Wildlife Inventory Plan
Alaska Maritime National Wildlife Refuge
Protocol #6

Version 1.4

Parameter: Productivity and phenology

Species: Ancient murrelet

PURPOSE

To estimate annual productivity and phenology of ancient murrlets and to track variation among years. Seabird reproductive parameters can serve as indicators of change in the marine ecosystem (Cairns 1987, Montevecchi 1993).

BREEDING BIOLOGY

Ancient murrelets (*Synthlibroramphus antiquus*) nest throughout the Aleutian Islands and Gulf of Alaska and south to British Columbia. Birds are nocturnal, foraging offshore on small fish and zooplankton during the day and returning to the colony at night. Nest sites usually consist of burrows along beach bluffs, shallow holes under grass tussocks, or cavities underneath roots and drift logs along beaches. Females lay two brownish, speckled eggs, usually one to two days apart, and both parents share incubation duties, which last for about 35 days. Female is not present between laying of first and second egg and incubation is initiated after second lay (so it's typical for a nest site to go from one cold egg to bird present with two eggs). Chicks are precocial at hatch and leave the nest after just one to three (usually two) days, when adults call chicks to sea. Chick development finishes at sea, with parents attending chicks for an additional month until chicks are fully grown and independent at about one month of age (Jones et al. 1987, Gaston 1994).

Predation at the breeding colony is usually a high source of adult mortality at colonies (Gaston 1994). In the absence of mammalian predators, hatching success is generally high, with most failure due to egg abandonment (Gaston 1992). Adult ancient murrelets are particularly sensitive to investigator disturbance during incubation and prone to desertion (Gaston et al. 1988).

PROCEDURE – PRODUCTIVITY AND PHENOLOGY

Data collection.—Ancient murrelet reproductive performance is monitored by following nest statuses of individually numbered burrows at 7-day intervals throughout the season. At each visit, nest status is determined by reaching an arm into a burrow (called "grubbing") and gently feeling nest contents.

Begin searching burrows for eggs and/or incubating birds in late May or early June. Check any marked nests you can find from previous years and look for additional new nests. Aim for a sample of 70 (minimum) to 100 (ideal) nests with known fate at the end of the season (based on power analysis of crevice-nesting auklets; Thompson et al. 2010). Because it is not possible to obtain known fates for all burrows, you should begin by monitoring an extra 20 to 30 nests. Reuse of nests from one year to the next may vary across sites and years, so the number of new nests you need to find will depend on how many old nests are active in a given year. Try to select only those burrows for which you can reach to the end of chamber; otherwise, you may not be able to tell for sure if chicks fledged successfully or are simply laying dead just beyond your reach, and the burrow will have to be excluded from analysis.

Mark all nests with individually-numbered flags near the entrance. It is helpful to choose a standard flag location relative to the entrance for all your nests (e.g., always putting flag at bottom left of entrance) to avoid confusing nests. In high density areas, tunnels and nest chambers may be everywhere, so check to make sure that the flag shaft does not pierce through into the tunnel or chamber

of another nest. Be aware that vegetation will grow throughout the season, sometimes a meter or more, so it may be helpful to use additional markers, such as flagging tape tied around vegetation, to find nest locations in areas of thick vegetation. Drawing a map of nest locations (see Figure 1) will also help locate nests on subsequent visits.

After initial nest searches, nests are generally checked every 7 days. However, because ancient murrelets are especially sensitive to investigator disturbance, we limit nest checks during incubation as much as possible. Therefore, once you find a bird with eggs in a burrow, don't check that nest again until just before expected hatch, when you should resume checking nests every 7 days until chicks fledge. If you know the lay date (the nest went from empty to bird with eggs on subsequent checks), wait about 25 days before checking again.If you don't know when the eggs were laid (i.e., there were eggs on the first check), use the earliest hatch date recorded in your field camp report as your guide.

To determine the status of ancient murrelet nests (during initial nest searching and all subsequent rechecks), carefully reach an arm into each entrance and slowly attempt to feel the contents of the nest. Be gentle when reaching your arm into a burrow, *walking your fingers slowly down the burrow floor rather than stabbing blindly with fingers extended*. Feel for the nest chamber, which will feel like a slight widening of the tunnel (you can usually spread your fingers a bit); there is often a slight depression and occasionally small amounts of nesting material. If no adult is present, carefully feel around in the nest material to search for eggs or chicks (they may be somewhat nestled among the nest material). If a bird is present, carefully slide your fingers underneath to check for eggs or chicks. If chicks are present, feeling for spines can well determine whether there is one or two chicks. Given chicks fledge just a few days after hatch, it is not uncommon for nests to go directly from eggs on one check to apparently empty with just membranes on the next. If the nest feels empty around expected hatching, you can remove the nest material to search for and count membranes, which are evidence of successful hatch but may be difficult to count by feel alone. (***Note: ONLY remove nest material if you are SURE a nest is empty***). If chicks are found in a nest, it is important to check the nest on the subsequent check to confirm that they fledged successfully and the nest is empty.

