Mass Audubon Progress Report to the Blake-Nuttall Fund

August 2016

Title: TERN VULNERABILITY AT STAGING GROUNDS: UNDERSTANDING PREY AVAILABILITY

Project Abstract: The Northwest Atlantic population of the Roseate Tern was listed as Endangered in 1987 under state and federal endangered species acts, and despite intensive efforts to protect birds at nesting colonies, has failed to meet recovery goals. Demographic analyses show that low recruitment of breeding birds is contributing to the population's failure to thrive. Therefore, terns are experiencing difficulty during the period between fledging and reaching sexual maturity at 3 years. The most vulnerable time in this period is during the time fledglings are preparing for their first migration to South America—the time they are staging with a care giving adult at locations in the region with abundant, suitable prey (typically sand lance). Very little is known about foraging of staging terns. In addition, there is no understanding of how a major shift in the marine community at critical staging sites on Cape Cod and Nantucket with the exponential growth of another sand lance specialist—Gray Seal—may be impacting tern foraging. We propose to investigate 1) the foraging ecology of staging Roseate Terns by documenting foraging locations, identifying prey species delivered to terns in roosting flocks, and quantifying prey size and delivery rate to staging terns; and 2) the impact of seals on staging terns through a meta-analysis of existing information including diet overlap, and spatial displacement. Our request to the Blake-Nuttall Fund is for support of personnel costs related to data collection and analysis.

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Start and Completion Dates: 1 November 2015 to 30 October 2016

Narrative: TERN VULNERABILITY AT STAGING GROUNDS: UNDERSTANDING PREY AVAILABILITY

Objectives: According to long-term nesting-site studies which demonstrate low recruitment, the Roseate Tern (*Sterna dougallii*) population has shown a pattern of losing individuals during the period after fledging and before reaching sexual maturity at 3 years. The most vulnerable time in this period is when fledglings are preparing for their first migration to South America—the time they are staging with a care giving adult at locations in the region with abundant sand lance (*Ammodytes sp.*; 80+% of diet of these fish specialists). Adult terns accompany fledglings to staging grounds and provide fish to them at roosting beaches. In time, the fledgling learns to fish for itself but remains with the adult throughout the staging period.

The nesting ecology of Roseate Terns has been well-studied including diet studies of birds at colony-sites. In contrast, very little is known about foraging of staging terns. Prey availability is likely to be the most important factor influencing successful staging of juvenile terns (evidence does not point to disturbance at staging sites), yet nothing is known about foraging locations, prey delivery rates, prey size or species while young birds are on staging beaches being fed by parents. In addition, there is no understanding of how a major shift in the marine community at critical staging sites on Cape Cod and Nantucket with the exponential growth of another sand lance specialist—Gray Seal (*Halichoerus grypus*)—may be impacting tern foraging.

We propose to meet these identified information needs through

1) a field study of the foraging ecology of staging Roseate Terns (*tern foraging at staging grounds study*) by
    a. documenting foraging locations through surveys and flight line analyses
    b. identifying prey species delivered to terns in roosting flocks
    c. quantifying prey size and delivery rate to staging terns
2) a meta-analysis of existing information, estimate the impact of seals on staging terns (*tern-prey-marine mammal food web analysis*) through
    a. analysis of diet overlap
    b. quantifying possible temporal/spatial displacement of terns by seals

Progress toward objectives:

Tern foraging at staging grounds study. We initiated preliminary data collection on staging tern foraging ecology during Aug-Sep 2015 and began 2016 field work in July. We updated data collection protocols and developed a training curriculum for involving CWP trainees in field work this year. Data collection protocols (Appendix A) and example training materials (Appendix B) are attached.

Preliminary analysis of data collected in 2015 show the following: We observed mixed species tern flocks to document prey transfer and flight directions during 12 days in the field from 9 Aug to 8 Sep 2015. A total of 19 observation sessions were comprised of 12 prey transfer observation sessions and 7 flightline sessions. Observations took place in Provincetown (Hatches Harbor, Race Point), Chatham (North Beach), Eastham (Nauset Marsh), and Wellfleet (Jeremy Point). The overall number of prey transfer observations in 2015 was 45. Size of sand lances brought to flocks ranged from 28-70 mm. The average size of sand lance brought to flocks was 43.5mm. During preliminary observations of tern flightlines in 2015, we observed that birds typically followed "routes" into and out of the flock (ie flight direction was non-random), although once in vicinity of flock, birds often circled repeatedly before landing.

Tern-prey-marine mammal food web analysis. We have begun to compile existing information (publications, online data, reports) to characterize the sand lance/tern/marine mammal food web as currently understood. Datasets in hand include the abundance, distribution and fledging rate of NW Atlantic Roseate Tern population over the period 1990-2015. In addition, we have completed an analysis of tern foraging studies (see attached annotated bibliography Appendix C). Finally, we presented a preliminary analysis of seal and tern population dynamics at the 2015 annual meeting of the Waterbird Society (poster attached Appendix D).

Roseate Tern Prey Protocols 8/3/16

Research Overview

Goal: To characterize foraging by ROST and COTE on staging grounds by quantifying prey delivery in flocks, determining primary foraging locations through flightline analysis, opportunistically observing foraging behavior, and evaluating possible competitive pressure from seals.

Six categories of data will be collected for this study as follows:

- **Observation Session Site-specific Conditions Data**
  - Data specifically related to the environmental conditions at the site and time when an observation (OBS) session is being conducted

- **Flock Count Data**
  - Estimates and/or counts of numbers of all terns; splits or ratio estimates of ROSTs and Common Terns (COTE); splits or ratio estimates of ROST and COTE adults/Hatch Years (HYs)

- **30-minute Prey Delivery/Exchange with resighting efforts for focal birds**
  - Information on prey delivery/exchange and other behaviors involving prey (courtship etc)
    - Prey delivery interactions usually involve two birds: The provider and the recipient. The goal is to obtain information on both individuals, as well as the fate of the prey item.
  - While observing flock for prey exchange behaviors, will have opportunity to scan flocks for banded birds (PFRs strong priority, also leg injuries)
  - Information on band placement, color(s), and codes; for ROSTs in priority order:
    - Plastic field-readable [PFR] bands (band color and 3-character codes),
    - Complete 6-band combinations of 2 metal bands and 4 butt-end colorbands,
    - Metal field-readable [MFR] bands and "incomplete" colorband combinations,
    - Brazilian bands [BB] and other devices (e.g., flags, geolocators, radio tags, etc.),
    - Great Gull Chick bands (GGCB: band color and 2-/5-character codes; used 2013),
    - USGS Bird Banding Laboratory [BBL] bands (aka; Survey/Service bands [SB])
    - Data related to the physical condition of colorbanded birds and whether or not the colorbands or other devices they are carrying might be causing injuries also will be collected.

- **30-minute Primary Flight-line Direction Data**
  - Information on direction of flight of focal birds in and out of staging flocks
  - Captures information on number of individuals entering or leaving a flock, and the general direction in which they are traveling to/from.

- **Seal Counts** (probably Gray Seals but Harbor Seals possible)
  - Record number of seals and time observed throughout session on an opportunistic basis
  - Record abundance, size, location, and activity of all seals present

- **Foraging Activity**
  - ROST generally forage in open water a mile offshore, but occasionally they can be seen foraging closer to shore or in an inlet. When this occurs, the observations should be recorded.

1. Observation Session Site-specific Conditions Data

Each full site observation session (OBS) is usually between four and six hours in length with some data collected in 30-minute segments. If no terns are present, or those present all leave as a result of a major natural (e.g., Peregrine or other bird of prey) or human-related (e.g., out-of-control dog, kids playing or kite-flying, etc.) disturbance, the observation session can be terminated. The observer can try to move to another location and attempt another session if time allows. Even if ROSTs or other terns are not present, please record the information below if an OBS session was attempted.

1. Record the following site specific data for each OBS session:

a. **Date**

b. **Arrival Time:** Time when resighting location is reached and first site specifics are recorded (remember you will also record the time when you begin the prey or flight line segments). (use military format, HHMM. eg. 6:30 am = 0630 hrs; 4:30 pm = 1630 hrs)

c. **Departure Time**: Conclusion of session

d. **Site name, town and location of resting flock(s):** (if at new site for project, record GPS pts)

e. **Observer name & initials:** Please record ALL observers (including yourself) present.

f. **Tidal stage:** low, low-rising, mid-rising, almost high, high, past high, mid-falling. If possible, use information from local tide charts to determine when high and/or low tide occurred and the number of hours you are past a high or low tide

g. **Weather conditions:**
   a. Temperature (degrees in Celsius)
   b. % cloud cover (clear sky, 10-24%, 25-50%, 51-75%, more than 75%, overcast)
   c. Precipitation (none, fog/mist, light rain [***do not*** use your scope in even light rain!])
   d. Wind speed using anemometer (kph)
   e. Wind direction (using compass or anemometer)
   f. Visibility
   g. Habitat

h. Session Cancelled Information

2. Weather and tidal stage data can be recorded again at the end of session if there is a significant change in conditions and/or the OBS session has been extended past 6 hours.

