NOAA FISHERIES

Pacific Remote Island Marine National Monument: Seabird Biology Case Studies

Case Study #1 – Wake Atoll

Wake Atoll is a very isolated atoll and the farthest north and west atoll of the Pacific Remote Islands Marine National Monument. Despite its remote location, Wake has a long history of human impact, mostly during WWII. Thousands of Japanese soldiers were under siege there during the war and over 2,000 American personnel lived on Wake in the 1970's. The military activity and predation from feral cats (originally pets brought by residents of the base) was very destructive to the seabird populations. Look at the table of bird numbers from Wake Atoll and prepare a brief, 5-minute presentation about how bird numbers have changed since observations have been made at Wake. Use the life history traits page to think about how species might vary in recovery. Include at least one visual in your presentation, discuss similarities and differences with Palmyra, and make a prediction for the future of birds on Palmyra based on this data.

Important Facts for bird populations:

- Cat control started in 1996 and all feral cats were moved away by 2004.
- It's estimated that 30,000 birds were killed annually by the feral cats.
- Typhoon Ioke hit Wake on August 31st, 2006 leading to damage of a shearwater colony at Peacock Point and the Grey-backed Tern colony on the north shore of Peale Island was abandoned.
- Ironwood trees were introduced and began expanding in range after the 1970s. They create habitat for tree-nesting species but their needles smother native vegetation.