Record nest status data in a field notebook using the appropriate standardized code (see pages 6-6 to 6-8 and Figure 2). It is important to record only what you feel and be sure to use the standardized codes *exactly* as instructed. Weird and unpredictable things can happen (e.g., a chick moving between connected nests or one bird usurping anothers' nest) and you may want to describe every detail and feel limited by the standardized list of codes and modifiers available. However, lengthy text explanations and comments tend to cause confusion later and cannot be interpreted by the database used to summarize the data. Choose a code then and there and stick with it - as the field biologist, you are the only person who can make a decision about what you saw that day. If you absolutely must record additional information about a nest, you can enter text in the comments section of the data spreadsheet, but keep in mind that this text is not used in any data summary so it should not contain any information pertinent to how the reproductive success data should be interpreted.

If a nest contains eggs or chicks, there are a few cases when you will need to record additional modifiers that provide more detailed information about the nest status (list of standardized code modifiers). For eggs, record if you find an old egg clearly from last year (Ely), a broken, crushed, or otherwise dead egg (Ed), an egg ejected from the nest (Ej), or an egg pipping just before hatch (Ep). Similarly, for chicks, record if you find a chick in the actual act of hatching (Co), a chick still wet from having recently hatched (Cw), or dead chick (Cd).

For ancient murrelets there are some important rules for using the membrane (M) code:

- Because ancient murrelet chicks fledge after just 1-3 days, it is not uncommon for nests to go from eggs to empty, with freshly-hatched eggshells or fresh eggshell linings (called membranes; Figure 3) left behind in or near the nest chamber as the only evidence of successful hatch. These are coded "M". Make sure to distinguish between a successfully hatched eggshell (usually shell bits held together by rubbery membrane) and eggshell fragments from a crushed egg. If you find eggshells/membranes, try to determine how many eggs they came from, for example if you find three ends you know two chicks hatched.

- The use of the membrane (M) code for ancient murrelets excludes the use of a modifier for eggshells (sh) used in monitoring of other species.

Although you should aim to record a "known" status egg, chick, membrane or nothing for each nest each visit, there will be times when you cannot determine a certain status. For instance, eggs from the previous visit are gone but you cannot reach the back of the nest chamber to tell if any dead eggs or chicks lay beyond your reach. If there is a grubber in the group with slightly longer arms, it may be helpful to have that person give the nest a try. Otherwise, record an unknown code (Unknown "U" if you cannot feel anything but cannot reach to the end of the burrow, Bird Unknown "BU" you can feel an adult bird but cannot determine if it has an egg or chick) and make a concerted effort to confirm the status of that nest on the next visit. Ultimately, these nests may have to be excluded from your sample if you cannot determine the nest fate (which is why you should avoid monitoring nests with unreachable ends to begin with).

Before leaving each nest, check to see that your recorded status makes sense based on what you saw last time (e.g., if you had chicks last visit, you shouldn't have eggs this visit). Data strings that don't make sense will have to be discarded. Before leaving each plot each day, check to see you have a status recorded for every nest. At the end of the day (or at the very least, before you take your data notebook into the field again), enter the day's plot data in the electronic data file provided. Once all eggs in a nest have either hatched or failed, it is no longer necessary to continue checking that nest.

Special considerations for grubbing in ancient murrelet colonies:

Ancient murrelets often nest in dense colonies with other burrow-nesting species where soil is honeycombed with numerous burrows. Burrows may be fragile and collapse if tread upon. In areas of high burrow density, substrate can be especially delicate. Use caution when traversing any area with burrows and avoid stepping above any burrow entrances. When monitoring a plot, it may be helpful to crawl on hands and knees. If a plot is on a slope, it is usually easiest to work uphill from the bottom to the top. If you do collapse a burrow, carefully dig out the entrance, ensure you have not crushed a bird, eggs, or chicks, and makes repairs as best as you can.

Burrow can be narrow and take snaky turns. To maximize the distance you can reach into a burrow and thus your chances of getting known nest statuses, grubbers should minimize the number of shirt layers they wear, as multiple layers will add bulk to arms and make it more difficult to access burrows. In general, wear just a single, thin layer (such as a polypropylene top) and a pair of tight sleeves called "grubbing gauntlets" (Figure 4). Vests and/or extra pants layers may help grubbers stay warm on cold, wet days. If available at your camp, sleeveless rain jackets (called "grubbing vests") are useful for staying dry without adding extra bulk to the arms.

***Data analysis*.—**Calculations for phenology and productivity parameters for ancient murrelets have not yet been automated in an Access database, so analysis needs to be conducted by field crews.

Phenology: For multiple-egg species such as oystercatchers, calculate a single hatch date for each nest based on the FIRST egg in a nest to hatch. Dates for chick hatching are calculated using the Julian date midpoint between the last time an egg was confirmed to be present and the first time a chick or membrane was confirmed to be present (*in leap years, be sure to use a leap year-specific Julian date calendar!)*. If the midpoint falls between two days, by convention we use the EVEN Julian date.

Occasionally, data may provide more exact information on hatching dates. If you observe an event occurring (e.g., the actual hatching) during your visit, use the day of the observation as the date the event occurred and not the midpoint between observations. Similarly, if a pipped egg is observed, assume it will hatch the following day. If a wet chick is seen, assume it hatched that day. Not all nest sites are included in phenology calculations; we require confirmed visualization of the egg and chick/membrane (e.g., no U's) less than or equal to 7 days apart for that site to be used.