2. Flock Size Data

1. Flock assessment of **total number of terns** (all species) at time of your arrival (use military format, HHMM. eg. 6:30 am = 0630 hrs; 4:30 pm = 1630 hrs). This concise flock count should be taken as soon as possible to cover the possibility that the flock may depart before a "full flock count" (species and age split) is undertaken.

2. Approach flock slowly, and if necessary, at a crouch to avoid flushing the flock. To obtain accurate counts observers must be within 50 m of a flock.

3. **If terns are not present upon your arrival** then you can leave the staging site. If time allows, try to relocate to a different site and attempt a new OBS session.

4. For **flocks of up to 200 terns**:
   - Count total number of ROSTs and the total number of other terns (usually COTEs).
   - For both species only: break down the total count by number of adults and number of HYs.
   - The suggested method for doing the above is as follows:
     - Hold a click counter in each hand; designate one for adults and the other for HYs.
     - Starting at the "front" of the flock as the terns face into the wind (where possible), count (silently to yourself if another observer also is trying to make a count) each tern you can identify, and each time you observe an adult or HY ROST click the appropriate counter.

5. For **flock of more than 200 terns**:
   - If more than 200 terns, estimate flock size as accurately as you can (e.g. 500-600 terns); sometimes it helps to count 100 or 200 terns in a large flock and try to figure out what percentage of the total flock you've counted.
   - Count several (at least 3) randomly distributed subsets of 50 terns at a time. Try to avoid always starting at ends of a flock (even though the flock may be less dense there and the terns easier to count), as species or age splits may not be representative of entire flock.

6. Also note if there are other tern species in the flock: Arctic, Black, Forster's, Least, Royal, Sandwich, etc.

Notes:
- If there are significant changes to the flock due to arriving and/or departing birds, then an additional flock count should be taken. This may occur multiple times during the site session however, not during a 30-minute timed segment (prey delivery and flight line segments).

3. 30-minute Prey Delivery/Exchange

- Record start time of session (each session is completed in 30 minute increments) (use military format, HHMM. eg. 6:30 am = 0630 hrs; 4:30 pm = 1630 hrs)
- While observing the flock, choose a target individual with a prey item. This is usually done on an opportunistic basis (ie: pick the first tern observed carrying a fish).
    - Most likely, the fate of the fish will involve two individuals (the provider and the recipient). Data should be collected for both individuals. It is worth noting that each interaction will have a provider, but may not have a recipient if the first individual eats the fish.
- For each target individual record the following:
    - Time first observed
    - Provider or Recipient (P or R)
    - Species (ROST or COTE)
    - Banding Information (Unbanded [UB], MFR, PFR, SB)
    - Age (Adult or HY)
    - Fish Species
    - Fish Length (in relation to tern's bill)
    - Delivery Result (fate of fish); use delivery codes provided below
    - Begging (yes or no)
    - Additional Comments (behavioral observations, etc)
- If possible, collect resighting data for both individuals (provider & receiver)
- If there are no birds with prey in sight, then collect resight data
- Record end of session time (use military format, HHMM. eg. 6:30 am = 0630 hrs; 4:30 pm = 1630 hrs)

Delivery Codes

E- Provider eats prey
D- Provider drops prey, prey left uneaten
K- Klepto-parasitic adult steals prey from Provider
O- Provider chased off by another adult, fate of prey is unknown
U- Provider flies out of view (not chased by another bird), fate of prey is unknown
A- Provider delivers prey to recipient, recipient eats prey
AU- Provider delivers prey to recipient, fate of prey is unknown (sight-line blocked)
AD- Provider delivers prey to recipient, Recipient drops prey, prey left uneaten
ADE- Provider delivers prey to recipient, Recipient drops prey, Provider eats prey
AK- Provider Delivers prey to recipient, Klepto-parasitic adult steals prey from recipient

4. 30-minute Primary Flight-line Direction Data

- Information on direction of flight of focal birds in and out of staging flocks
- The main focus of this section is ROST (COTEs can be included in data collection if time allows).
- Observers should position themselves between the flock and the general direction of travel of birds entering or leaving the flock.
    - Observers should record the bird's direction as birds leave or arrive the flock
- Record start time of session (each session is completed in 30 minute increments) (use military format, HHMM. eg. 6:30 am = 0630 hrs; 4:30 pm = 1630 hrs)
- Once a new departure or arrival has been observed, record the following information:
    - Time first observed
    - Species (ROST/COTE)
    - Age (Adult or HY)
    - Are they Entering (E) or Leaving (L) the flock
    - Direction of travel (North, North-east, East, South-east, South, etc)
    - Origin/Destination, if known (body of water or land mass)
    - Approximate cruising altitude
    - Number of individuals (if flying with 1 or more terns)
    - Flock Movement: record if the departure/arrival caused the rest of the flock to shuffle/flush
    - Additional Comments
- If there are many birds flying in and out, then data on only incoming flights can be recorded
- Record end of session time

7. **Seal Counts** (most likely Gray Seals bur Harbor Seals possible)

- Record species and number of seals and time observed throughout session on an opportunistic basis
- Record time, abundance, size, location, and activity of all seals present

    - Location:
        - Sandbar, spit, shoreline, in water
        - Estimated distance from viewing area (to determine GPS location)

    - Total abundance
        - Adult vs Juvenile
        - Male vs Female

- **Foraging Activity**
  - ROST generally forage in open water a mile offshore, but occasionally they can be seen foraging closer to shore or in an inlet. When this occurs, the observations should be recorded. The following information should be captured in foraging observations:
    - Time observed (start/stop)
    - Size and composition of foraging flock
    - Approximate location of foraging flock
  - For focal bird
    - Foraging method:
      - High plunge dive (HPD): two or more meters above surface of water and involves complete or partial submersion
      - Low plunge dive (LPD): less than two meters above surface of water and involves complete or partial submersion
      - Contact Dipping (CD): dipping head or bill into water during low flight without body submersion
      - Submersion dipping (SD): successive full or body submersions during a horizontal flight, often in a series of oncoming waves
    - Number of attempts
    - Number of successful attempts
    - Prey ID when possible

- **ROST Individual Identification Resighting Data**

Resighting Time (use military format, HHMM. eg. 6:30 am = 0630 hrs; 4:30 pm = 1630 hrs): Record the time you start resighting whenever you make a shift in your position (such as move to a new area or turn to look at a different flock) and/or at about 15-minute intervals if you are stay in one place for a long period of time.

Recording the placement of the different types of bands used on ROSTs

1. **Band Position Placement**
2. **Band Identification/Description**

The placement of bands is always read in the same order: See Figure 1 below for recording band placement: Record left leg top to bottom first, then right leg top to bottom.