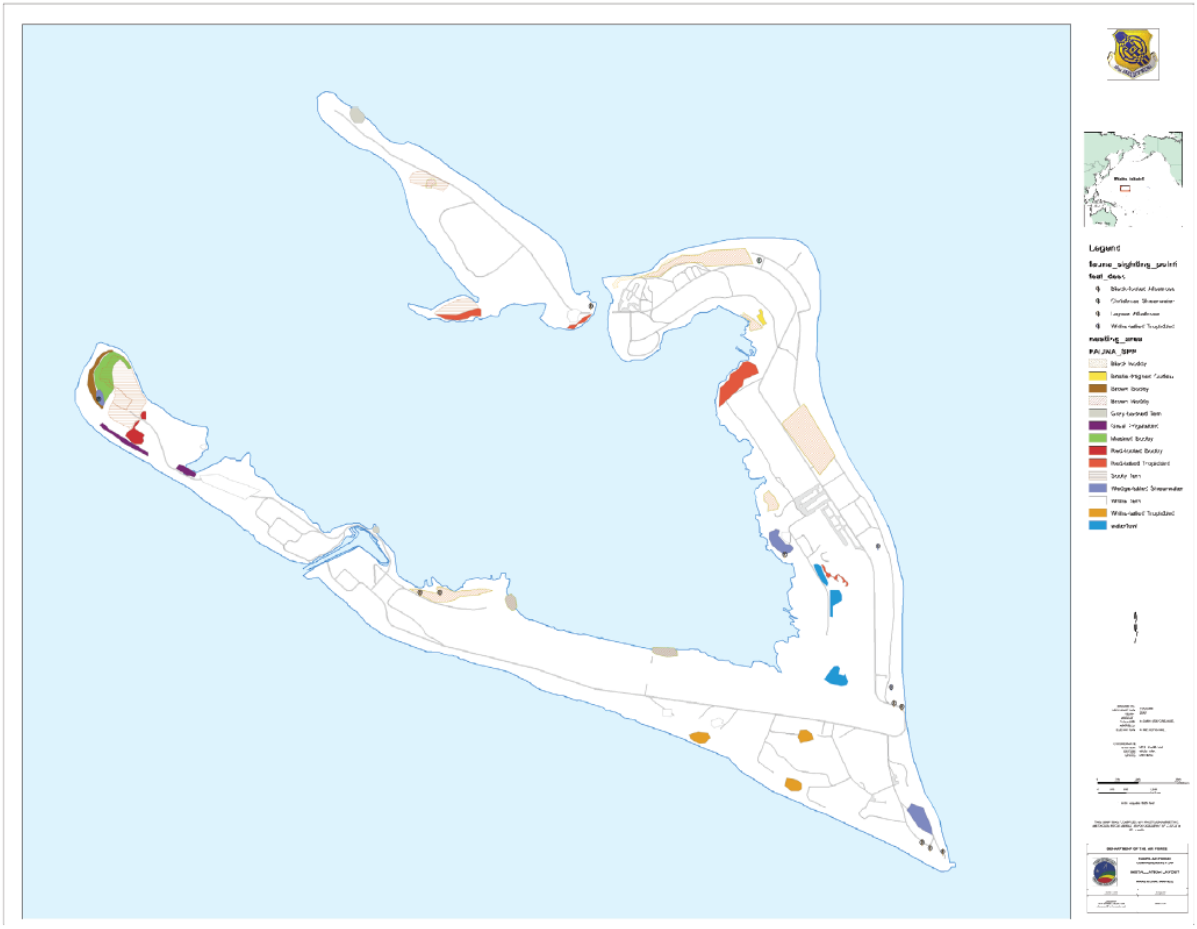

Figure 4: Bird areas on Wake Atoll. Map courtesy of A. Hebshi.

Table 2. Wake Bird Population Counts

(Population count/number of nests)

BIRDS	1923	1939-40	1949-53	1967	1988-92	1993	Dec-96	Jul-98	Mar-99	Jul-03	Dec-03	Aug-04	2005	2006 IOKE	Jun-07	Jan-08
Laysan Albatross	0	?	0	0	5/1?	p/1	5/1n?	0 (1 n-'97)	2/(1n-'98)	0	2/n	Feb-00	2/1chick	p/0	2/failed nest	0/0
Black-footed Albatross	p/0?	3/0?	0	0		6/?	3/1n	6-'97/?	4/0n	0	3-6/1n?	0	p/0	p/0	1 Dead, p/0	p/0
Wedge-tailed Shearwater	100/n	100/n	0	6/?	0	0	0	?/50	0	?/70	?/n	176/105			81/90 burrows	24 active nests
Christmas Shearwater	2/?	+ in 1936	0	0	0	0	0	0	1/?	0	0	1/?			1/n?	
White-tailed Tropicbird		?	2	15/n?						2	4	5/2n?			3/courting	
Red-tailed Tropicbird	30/n	"many"/12	0	20/2		4/n	0	25/?	100/25	p/40	p/?	p/15			p/n	
Masked Booby	3/2n	?/"many"	0	0	?/2n	5/n	10/2n	21/5n	11/5n	25/7	75/18	70/18			60/25	p/31
Brown Booby	500/n	?/100	0	40/23	212/106n	111/56n	26/13n	400/107n	111/?	400/162	300/31	p/76			313/164	p/60
Red-footed Booby	5,000	2000+/++	p/n	p/18	p/41	p/35n	1,500/32n	2,200/5n	p/25n?	2500/20?	2500/76	3000/5			733/n	
Great Frigatebird	2,000/n	"very many"/25	"a few"/?	30/2n	274/0	225/0	500/0	100/0	400/n	150-300	150-300	150-300	Possible Nesting		Possible Nesting	Nesting/one red-headed juvenile
Sooty Tern	?/300n	p/500	"1000's"	p/230,000	p/143,000	p/300	10K/n	11K/75	200,000 87,000	p/n	p/0	p/0			Chick mass starvation	50,000 @Peale
Gray-backed Tern	100/n	400/?	0	21		8/?			4/0n	5/1?	0	60/9			75/n	
White Tern	2,500/n	p/14	p/n	p/n		6/n	p/1n	100/3	60/n	200	300	400/n			all isles nests	
Black Noddy	200/n	p/25	0	0		2/?	200/100n	300/100n	715/2n	1000/n	1500/n	2000/n			common/n	
Brown Noddy	6,000/n	"abundant"/ 4 nests	p/n	50/0		98/3n	Jun-00	100/50n	20/4n	200/n	500/n	1000/n			Tree&ground nesting	
Pacific Golden Plover	200	"abundant"	24	250		p	200	31	160	20	200	20			23	6
Bristle-thighed Curlew	3	4		p					4	0	1	1				
Wandering Tattler	2	26	2	10		p			30	5?	15	5			4	5
Ruddy Turnstone	2	25	1	20	p	1	4	2	1	5	12	5			3	
Pintail Duck				9	5		4	0	6	0	2	0			9	26 on 10/07