For example:

Julian Dates:	150	157	163	170	177	184	190	198	Hatch date
Nest 1	BE2	BE2	BE2	BE2	BC2	N			174
Nest 2	BE2	BE2	BE2	BE2	M2				174
Nest 3	BE2	BE2	BE2	BEpE	M2				171 (pipped egg)
Nest 4	BE2	BE2	BE2	BE2	BCw2	N			177 (wet chick)
Nest 5	BE2	BE2	BE2	BU	M2				Not used, >7d interval

From your nests, calculate mean, first, and last hatch dates.

Productivity: Reproductive success is calculated as the number of known fate nest sites that fledged a chick. Because ancient murrelet chicks fledge so soon after hatching and nests are visited only every 7 days, it is possible to miss seeing a chick; therefore a membrane (M) is used as evidence that a chick hatched and is treated as equivalent to a chick (C) code. Chicks are considered successfully fledged if the nest is empty and (a) chicks were present last time, or (b) membranes are found (basically, for ancient murrelets, all chicks "fledge" unless you find a dead chick or you cannot reach the end of the burrow so you don't know what happened). If a nest "fails", we keep track of what stage this happens (egg or chick period). By convention, if an egg dies while pipping, the egg did not hatch (egg failure). If a chick is partially out of the shell when it dies or if it dies immediately after hatching, it is still considered a successful hatch. If a nest never had an adult present, we cannot be sure it was an active nest from this year, so discard the nest from analysis.

For each nest, count the maximum number of eggs and chicks/membranes ever observed and determine whether chicks fledged. If the nest contains a combination of chicks and membranes, use the minimum number of combined chicks and membranes (membranes may belong to the same chicks you observe). For example:

BE2 BE2 BE2 E2 E2 N = 2 eggs, 0 chicks
BE2 BE2 BE2 BC2 N = 2 eggs, 2 chicks, 2 fledglings
BE2 BE2 BE2 BC2 Cd = 2 eggs, 2 chicks, 1 fledglings
BE2 BE2 BE2 M2 N = 2 eggs, 2 chick, 2 fledglings
BE2 BE2 BE2 MC N = 2 eggs, 1 chick, 1 fledgling (chick/mem. may be from same egg)
BE2 BE2 BE2 M N = 2 eggs, 1 chick, 1 fledgling
BE2 BE2 BE2 C2 U = unknown fate of chicks, remove entire nest from analysis

If you cannot determine the fate of a nest for any reason (the flag was lost partway through the season, or nest statuses don't make sense [goes from eggs to chicks back to eggs], or there are too many unknown codes so you don't know if eggs hatched or not, etc.), discard that entire nest from analysis. If you destroy a nest during the season (e.g., accidentally collapsing), discard that entire nest from analysis.

After determining a fate of each nest, calculate the following parameters:

- Nest sites with eggs (B) – number of nest sites containing any eggs
- Total eggs (C) – number of eggs seen (the sum of the highest egg count from every nest)
- Nest sites with chick (D) – number of nest sites containing any chicks/membranes
- Total chicks (E) – number of chicks seen (the sum of the highest chick/membrane count from every nest)
- Nest sites with chicks fledged (F) – number of nest sites that fledged chicks
- Total chicks fledged (G) – number of chicks fledged (the sum of the highest fledgling count from every nest)

From the above values, calculate the following summary parameters:

- Mean clutch size (C/B)
- Mean brood size (E/D)
- Nesting success (D/B)
- Hatching success (E/C)
- Chick success (G/E)
- Egg success (G/C)
- Fledging success (F/D)
- Reproductive success (F/B)
- Fledglings/egg (F/C)

Literature Cited

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Standardized Productivity Codes: List of Productivity Codes (ANCIENT MURRELETS)

Always use CAPITAL LETTERS for productivity codes

See list of "Important Rules to Follow" for more details on correct use

B	**Bird**	Adult bird occupying a nest site, with no egg or chick present. Used when the observer is sure the bird has no egg or chick (this code means a site is confirmed empty other than the adult bird, there is no need to combine B and N codes into BN). For kittiwakes, used between the time a nest is constructed and the first egg is laid, or after egg(s) or chick(s) is lost.
BU	**Bird w/ Unknown**	Adult bird occupying a site, with no egg or chick **visible**. Used when the observer cannot see the entire nest contents to be sure whether there is an egg, a chick, or nothing.
BE	**Bird w/ Egg**	Adult bird with an egg.
E	**Egg**	Egg present, with no adult. Use numbers and/or "+" to indicate more than one (e.g., E2+ = at least two eggs) Use standardized modifiers to describe special egg status (e.g., Ed = dead egg)
M	**Membrane (oystercatchers, gulls, ancient murrelets only)** Freshly-hatched eggshell/ membrane present	Use numbers and/or "+" to indicate more than one (e.g., M2+ = at least two membranes)
BC	**Bird w/ Chick**	Adult bird with chick.
C	**Chick**	Chick present, with no adult. Use numbers and/or "+" to indicate more than one (e.g., C2+ = at least two chicks) Use standardized modifiers to describe special egg status (e.g., Cd = dead chick)
U	**Unknown**	Nest site with nothing clearly visible. Seldom used - only when the observer is not sure of the nest contents (e.g., cliff nest site obscured by fog or other birds, crevice nest site offering a poor, incomplete view, etc). If an observer records "U" many times, especially at crucial times (hatch and fledge), the nest site may not be included in analysis.
N	**Nest**	Empty nest site. Used when an egg or chick that was in the nest has been lost and no adult is present. For kittiwakes, this code indicates that a nest structure from the current year is physically present, either before eggs are laid or after the nest fails.
NC	**Not Checked**	Used between the previous and current check, when a site was not checked (e.g., it was skipped on purpose) or could not be found on that date. This code does not have to be used at the very beginning or end of the season before checks begin or after checks end for a particular nest.