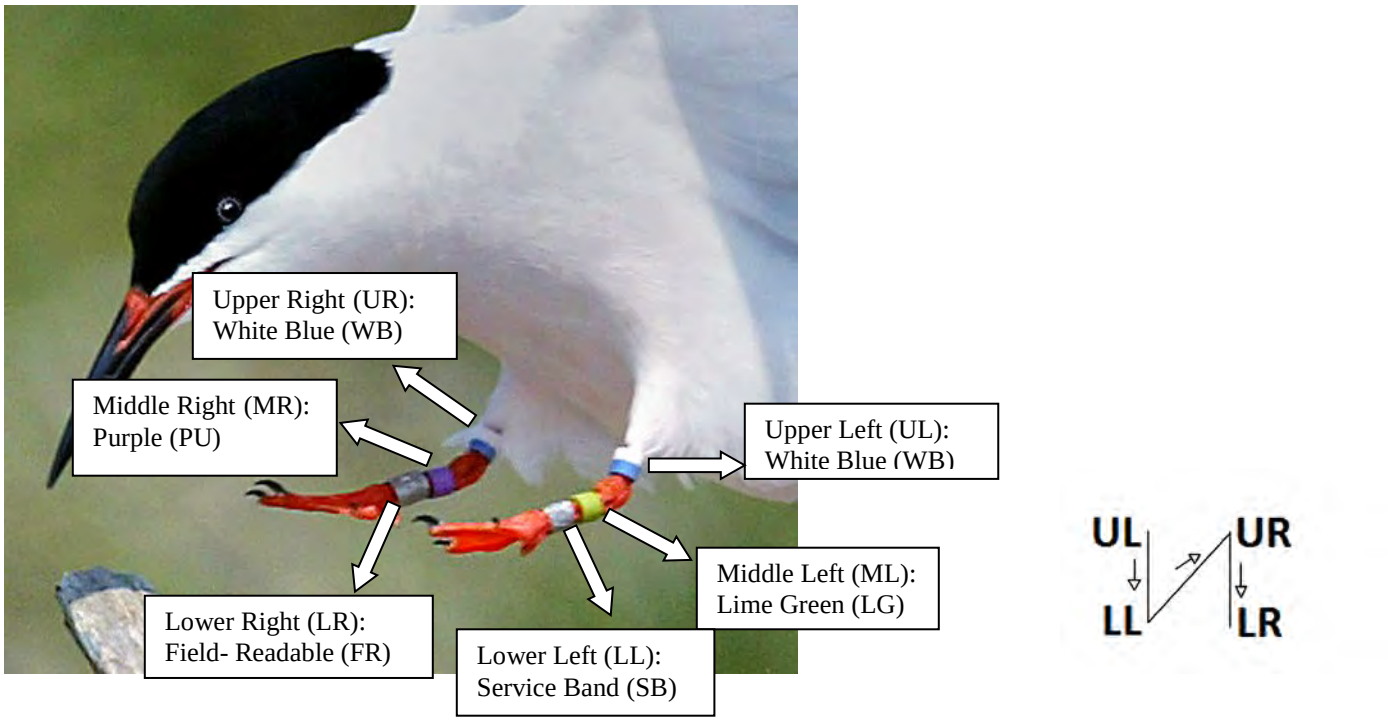


Figure 1. Band placement in a 6-band combination.

1. Band Position Placement

- Band positions as shown in the photo above are named as follows:
  - Upper left (UL: above the tarsus-metatarsal joint unless otherwise noted)
  - Middle left (ML)
  - Lower Left (LL)
  - Upper right (UR: above the tarsus-metatatsal joint unless otherwise noted)
  - Middle right (MR)

- Lower right (LR)

8. ROST Individual Identification Resighting Data

2. **Bands and flags are identified/described by the following characteristics:**
   - o Type [metal (3 varieties: BBL, MFR, Brazilian) or plastic (several varieties, including flags)]
   - o Color(s)
   - o Code [MFR, PFR, and Great Gull Chick Bands (GGCB) have different alpha-numeric codes – see Figures 2 and 3.]

Figure 2. USGS-BBL (SB), PFR, and MFR bands. Note: FRs usually are 40% taller than SBs.

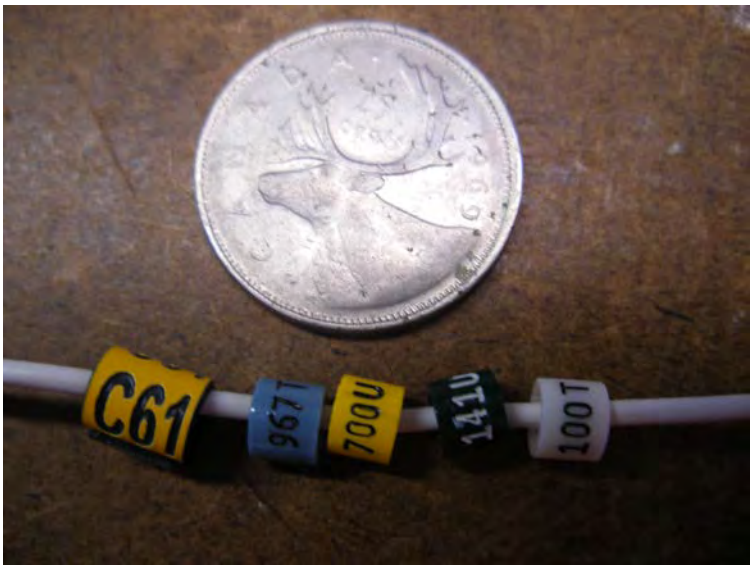


Figure 3. 3-character Yellow PFR band (C61) and variable-character length Great Gull Chick Bands (GGCB) used in 2013. Colors shown include light blue, yellow, dark green, and white; not shown: dark blue and red.

2. Band types (cont.)

TYPE: Plastic field-readable (PFR) bands

3-character "slightly overlapping" plastic colorbands (See Figures 2 & 3).
Record the following:

- Color of band
- Color of font
- 3-character alpha-numeric-numeric code (engraved 3 times from top to bottom)
- Example: "**Yellow band (black font) H28**

- **Recorded would be:**
  - Left Leg: No Band /No Band /Yellow with black font H28
  - Right Leg: No Band / No Band / Service Band

TYPE: Plastic butt-end colorbands and "flags" (for 6-band combinations, see Fig. 1)

- Describe the colors you see
  i. Some have faded, so be specific
- Flags (used mostly on shorebirds, some on terns) have a projecting tab.
- If there is a bicolored band read the top color first, then the second color (example: White over Blue)
- If a 6-band combination is incomplete and/or a colorband is faded or broken, you usually need to read all/some of the 4-character MFR code

Bicolored plastic butt-end bands (celluloid only)
BW=Blue/White GW=Green/White WB=White/Blue WG=White/Green

2. Band types (cont.)

TYPE: Metal bands (MB): BBL, Brazilian, MFR (see Figures 1 & 2)

USGS Bird Banding Laboratory (BBL) Band or Survey/Service Band [SB]

- 3- or 4-digit prefix followed by a hyphen and then a 5-digit number (e.g., 1172-02673).
- Reading the entire SB number is difficult (understatement!) but if you do read some digits (usually done on a large-font stainless steel band used at Great Gull) try to determine where the digits are located relative to the hyphen and the butt ends of the band. Example: 9802-xx536

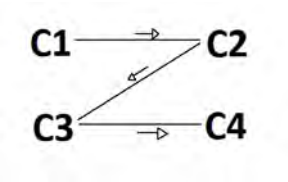
Brazilian Band [BB] (not shown; example on display at training)

- Usually begin with "H" (rarely "J") followed by a 5-digit number (e.g., H46768). "Avise CEMAVE" is written "sideways" on the band. This information originally was etched in black, but the black fades with time and often no longer is visible.

Metal Field-readable (MFR) Bands

- 4 characters (1 letter and 3 numbers) in a 2-row, 2-column format which is usually stamped twice on the band (3 times in old MFRs where C1 = E, H, or J).
- Read MFR character position in a "Z" pattern as follows: C1, C2, C3, and C4.

C1	C2
C3	C4



Metal Field-readable Example

Z	7
1	1

Recorded as: Z 7 1 1

Metal Field-readable Example

8	3
H	7

Recorded as: 8 3 H 7

Incomplete Recording Example:

8	?
H	?

Recorded as: 8 _ H _

Notes

- Only one letter, but it can appear in any of the four positions.
- At times you will see C2 & C4 from one set of impressions, a blank area, and then C1 & C3 from the second set. Make sure you know if you've seen C1 & C3 vs, C2 & C4! Look for the butt end of the band to help you make this determination.
- Record incomplete MFR bands in usual sequence, but say "unknown" for characters you cannot positively identify.

8. ROST Individual Identification Resighting Data (cont.)

Notes:

- **Only record what you see**!! If you cannot positively identify a character, DON'T guess.
- If you only see one upper band and not the other, record latter position as "unknown"
- Repeat the band reading twice into the recorder to confirm what you have observed.
- If you see the same bird again after more than 5 minutes, record each observation.
- Metal bands (SB, BB, MFR) are almost always placed lowest (i.e., LL or LR) on each leg.
- Record "no band" as (NB).
- Record band positions not seen as "UK" for unknown.

For 6-band combinations, it is essential to try to distinguish between MFR & SBs: If this is not possible, then just record it as MB (metal band). The reason it is important to correctly distinguish between FR and SB bands is because the placements of the 4 plastic colorbands are duplicated and the only difference in the 6-band combinations is the placement of the FR and SB bands on right (RF) vs. left feet (LF).

Additional information about colorbanded ROSTs should be recorded whenever observed:

- For begging HYs with PFR bands, record, if possible, the identity of the adult(s) to which it is begging.
- For adults with PFR bands or a 6-band combination that are being begged at, record, if possible, the identity of the HY that is doing the begging.
- Note the condition of the band and of the bird if a ROST with a 6-band combination has a band that has slipped down below the joint (this will appear as 3 bands below the "ankle"). Is the bird being hampered in any way? Is there any swelling at the joint and/or has the bird lost any toes? Does it limp or hold its foot in the air when resting?
- If a band has risen above the joint (this will appear as 2 bands above the "ankle").
- If the bird appears to have an injured leg, foot or toes (deformed, truncated, not putting any weight on it, etc.).

