yearling - note: top arrow - new (replaced previous winter) primary [outer 7 primaries are 'new']; 2nd arrow - old (not replaced previous winter - juvenile feather) [inner 3 primaries are 'old'; all secondaries 'new']. Bird has Partial Postjuvenile Wing (PPW) Molt, which would be written as (assuming right wing is the same, which is not always true, reading across bird's back from left to right wing): $N^7O^3N^{10}/N^{10}O^3N^7$. 3rd arrow - pointed (worn) median coverts; 4th arrow - rounded innermost median coverts in yearling.

4. Fall Yearling - a more eccentric version of PPW Molt: primaries 6-10 (outermost) 'new', 3-5 'old', 1-2 (innermost) 'new'; secondaries 6-10 'old', 1-5 'new': $N^5O^3N^2O^5N^5/N^5O^5N^2O^3N^5$