Standardized Productivity Codes: List of Modifiers

Always use lowercase letters for modifiers!

See list of "Important Rules to Follow" for more details on correct use

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Modifiers to egg status codes

Eo	**Egg lay observed**	Observer sees egg being laid; used only when event was actually observed, not simply suspected lay
Ep	**Egg pipped**	Hole in egg, sometimes chick bill poking through; hatch date determined to be following day. Note: do ***not*** use for eggs just starred (localized cracks in shell resulting from chick's chipping action, often occurs before egg is pipped)
Ed	**Egg dead**	Egg is obviously damaged or broken (this includes eggs that have become partially buried in chamber/tunnel bottom)
Ej	**Egg ejected**	Egg once in a nest ejected outside the nest cup
Ely	**Egg last year**	Egg assumed to be from last year from appearance or other evidence

Modifiers to chick status codes

Co	**Chick hatch**	Observer sees chick hatch; used only when event was actually observed, not for pipping **observed** eggs, observations of newly-hatched wet chicks, or other reasons leading to suspected "probable" hatch. Do not combine Co modifier with Cw (see below) if you observe a hatching event that results in a wet chick; simply use Co to indicate hatch and not Cow/Cwo
Cw	**Chick wet**	Newly-hatched wet chick observed; indicates chick hatched that day but hatching event was not actually observed
Cd	**Chick dead**	Chick actually observed dead (not simply disappeared from nest)
Cf	**Chick fledged**	Chick actually observed in the act of flying (or jumping for murres) from the nest; very rare!

Additional clues to nest fate

sh	**eggshells**	Presence of fresh eggshell fragments in the nest. Used ONLY with Bird Unknown or Unknown status codes (BUsh or Ush) to give more information about potential hatch; there is no need to use with known status codes (such as C or N)
poop	**poop**	Presence of fresh poop in or at the entrance of the nest. Used ONLY with Unknown status code (Upoop) to give more information about potential presence of a chick; there is no need to use with known-status codes (such as C or N)
call	**chick calling**	Chick heard calling but not actually observed. Used ONLY with Bird Unknown or Unknown status codes (BUcall or Ucall) to give more information about potential presence of a chick; not appropriate to use with known-status codes (such as C or N)

Standardized Productivity Codes: Important Rules to Follow

Use capital letters for basic productivity codes and lowercase letters for modifiers. Do not use superscripts or subscripts for any modifiers. Do not put spaces between any characters.

Use numbers to indicate quantities of birds, eggs, or chicks greater than one (do NOT use 1 to indicate single numbers). Numbers should always go AFTER the code that the number describes.

e.g., B2E means two adult birds with a single egg
BE2 means a single adult bird with two eggs

Use a plus sign (+) when you can see at least some but not all nest contents in multiple-egg clutches. As with numbers, the plus sign should always go AFTER the letter code (and when more than one, also after the number) that is being described.

e.g., BE+ means an adult bird and at least one egg were observed but entire nest contents could not be seen to determine if there was anything more
BE2+ means an adult bird and at least two eggs were observed but entire nest contents could not be seen to determine if there was anything more

Some codes and modifiers can be combined when appropriate as long as order (see below) is maintained. For instance, with multiple-egg species, if one egg hatches before another so that there is an adult bird present with both an egg and a check, enter BEC.

The specific order in which these codes and modifiers are used is VERY IMPORTANT. The codes BEC and BCE, or BE2+ and BE+2, may mean the same thing to us but they are NOT the same to the computer database. Follow these rules for the correct order of codes and modifiers:

(1) Always write codes in the order of **adult - egg - membrane - chick**.
e.g., BE and not EB, EMC and not ECM, M2C and not CM2

(2) When adding modifiers (numbers, letters, or symbols that give more information), always follow the order of: main productivity code - letter modifier - number - plus sign
e.g., BEp2+ for adult bird with at least two pipped eggs
BE2Cd for adult bird with two eggs and one dead chick
B2E+Cd for two adult birds with at least one egg and one dead chick

NOTE These standardized codes and modifiers should be used for ALL species, even those that we are still summarizing by hand this year (e.g., storm-petrels, cormorants, oystercatchers, gulls, ancient murrelets). The ultimate goal in future years is to use the database to summarize productivity data for all species and the more consistent we can make the data now, the easier it will be to make that transition.