Roseate Tern Foraging Study

Prey Identification

ROST (Adult)

8/3/2016

Outline

- Roseate tern and Common tern Prey
- Field Marks to Look For
- Fish Anatomy
- Roseate Tern Prey Species

Roseate and Common Tern Prey

- Many of the same fish
  - This study will be focusing on some of the more common prey species

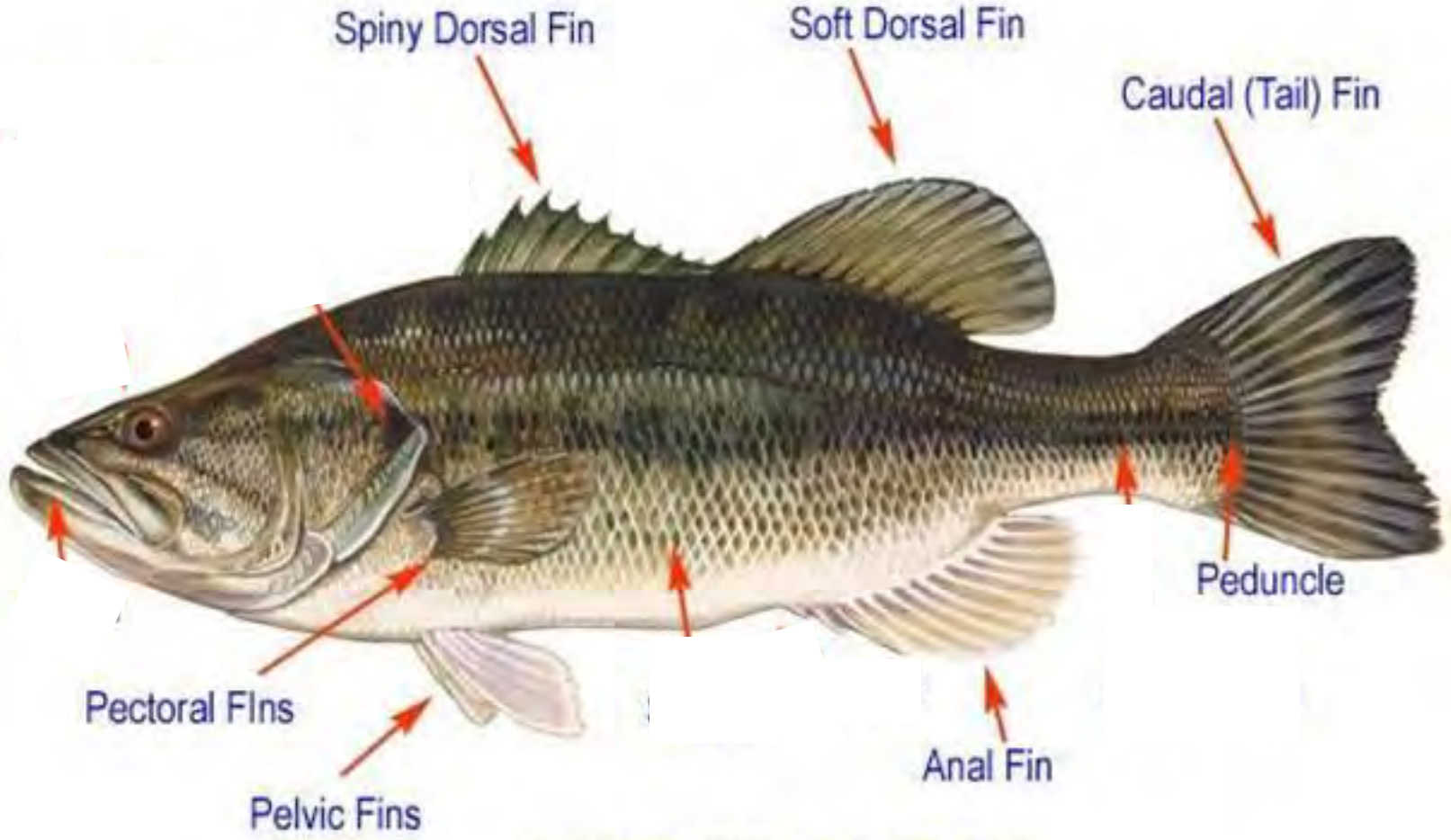
- Identification of these fish is three-fold
  - **Look**: basic fish ID
  - **Length**: in comparison to bill
  - **Rigidity**: how the fish is held in the bill

Field Marks to Look For

- Shape of Body
- Shape of Tail (forked, rounded, etc)
- Coloration
- Positioning in tern’s bill (rigidity)

Basic Fish Anatomy

- Pectoral fins
- Pelvic fins
- Dorsal fin
- Caudal peduncle
- Anal fin
- Caudal fin



Common Fish Prey of Roseate Terns

There are over a dozen ROST prey species. The goal of this project is to determine Sand Lance versus non Sand Lance and if possible, the identification of non Sand Lance species.

- Sand Lance
- Atlantic Silverside
- Atlantic Herring
- Hake
- Mummichog
- Bluefish
- Butterfish

Sand Lance (*Ammodytes americanus*)

- Slender fish with long head & sharply pointed nose
- 1 long dorsal fin
- Forked caudal fin, appears straight when wet
- 1 anal fin
- Olive, brownish or bluish green above, silvery lower sides and duller white belly
- Length - 4-6“
- 2 times length of tern bill
- “Droopy mustache” rigidity

Drawing by H.L. Todd

Sand Lance (*Ammodytes americanus*)

Common tern with Sand lance

ROST (adult)

ROST (adult)

Atlantic Silverside (*Menidia menidia*)

- Long, slender, thin-bodied fish
- 2 dorsal fins, lay flat when out of water
- Moderately forked caudal fin
- 1 anal fin
- Sea green above, white (light) belly
- Distinct silver band outlined by narrow black stripe from pectoral fin to caudal fin
- Length - 5.9”
- 2 times length of tern bill
- Hangs at a 90 degree angle

Atlantic Silverside (*Menidia menidia*)

COTE (adult, HY)


ROST (adults)

Atlantic Herring (*Clupea harengus*)

- Fusiform body with no lateral line
- 1 dorsal fin, lays flat when out of water
- Distinctly forked caudal fin
- 1 anal fin, almost square
- Greenish blue to steel blue on back, lower sides and belly silvery
- Length- 11-18”
- 3 times length of tern bill
- Hangs at a 90 degree angle

Atlantic Herring (*Clupea harengus*)


COTE (adult)

COTE (adult)


COTE (adult)

Silver Hake (*Merluccius bilinearis*)

- Long thin body with a protruding lower jaw
- 1 Long Dorsal fin, lies flat out of water
- Fan like caudal fin, appears pointed when wet
- Rounded caudal peduncle
- 1 anal fin
- Dark dorsal; dull metallic belly, sometimes washed yellow
- Length - 3.5”
- 1-2 times the length of tern bill
- Hangs at a 90 degree angle

Silver Hake (*Merluccius bilinearis*)

When fresh, bounces around in tern's bill

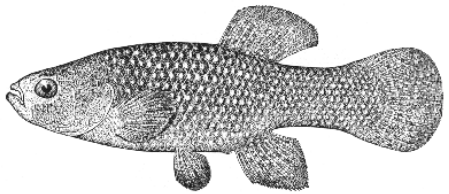
© ASNH

Notice how tail looks pointed (like it is stuck together)

Mummichog (Multiple Species)

Common mummichog – *Fundulus heteroclitus*

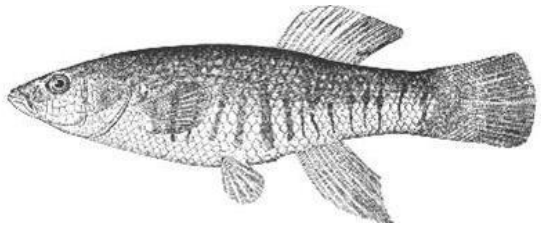
not streaked, rounded tail fin

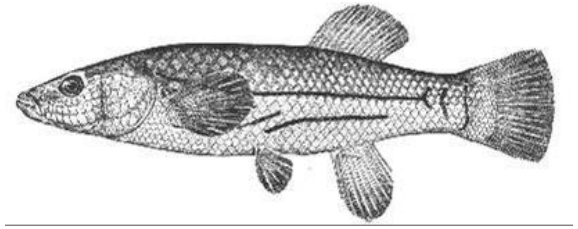


Striped mummichog – *Fundulus majalis*

stripes on sides of both sexes and all ages

male/vertical, female/horizontal



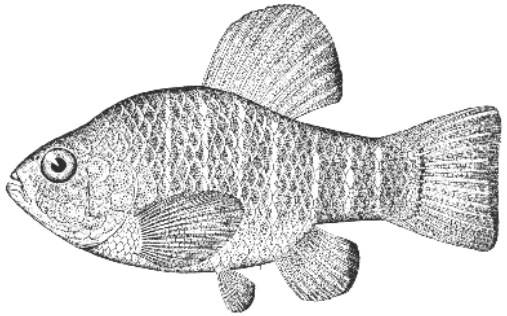


Sheepshead minnow – *Cyprinodon variega*

deep bodied,

half as deep as long,

square tail fin



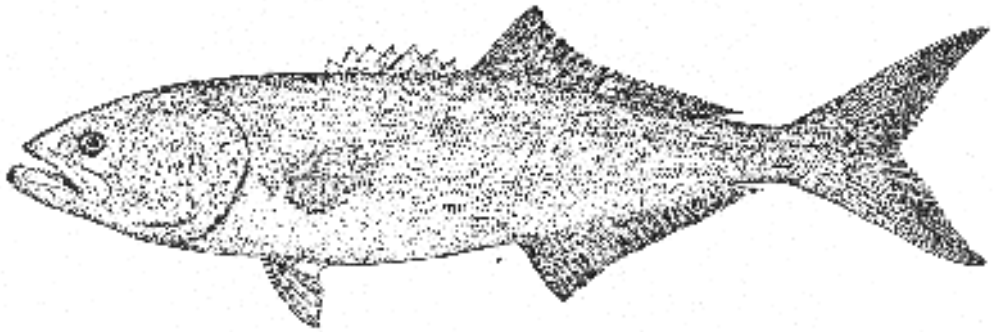
"Stiff as a board" rigidity

Mummichog (Multiple Species)

LETE (adult)

Bluefish (*Pomatomus saltatrix*)

- Stout body
- 2 dorsal fins
- Broad and forked caudal fin
- Rounded caudal peduncle
- 1 anal fin
- Sea green above; silvery below
- Length – 3”
- “Bendy” rigidity

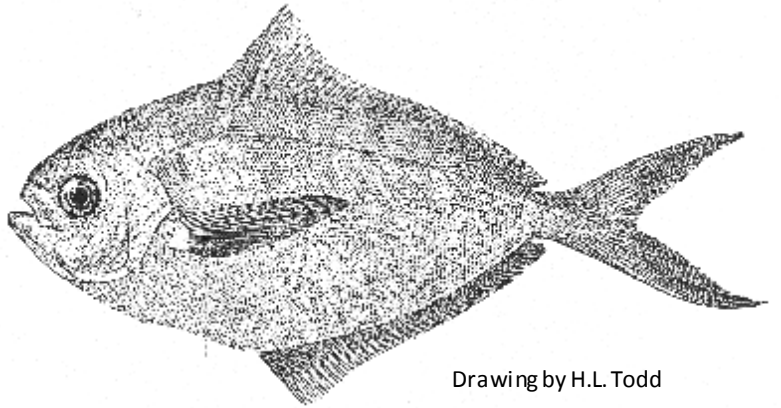


Drawing by H.L. Todd

Bluefish (*Pomatomus saltatrix*)

Butterfish (*Porontus triacanthus*)

- Broad and flat
- 1 long dorsal fin
- Deeply forked caudal fin
- 1 long anal fin
- Bluish above, pale on sides, silvery belly
- Length - 4”
- “Stiff as a board” rigidity



Drawing by H.L. Todd

Only fish in Gulf of Maine with this shape

Butterfish (*Porontus triacanthus*)

COTE (adult feeding chick)

COTE (adult feeding chick)

Key Points to Remember

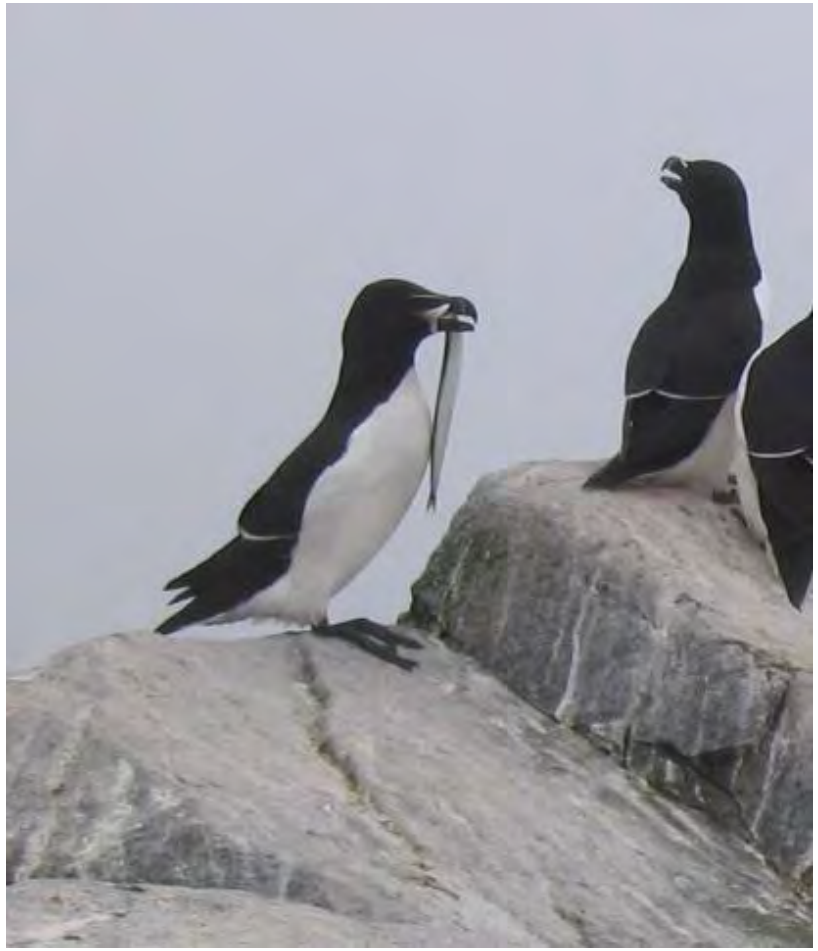
- Fish ID field markers
- Fish to bill ratio
- Fish rigidity

- Sand Lance or Non Sand Lance
  - For non-sand lance species capture as much ID detail as possible
  - Attempt to ID non-sand lance species if enough detail can be observed

Pollock (*Pollachius virens*)

- Forked Tail
- Large head, large eye
- Coppery coloration

Razorbill & sand lance



Alex Bond, ACWERN-UNB
Machias Seal island, NB

Atlantic Herring (*Clupea harengus*)

Black Guillemot with Atlantic Herring

Sand Lance

- **Key Field ID:**
  - Long length
  - Slender like an eel
  - Pointed snout
  - Small, forked tail

ROST Prey Annotated Bibliography a/o 6/7/16

Prey

Dalley, E.L., Winters, G.H. (1987) 'Early life history of sand lance (*Ammodytes*), with evidence for spawning of *A. dubius* in Fortune bay, Newfoundland'. *Fishery Bulletin*. Vol 85: 3.

- Surveys indicate that sand lance larvae occur annually in Fortune Bay from Feb-July/August
- Length-frequency data indicate spawning season extends from Dec-May/June
- First record of *A. dubius* spawning in Newfoundland coastal waters
- Data contributes to current confusion of appropriate taxonomy of Northwest Atlantic sandlance
- Looks at early life stages of sandlance. This article would only be helpful if roseates are feeding on juvenile sandlance, or the sandlance populations are migrating from Newfoundland to Cape Cod.

Goyert, Holly F. (2014) 'Relationship among prey availability, habitat, and the foraging behavior, distribution, and abundance of common terns *Sterna hirundo* and roseate terns *S. dougallii*', *Marine Ecology Progress Series*. Vol 506:291-302.

- Data collected aboard trawl surveys of the coast of Massachusetts, USA
- 3 dominant prey categories: northern sandlance, herring, and anchovies
- Significant positive effect of tern flock size and variable prey abundance on tern spatial patterns
- Foraging roseate terns were associated with high sandlance abundance
- Data were collected on trawling surveys in Buzzard's Bay, and other areas around Cape Cod.

Goyert, Holly F. (2014) SUPPLEMENT TO 'Relationship among prey availability, habitat, and the foraging behavior, distribution, and abundance of common terns *Sterna hirundo* and roseate terns *S. dougallii'*, *Marine Ecology Progress Series*. Vol 506:291-302.

- Figures and tables of estimated tern abundance

Goyert, Holly F. (2015) 'Foraging specificity and prey utilization: evaluating social and memory-based strategies in seabirds', *Behaviour*. Vol 152: 861-895.