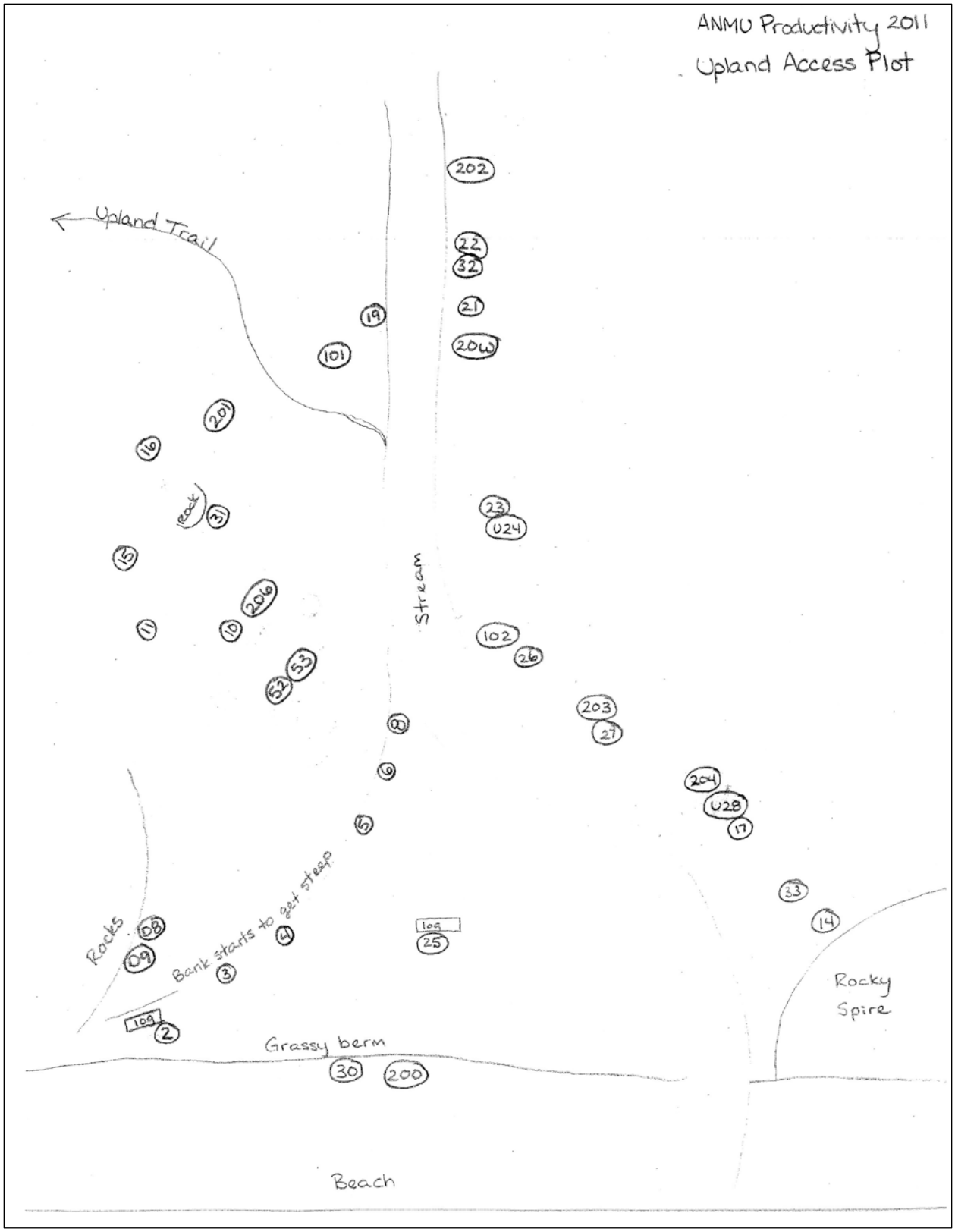

Figure 1. Example plot map showing ancient murrelet burrow locations.