- Capacity for behavioral plasticity in response to predictability of resources
- Hypothesis that roseate terns rely more heavily on foraging-site fidelity than common terns
- Analyzed chick-provisioning observations, commuting trajectories between colony and foraging areas
- Roseate terns rely on spatial memory to locate foraging sites rather than social cues
- Common terns rely on feeding aggregations, based on social facilitation
- Compares roseate and common tern foraging behavior. Does not mention specific prey items, only that roseate terns are specialists and common terns are generalists

Goyert, Holly F., Gardner, Beth, Sollmann, Rahel, Veit, Richard R., Gilbert, Andrew T., Connelly, Emily E., Williams, Kathryn A. (2015) 'Predicting the offshore distribution and abundance of marine birds from shipboard surveys, using a hierarchical community distance sampling model'. *Wildlife Studies on the mid-atlantic outer continental shelf: Final Report to the Department of Energy Wind and Water Power*.

- Proposed offshore wind energy development requires need for baseline studies of marine birds
- 40 marine bird species observed to create hierarchical community distance sampling model
- Six oceanographic parameters: distance to shore, slope, sediment grain size, sea surface temperature, salinity, primary productivity.
- Results show the importance of quantifying detection and determining the ecological drivers for evaluating the potential exposure of marine birds to offshore development.

Howell, Penelope, Auster, Peter J. (2012) 'Phase shift in an estuarine finfish community associated with warming temperatures'. *Marine and Coastal Fisheries: Dynamics, management, and ecosystem science.* 4:1, 481-495

- Finfish abundance from seasonal trawling surveys in Long Island Sound
- Surveys examined for changes in community composition related to dynamics of water temperature
- Compares cold-adapted species with warm-adapted species
- Results indicate a rapid shift in estuary community composition in response to warming climate
- Talks about cold water species vs warm water species. Does not reference specific finfish species. May be useful to roseate project if coastal water temperatures are changing. Could indicate a change in community composition (aka prey species of roseate terns moving to different areas).

Meyer, Thomas L., Cooper, Richard A., Langton, Richard W. (1978) 'Relative abundance, behavior, and food habits of the american sand lance, *Ammodytes americanus*, from the gulf of maine. *Fisheries Bulletin.* Vol 77:1.

- Trawling surveys, diver, and submersible observations
- Significant increase in abundance of sand lance since 1975 on Stellwagen bank
- Trend was typical of Northwest Atlantic from North Carolina to Maine
- Schools vary from 100 to tens of thousands of individuals
- Gives description abundances and behavior of schools of sandlance. Also describes important food sources of the sandlance (copepods).

Monteleone, Doreen M., Peterson, William T. (1986) 'Feeding ecology of American sand lance *Ammodytes americanus* larvae from long island sound'. *Marine Ecology- Progress Series.* Vol 30: 133-143.

- Sand lance larvae consume phytoplankton and copepods of varying life stages
- Diet changes with ontogeny
- Small larvae consume phytoplankton, larger larvae consume copepods of increasing life stages
- Larvae have gut capacity of 0.56%
- Small larvae exhibit passive feeding, while larger larvae exhibit more aggressive feeding behaviors
- Biomass of larvae increased with increased prey density and water temperature
- Sandlance predation has an insignificant effect on copepod populations. Paper talks about food consumption of larval sandlance and their impact of predation on copepods.

Monteleone, Doreen M., Peterson, William T., Williams, George C. (1987) 'Inerannual fluctuations in the density of sand lance, *Ammodytes americanus*, larvae in Long Island Sound, 1951-1983'. *Estuarine Research Federation.* Vol 10: 3. 246-254.

- Enumeration data from 2,300 ichthyoplankton samples compiled to determine interannual variations in density of sand lance larvae
- Increases in population in the late 1970s in the long island sound coincide with population trends throughout the Atlantic coast
- Population decline in the early 1980s in sound while Atlantic coast trends remain high
- Fluctuations in density of sand lance larval populations could be explained by water temperatures in December. Warm winter temperatures are associated with low larval densities

Nizinski, Martha S., Collette, Bruce B., Washington, Betsy B. (1990) 'Separation of two species of sand lances, *Ammo americanus* and *A. dubius,* in the Western North Atlantic'. Fishery Bulletin, U.S.. Vol 88: 241-255.

- Two Species: *Ammodytes americanus* (inshore) and *A. dubius* (offshore)
- External separation of species achieved by number of plicae (oblique folds of skin on lateral body surface)

- *A. americanus* has fewer meristic structures (lateral plicae) than *A. dubius*
- Geographic variation in number of vertebrae
- Compares two different species of Sand lance. Does not pertain to the ROST project because variations in species can only been observed by having the fish in the hand or by dissection.

Richards, Sarah W., Kendall, Jr., Arthur W. (1972) 'Distribution of Sand Lance, *Ammodytes* sp., larvae on the continental shelf from cape cod to cape hatteras from rv *Dolphin* surveys in 1966'. *Fishery Bulletin.* Vol. 71:2.

- Sandlance (*Ammodytes marinus*?) collected between Massachusetts and North Carolina
- Specimens of 4-8mm were more abundant in shallow water
- Greatest abundance occurred in winter off the mouths of the principal estuaries in New England
- Collected all the way to the edge of the continental shelf
- As larvae increased in size, abundance became directly related to abundance of plankton, which are also affected by presence of estuaries along the coast
- Sand lance larvae appear congregate near the mouths of estuaries, where their primary food source also congregates.

Safina, Carl, Burger, Joanna, Gochfeld, Michael, Wagner, Richard H. (1988) 'Evidence for prey limitation of common and roseate tern reproduction'. *The Condor.* 90. 852-859.

- 2 year studying looking prey population limitations on reproduction in tern species
- Common and roseate terns were more productive in the year with higher prey populations
- Reproductive productivity data obtain from tern populations at Cedar Beach, Long Island, NY.
- Prey fish population density data obtained by sonar
- 2 year studying showing that in years with higher prey populations tern species were more productive.

Shealer, David A., (1997) 'Mate Feeding and Chick Provisioning and Their Effects on Breeding performance among Known-Age Roseate Terns at the Falkner Island Unit of the Steward B. McKinney National Wildlife Refuge, Connecticut". *1997 Research Summary*. Colgate University.

- 3 year study for prey deliveries at the nest with 91.4% (n= 1216) prey identified
  - 52.5% = Fourbeard rockling (Enchelyopus cimbrius) - dramatic increase
  - 17.7% = Sand lance (Ammodytes hexapterus) – dramatic decrease (use to be 70% in 1995)
- Focused on male provisioning rates – older vs younger
- Need to determine if prey species are similar with the Cape

Shealer, David A., (1998) 'Size-selective Predation by a Specialist Forager, the Roseate Tern." *The American Ornithologists' Union*. Vol. 115, NO 2 (5119-525).

- Nesting prey study
- Terns appear to meet the increased demands of chicks by delivering increasingly larger prey items (rather than increasing provisioning rate) hence size-selective predation
- Study in Puerto Rico found
  - Feed in deep eater over schools of predatory fishes that drive smaller fished to the surface
    - Terns avg. 1 dive every 6 seconds w/ low capture success (28% - other source cited)
  - Forge in shallow inshore areas in absence of predatory fishes
    - Capture success is 60% but dive less frequently = poss. Discriminate size
- Detailed methods for determining the size of prey delivered to chicks are given in Shealer (1995)
  - Prey were grouped into one of four size categories (tiny, small, medium, large) corresponding to one-half bill-length increments (e.g. tiny, <0.5 bill lengths; medium, 1 to 1.5 bill lengths). 3 year study for prey deliveries at the nest with 91.4% (n= 1216) prey identified

Shealer, David A. and Stephen W. Kres (1994) 'Post-Breeding Movements and Prey Selection of Roseate Terns at Stratton Island, Maine." *Association of Field Ornithologist.* Vol. 65, NO 3 (349-362).

- 2 year study
- Stratton Island used as staging site = 200 adults & 100 Juvenilles
- Used Jolly-Sever sighting-resighting models – est. 5-10% of breeding adults in August at Stratton
- Prey was exclusively sand lance (*Ammodytes sp.*) in Saco Bay

Watson, Maggie J. and Jeremy J. Hatch (1999) 'Differences in Foraging Performance between Juvenile and Adult Roseate Terns at a Pre-Migratory Staging Area". Waterbirds: The International Journal of Waterbird Biology, Vol. 22, No. 3 (463-465).

- Study at Eel Point, Nantucket August 20-30 1996
- Comparison: adults vs. juveniles (8-10 wk) foraging proficiency
- Adults = high plunge dives
- Juveniles = four dive types (modified from Ashmole & Ashmole 1967)
- Adults = 0.98 prey capture/min w/ 0.52 prey captures/attempt
- Juveniles = 0.27 prey captures/min w/ 0.15 pre captures/attempt
- All prey caught = sandeels – Ammodytes sp.
- Feeding by adult well into migration sourced

Cape Cod Specific

Anonymous (1998) A Study of Roseate Tern (Sterna dougallii) Roosting and Staging Areas in Massachusetts during the Post Breeding Period- 1998.

- 1998 - 7 sites simult. monitored over 6-wk period
- Peak staging numbers occur in early September (9/1/98) 35% of flock (3,850) seen at South Beach Chatham
- Two primary roosting areas: South Beach, Chatham & Sandy Neck, Barnstable
- **One primary staging site: Coast Guard Beach, Eastham**
- CC supports lgest pre-migratory concent. of ROST in N. America
- Lgest #'s b/t 8/20 – 9/10 (staging b/t 8/18 - Mid Sept) w/ lg rapid decline
- Staging areas: usu. remote, relatively undisturbed & adjacent to dynamic inlet
- Keeping staging & roosting areas vehicle free may be single most important mgmnt factor in securing preserved habitats
- Recommendations:
  - Adequate funding 2 study importance of staging & roosting areas
  - Towns of Barnstable, Chatham, Eastham & Wellfleet – cont. protection & monitoring
  - Towns should encourage & support protection thru public education

Hecker, S. (1994) A Survey and Census of ROST on their Postbreeding Staging Areas in Massachusetts. Mass Audubon: Coastal Waterbird Program

- MAS CWP contracted by USF&W survey & census of ROST
  - Identify & map all sign. staging areas
  - Census ea & identify peak cts

    - Record samples of adults to juven. ratios
    - Record color banded combos
    - Assess threats or disturbances
- 225 sites identified, all sites w/ 50+ ROST were visited
- Peak cts = 2,640 South Beach & Monomoy; 500-600 Smith's & Eel's Points; 200 Katama Flats, MV
- **Staging period: late July – end of September**
- Peak period: August 1 – September 15
- Adult to juvenile ratio = 3.6 to 1; @ lgest flock 5.2 to 1
- 51% of adults banded & 70% of juveniles
- Areas of least disturbance: Monomoy & South Beach, Chatham where approx. ¾'s of MA ROST stage

Spendelow, J. A. and Jedrey, E. (August 2012) Endangered NW Atlantic Roseate Terns: on beyond breeding…(Is Cape Cod National Seashore…a magnet for staging Roseate Terns?) Powerpoint presentation given at Cape Cod National Seashore Visitor Center.

- Recovery goal: 5,000 prs (@ < 3,100 prs in 2011)
- Staging period: 7/16 – 10/15; 2.5 months, 30-50% of time spent in U.S.; stage briefly in Caribbean
- Decline since 2000: adult survival & productivity has not changed…need 2 det. postfledging survival **Survival of HY & recruitment of these individuals as breeding birds appear 2b major limiting factor**
- Post breeding dispersal period research began in 2005
- Before 2009, only adults were color banned
- 2011 began using PFR on chicks from CT, NH, ME & Nova Scotia
- Specific stats on PFR HYs from 2011; disturbances, PDP study from 2007-2009

Teets, M.J. 1998. Allocation of parental care around the time of fledging in the Roseate Tern (*Sterna dougallii*). Unpublished M.Sc. Thesis, University of Massachusetts, Boston, MA. Part 2 pgs 45-59

- Research in Nantucket only (7/26 – 9/8/96 & 8/9 – 8/24/12)
- 3 areas: id of banded birds, observ. of juven & adult interactions & foraging diff b/t juven & adult
- Best monitor observ. method = 'water standing' method
- Juven. land away from flock 2 get fed by adult. Mention juven. begging at adult
- 'Entire field season only 3 bands were sighted more than once on a diff day' – 3 hypotheticals offered on why extensive mvmnt b/t staging areas w/ food being the most likely
- **Fledglings inexper. & ineff feeders leading to parental care continuing in2 migration period**
- Lowest juven. success. foraging on windy days
- Comparison to current MA staging sites, juven inability to forage could be tied into hurricane issues

Trull, P., S. Hecker, M.J. Watson, and I.C.T. Nisbet. 1999. Staging of Roseate Terns *Sterna dougallii* in the post-breeding period around Cape Cod, Massachusetts, USA. Atlantic Seabirds 1:145-158.

- Authors identified 20 ROST & COTE Cape Cod staging sites (all outer beaches)
- Most birds from warm water group gather at post-breeding staging sites
- Utilized aerial & land tern surveys b/t 1990-1998 (July – Sept)
- **Identified at least 1 major roosting site on CC**
- Looked at temporal patterns
- Found at least 1 major roosting site on CC|
- Deter. large concentration in sm area made spp. highly vulnerable & laid foundat. of CC staging sites

Dispersal & Migration

Shealer, D.A., and S.W. Kress. 1994. Postbreeding movements and prey selection of Roseate Terns at Stratton Island, Maine. Journal of Field Ornithology 65:349-362. (staging sites)

- 1989-1992 observations 193 adults & 31 fledglings representing 8+ colonies
- **Reasons for PBD = reduced predation, overcrowding & competition for food, avoid inbreeding**
- Stats on incr. #'s ROST seen on Stratton Is, ME – suggested due to prey availability
- Listed resighting protocol employed
- Program JOLLY used to compute pop. est. from sighting-resighting data – discussed modeling method
- **Observed interactions b/t adult & HY**
- Proportionally more resightings came from smallest of the 4 principal colonies & farthest distance
- Highest resightings in early am & late afternoon
- Good review of what methodology, analysis & modeling can be done on post breeding resights

Spendelow, J.A., J.E. Hines, J.D. Nichols, I.C.T. Nisbet, G. Cormons, H. Hays, J.J. Hatch, and C.S. Mostello. 2008. Temporal variation in adult survival rates of Roseate Terns during periods of increasing and declining populations. Waterbirds 31:309-319.

- 1988-2006 (19 yrs)mark/recapture& resighting at 5 warm water breeding colonies = 90% of study pop.
- Warm water pop. comprises > 90% of entire population
- Annual survival of warm water breeding pop. 0.81-0.85 for 2 decades (1988-2006)
- No indication that 2004 BB oil spill reduced survival rates
- **Conclusion: Declining pop. b/t 2000-2006 not due to reduction in adult survival but rather a reduction in post fledging survival & recruitment of young from latter cohorts**
- Post fledging pop. decr. …need to protect after departure from breeding colony

ROST Biology

Spendelow, J.A., J.D. Nichols, I.C.T. Nisbet, H. Hays, G.D. Cormons, J. Burger, C. Safina, J.E. Hines, and M. Gochfeld. 1995. **Estimating annual survival and movement rates** of adults within a metapopulation of Roseate Terns. Ecology 76:2415-2428. (low adult survival rate for seabird)

Nisbet, I.C.T., and J.A. Spendelow. 1999. Contribution of research to management and recovery of the Roseate Tern: Review of a twelve-year project. Waterbirds 22:239-252. (re: pre-breeding birds accompany breeding birds during post breeding period)

- Summary of research programs b/t 1987-1999 & resulting management implications
- Skewed adult sex ratio, high avg product.,low annual adult survival, low fled-adult survival
- Past thinking = low fled.-adult survival due to low suitable feeding sites (1987 = gulls were limiting factor, however 1999 thinking = high postfledging mortality & skewed sex ratios are the limiting factors
- Metapopulation distinction for LI-CC birds due to high degree of inter-site movement
- Warm vs. cold water population distinction made
- Parental 'quality' r primary determinants of chick growth & survival
- Nesting colonies usu. r on islands & always r w/in COTE colonies (historical nesting site data provided)
- Major predators incl. black-crowned night herons & gr horn owls. Benefit from diurnal COTE protection
- **Foraging methods: shoal (primary), flock & shallows feeding**
- Historical population crashes
- Most mortality in adults occurs when away from breeding colonies
- Mgmnt activities centered around site accessibility, funding & motivated personnel rather than biosuitab
- Recap of research goals, limitations & contributions
- Staging in Aug & early Sept from warm-H_2O gr mostly in cold- H_2O areas @ CC quoted from Nisbet 1984) & 'hurricanes pose serious risk'

USFWS (U.S. Fish and Wildlife Service). 1998. Roseate Tern *Sterna dougallii*. Northeastern population recovery plan: first update. U.S. Fish and Wildlife Service, Hadley, MA. (summarizes 12 yr research program results, nesting colonies almost always on islands & always w/in colonies of COTE)

Disturbances

Erwin, M. (1989) 'Responses to Human Intruders by Birds Nesting in Colonies: Experimental Results and Management Guidelines', Colonial Waterbirds. 12:1.