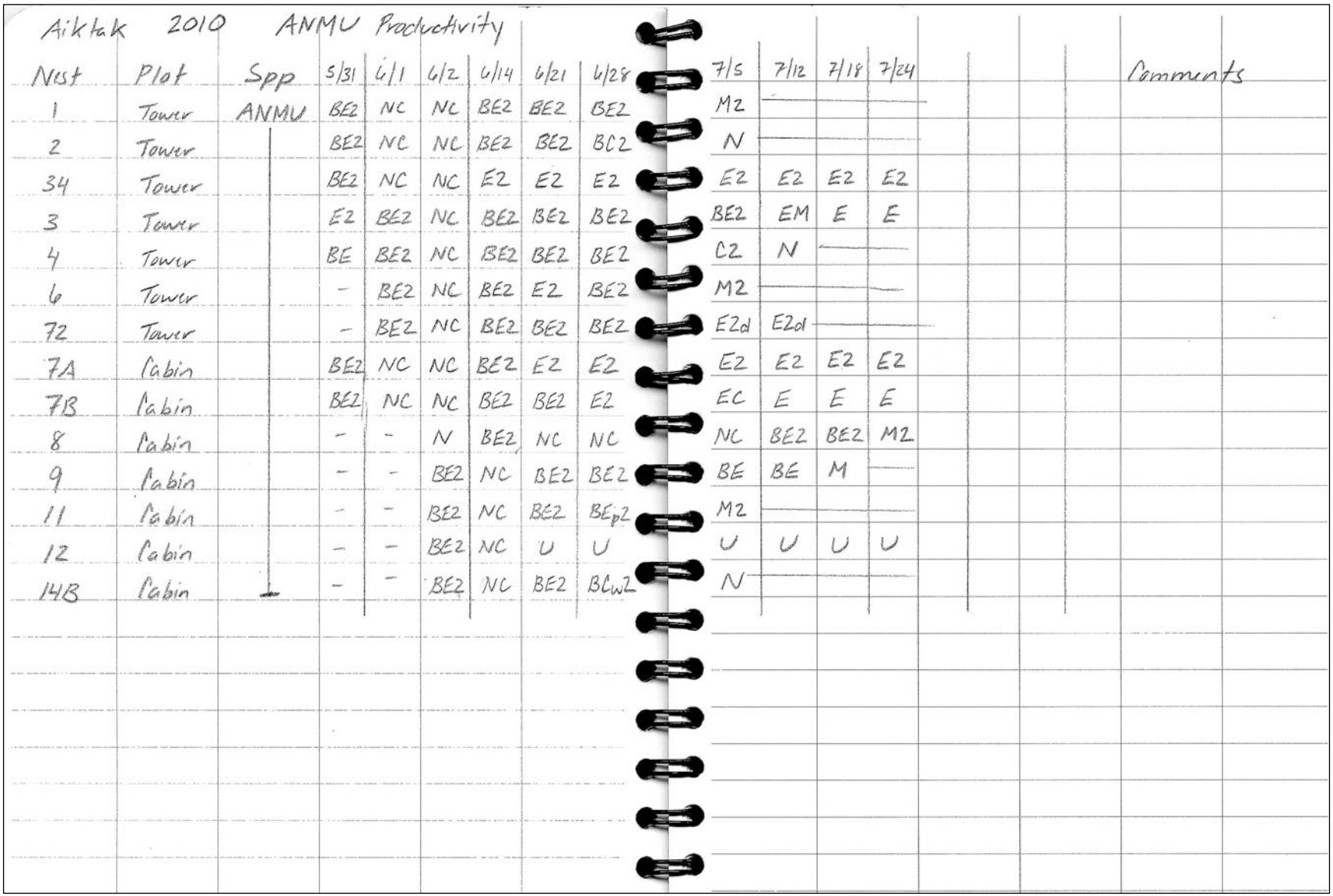

Figure 2. Example of data notebook page for recording ancient murrelet productivity data.