- To det. distances at which birds flush responding to human intrusion
- Few response diff. b/t incubation& post hatching periods
- Recommend distances of 100 m rather than suggested National Park 50 m distance
- COTE responded at greatest distances to human intrusion
- Based on nesting colonies & did not mention ROST specifically

MAS CWP (2012?) Characterization of disturbance to Roseate and Common Tern flocks, southeast Massachusetts 2008 (draft do not cite or distribute) (unpub data)

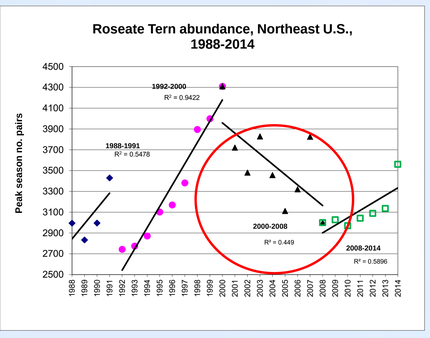
- Disturbance categories (10) in 2008 in SE MA
- Does not take into acct unidentified disturb.
- Highest rate of disturb. = Hatches Harbor
- All wildlife disturb. were avian (gull 53% & peregrine falcon 13%)
- No banded identification data but could be used to discuss mgmnt needs/issues

Roseate Tern (*Sterna dougallii*) population decline: The case for prey base competition with Gray Seal (*Halichoerus grypus*)

Katharine C. Parsons
Coastal Waterbird Program, Mass Audubon, Lincoln MA

Introduction

The Northwest Atlantic population of the Roseate Tern (*Sterna dougallii*; ROST) was listed in 1987 as "endangered" under U.S. and Massachusetts Endangered Species Acts. In 1988, the population stood at approximately 3,000 breeding pairs and with protective management at breeding colonies, peaked in 2000 at 4,300 pairs. After **a decade of decline,** recent data suggest the population may be stabilizing, however to reach the recovery goal of 5,000 pairs, the current population must increase by 43%.



Compiled by Carolyn S. Mostello (MDFW) for the Roseate Tern Recovery Team.

Figure 1. Abundance of Northwest Atlantic breeding ROST, 1988-2014.

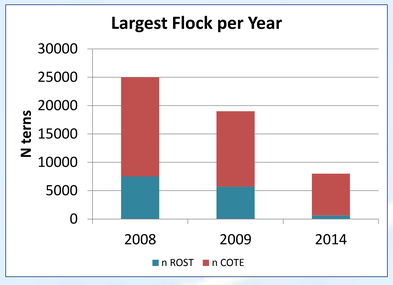


Figure 2. Largest tern flock observed at staging sites on Cape Cod, 2008-2014 (unpubl data; Karpanty et al. 2015). 10-12 observers; 100-125 da observations each year

Demographic studies do not provide evidence that ROST population losses since 2000 result from changes in fledgling production or adult survival; both are estimated to be at levels that would sustain a stationary population (Nisbet et al. 1999; Spendelow et al. 2008). **Drivers of population decline are assumed to be occurring away from the breeding colonies.**

Survival of juveniles and sub-adults has not been quantified, and scientists have not identified factors limiting recruitment. Preliminary field studies suggest that **60-80% of fledged (HY) ROST disperse from breeding sites in mid-summer to staging habitats located on Cape Cod** and Nantucket MA (Jedrey et al. 2010; unpubl. data).

Acknowledgements

I thank members of Mass Audubon's Coastal Waterbird Program staff, Dick Veit and Ian Nisbet for thoughtful discussions about factors limiting Roseate Tern recovery. Mass Audubon's research on staging Roseate Terns has been funded by the Island Foundation, the Canadian Wildlife Service, USFWS, NPS and private donors.

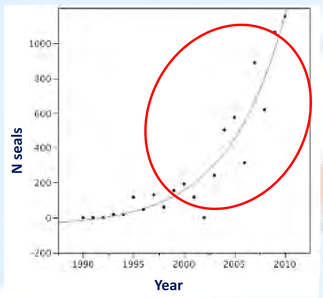


Figure 3. Gray Seal population growth 1990-2010 as indicated by bycatch data (Frungilllo 2014).

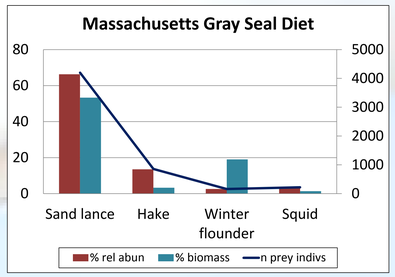


Figure 4. Gray Seal diet from scat analysis (n=305). Sand lance (*Ammodytes spp*.) dominated MA seal diet (Ampela 2009)

Results and Discussion

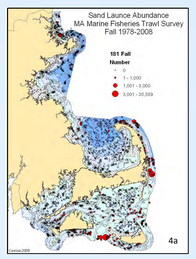
The decline in ROST abundance coincides with exponential growth (700% increase; 2000-2010) of the Gray Seal (*Halichoerus grypus*; GRSE) population on Cape Cod and Nantucket**. Both species are sand lance (*Ammodytes sp*.) specialists** (ROST 85% of diet; GRSE 63%) whose prey size selection in MA overlaps significantly (53% of ROST diet; 67% GRSE) (Shealer & Kress 1994; Ampela 2009; Nisbet et al. 2014).

The southeastern MA population of **GRSE consumes more than 6.7M sand lance daily** and feeds preferentially inshore at inlets and other areas of sand lance concentration (Ampela 2009). ROST staging activity similarly is focused at these spatially distinct resource areas where terns exhibit foraging philopatry (Figure 5; Goyert 2014).

The plausibility of direct competition between ROST and GRSE is supported by the following:

- Top predators in marine systems are known to impact prey populations and structure ecological communities (Bowen 1997)
- Since the late 1990s, seal biomass in MA has increased by 3.5M kg
- ROST is known to be sensitive to prey depletion (breeding grounds; Safina et al. 1988)
- ROST and GRSE are known to be narrowly targeting the same prey resource (species, prey size, habitat, location, timing) at staging sites used by the majority of the endangered tern population

As identified by Goyert (2014), there is a need for researchers to address the extent to which prey sensitivity may limit the potential for Roseate Tern population recovery.



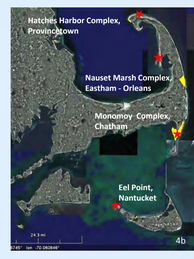


Figure 5. Distribution in southeast MA of a) sand lance (*Ammodytes spp*.) from trawl surveys, 1978-2008, and b) primary ROST staging sites 2007-2009 (unpubl. data). GRSE haulout locations shown in red.

References

•Ampela, K. 2009. The diet and foraging ecology of Gray Seals (*Halichoerus grypus*) in United States waters. PhD thesis, CUNY.
•Bowen, W. D. 1997. Role of marine mammals in aquatic ecosystems. Mar Ecol Prog Ser 158: 267-274.
•Frungillo, J. 2014. An analysis of Gray and Harbor Seal strandings in Cape Cod MA from 1999-2012. MSc thesis, Duke Univ.
•Goyert, H. 2014. Relationship among prey availability, habitat, and the foraging behavior, distribution, and abundance of common terns *Sterna hirundo* and roseate terns *S. dougallii*. Mar Ecol Prog Ser 506: 291-302.
•Jedrey, E.L. et al. 2010. Roseate Terns – citizens of the world: the Canada to Cape Cod connection. Bird Observer 38:146-150.
•Karpanty, S. et al. 2015. Importance of Cape Cod National Seashore to the Endangered Roseate Tern (*Sterna dougallii*) during the Fall Pre-Migratory Staging Period. 2014 Annual Report submitted NPS Mar 2015.
•Nisbet, I.C.T. et al. 1999. Predicting chick survival and productivity of Roseate Terns from data on early growth. Waterbirds 22:90-97.
•Nisbet, I.C.T. et al. 2014. Roseate Tern *Sterna dougallii*. BNA online (A. Poole, Ed.). Cornell, Ithaca.
•Safina, C. et al. 1988. Evidence for prey limitation of common and roseate tern reproduction. Condor 90: 852-859.
•Shealer, D & S. Kress. 1994. Post-breeding movements and prey selection of Roseate Terns at Stratton Island, Maine. JFO 65: 349-362.
•Spendelow, J.A. et al. 2008. Temporal variation in adult survival rates of Roseate Terns during periods of increasing and declining populations. Waterbirds 31:309-319.