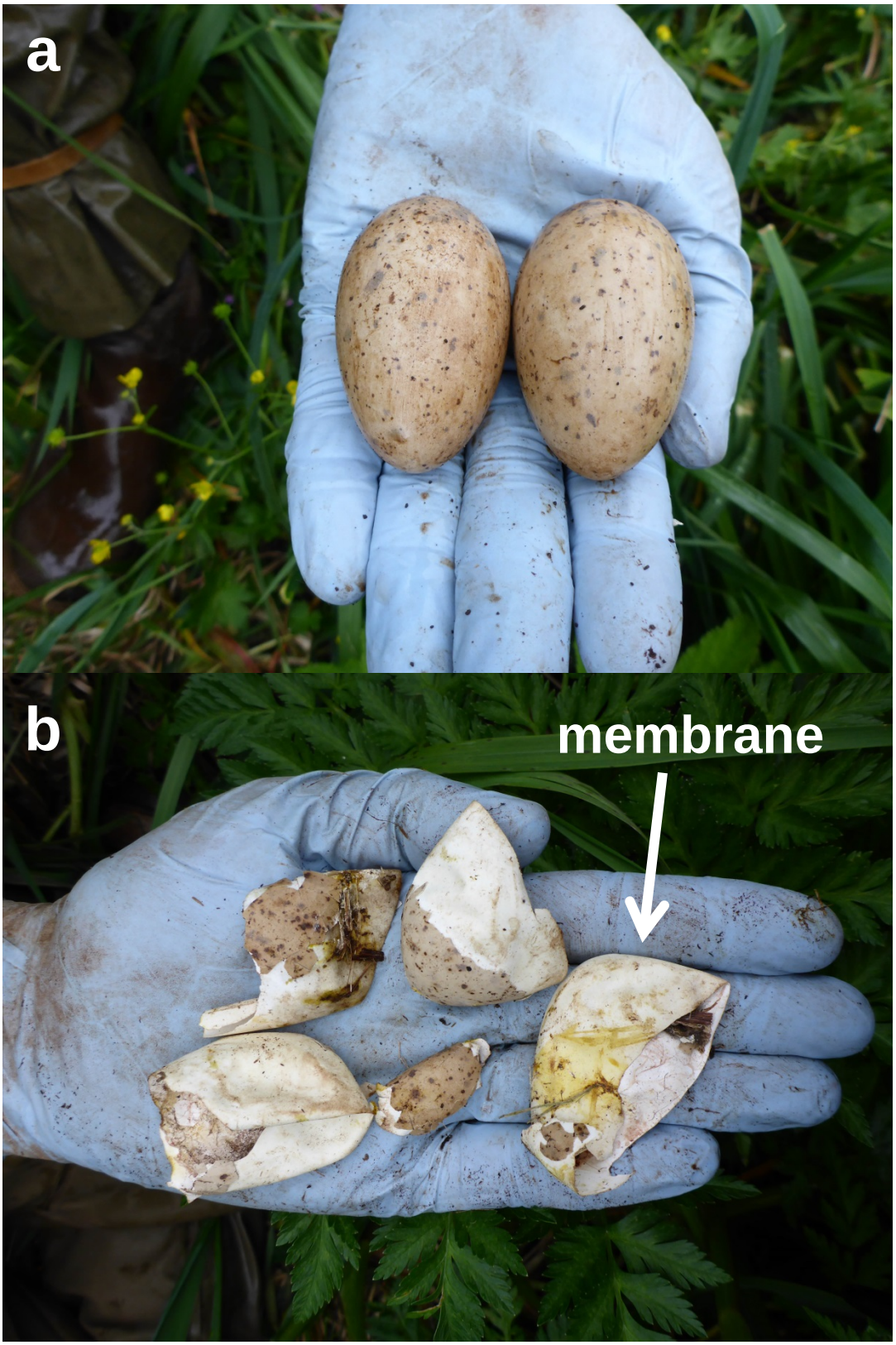

Figure 3. Photos showing (a) ancient murrelet eggs and (b) ancient murrelet eggshell membranes.

Figure 4. Ancient murrelet grubbing attire of “grubbing gauntlets” (tight sleeves) and “grubbing vest” (sleeveless rain jacket).

Attachment A. Aiktak Island specifics (includes Figure A1)

PROCEDURE DETAILS SPECIFIC TO AIKTAK

At Aiktak, ancient murrelets nest in burrows in the bluffs along the northern coast. Egg laying generally occurs in late May to mid-June, hatching from late June through July. At night throughout July, large numbers of young can be heard and observed departing from their burrows.

Nests monitored for productivity are located in four general areas: Tower Cove, Upland Access, New Camp Beach, and Cabin Area (Figure A1). These plots are based on the highest concentrations of burrows found in past years; you can search for new burrows in these plots as well as new areas if you wish (a potential place for a new plot would be the south end of Pleasure Cove south of horned puffin crevices; a good number of nests were found there in 2012).

Begin searching for nests to monitor in late May or early June. Aim for 70-100 nests. Not all nests used in past years will be occupied the following year, so you will likely have to search for new nests as well. Before looking for new burrows, it may be helpful to locate and check nests from previous years in order to develop a search image for ancient murrelet burrows – there are hundreds of thousands of holes in the ground on Aiktak and several burrow-nesting species, so you will save yourself a lot of time if you know what to look for. Birds will continue to lay into the first part of June, so you should continue to check old nests and search for new nests about every 7 days until mid- to late June (or until you have a large enough sample size). It will be helpful to map the locations of your nest sites, as the vegetation will grow tremendously over the season and can completely obscure any flag markers by July.

In mid-August, when hatching is definitely complete and any remaining eggs are clearly not going to hatch, discard all nest contents so that old eggs or eggshell membranes won't confuse crews next year. Then make sure all nests are flagged well and mapped, to facilitate next year's crew finding them.

It is important to have the same person grub the same plot all season, as you learn which way to insert your arm into each burrow and thus cause less disturbance thrashing around trying to feel for the chamber. Depending on personal preferences, you can do each plot with two people (one to record data and the other to grub) or just one (one person grubs and records data).

With several burrow-nesting species nesting on Aiktak, it is important to distinguish ancient murrelet nests from others. It is fairly easy to distinguish between an ancient murrelet nest and a storm-petrel nest by feel: the former contains a large bird with large eggs, the latter a small bird with a small egg. A few ancient murrelets will have just one egg, however, which can cause some confusion with tufted puffins. If there is no bird present, carefully remove the egg and look at it: puffin eggs are white, ancient murrelet eggs are brownish green with speckles. If there is a large bird present and just one egg underneath, listen for any vocalizations that will give a clue as to the species (puffins tend to growl). Otherwise, wait for a future check: at the very least, you will be able to identify the species when the chicks hatch. Never remove an ancient murrelet adult to confirm the species, they are just too sensitive to disturbance and will probably abandon the nest thereafter. (In practice, most puffins will bite you – hard – when you try to grub them, whereas ancient murrelets are more docile, but this isn't a concrete identifier).

Specific Requirements for Aiktak

Dates: *Late May/early June*: Begin searching for burrows.
June – July: Monitor nests every 7 days from earliest potential hatch until chicks fledge.
August: Remove old eggs and membranes, remark nests, update maps for next season.
Optimal sample size: 70 (minimum) to 100 (ideal)
Time of day: Anytime.
Weather: Any weather.
Equipment needed: Grubbing gauntlets and vests, Rite-in-the-Rain® notebook, plot maps, flags (for initial nest searching), two permanent markers (for initial nest searching), two pencils.

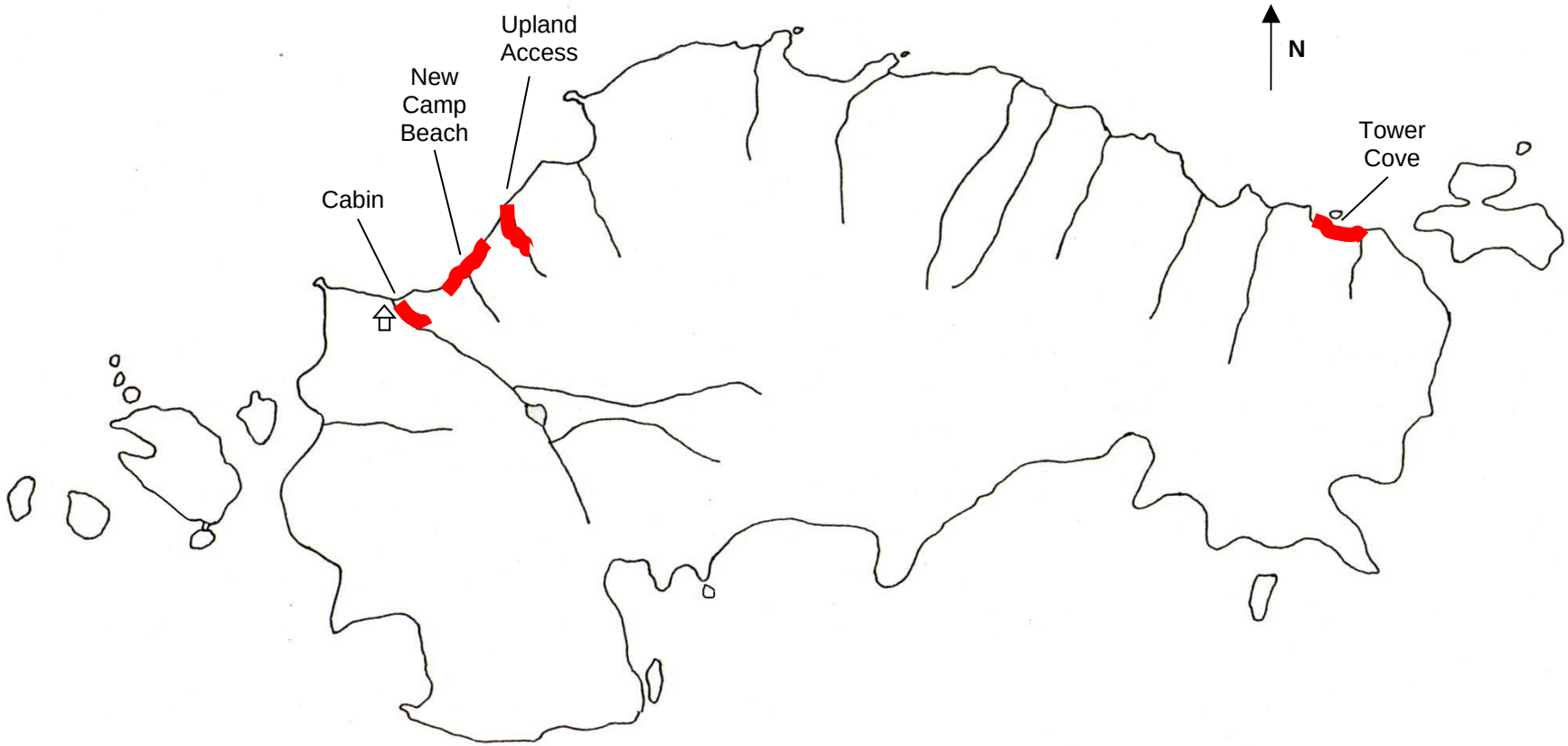

Figure A1. Location of ancient murrelet plots at Aiktak Island.

Protocol Revision History Log

Revision Date	Changes made	New version #
April 2017	Specified that a leap year Julian date calendar should be used in leap years, clarified that for phenology calculations we require confirmed visualization of the empty nest site, egg, or chick less than ***or equal to*** 7 days apart for that site to be used, changed photos in Figure 3 to examples of ancient murrelets, made minor clarifications	1.4
Oct 2015-Jan 2016	Fixed typos, clarified Ed modifier to include eggs that get squashed into dirt, specified in analysis that nests without adults should be excluded as potentially inactive, clarified Aiktak details, clarified Ep modifier, fixed page number references in text	1.3
April 2015	Clarified order of membrane in standardized codes	1.2
April 2014	Changed font to Arial, added revision history log, replaced revision date with version # on first page, added protocol # to first page, changed number format of figure in island attachment, changed page number format to include protocol #, made minor grammatical edits	1.1
May 2013	Protocol developed in standardized format from historic protocols, includes Aiktak attachment	1.0