CHART KEY

p/n = number present/number of nests

/ ? = not known if nesting

"many" are quotes taken from papers

87K= 87,000

From "The Status of Birds of Wake Atoll," Mark Rauzon, et. al, 2008

Case Study #2 – Rose Atoll

Rose Atoll is located near American Samoa and is a Marine Monument all by itself. While it is a relatively small atoll, like many other uninhabited islands and atolls of the Pacific, Rose is home to a sizeable seabird population. Rats were introduced to Rose Atoll on or sometime before 1920 and were removed between 1990 and 1991. Look at the table of bird numbers from Rose Atoll and prepare a brief, 5-minute presentation about how bird numbers have changed since observations have been made there. Note the key at the bottom of the table that includes other environmental events that may have affected seabirds. Use the life history traits page to think about how species might vary in recovery. Include at least one visual in your presentation, discuss similarities and differences with Palmyra, and make a prediction for the future of birds on Palmyra based on this data.

Table 9: Seabird observed active nests by year at Rose

Year	Species						
	Black Noddy	Brown Booby	Brown Noddy	Masked Booby	Red-footed Booby	Red-tailed Tropicbird	White Tern
1975 (Oct)*	351	90	5	5	14	4	100
1976 (Dec)		10					
1976 (May)	0	217	0	2	2	16	0
1976 (Nov)		10		0	0		
1976 (Oct)	2	23		25	0	2	0
1978 (Mar)	250	0	10	0	0	3	0
1980 (Nov)	235	39	145	3	0	1	120
1981 (Nov)	746	8	136	2	0	0	27
1982 (Mar)	294	375	143	17	205	8	0
1982 (Oct)**	0	0	0	2	10	0	0
1984 (Apr)	356	250	116	15	450	11	0
1984 (Oct)	365	8	128	6	35	5	75
1986 (Nov)Φ		0	30	0	0	2	51
1987 (Feb)	0	0	0	0	9	3	0
1988 (Feb)	292	35	82	3	4	8	9
1988 (Oct)*	81	35	187	10	205	6	15
1989 (Mar)	180	111	204	15	93	12	10
1989 (Oct)	7	15	148	4	270	6	4
1990 (Apr)Φ		0	55	7	0	27	0
1990 (Oct)Ψ	0	5	1	12	420	12	18
1991 (Apr)Ψ		249		18	691	25	
1991 (Sep)Ψ	0	0	0	2	0	0	0
1992 (Sep)Ψ	0		48	4	253	13	0
1993 (Oct)Φ	0		0		0	3	0
1996 (Jul)	541	28	16	10	469	24	1
1998 (Aug)***	566	12	28	12	160	21	5
2002 (Feb)	362	232	111	8	142	38	63
2004 (May)Φ		23		1	5	15	
2005 (Jul)Φ	583	0	40	5	15	26	0

* *Pisonia* Die-off Event, ** *Pisonia* Defoliation Event, *** Scale Infestation of *Pisonia*, Φ Hurricane, Ψ Rat Eradication

Table 10: Median nest count values for seabirds at Rose prior to and after the 1991-1992 rat eradication

	Rats Present (n*=21)	Rats Removed (n=7)
Black Noddy	180	451.5
Brown Booby	12.5	23
Brown Noddy	68.5	34
Masked Booby	4	6.5
Red-footed Booby	9	142
Red-tailed Tropicbird	5.5	21
White Tern	4	0.5

*n values = number of samples for each species prior to and after rat eradication

From "Rose Atoll National Wildlife Refuge Research Compendium," Wegmann and Holzwarth, 2006.

Case Study #3 – Baker, Howland, and Jarvis Islands

Baker, Howland and Jarvis are the southernmost islands of the Pacific Remote Islands Marine National Monument. Cats were introduced in the 1930s to control rat populations. While the cats got rid of the rats, they also killed off a number of small bird species, including grey-backed terns, blue noddies, brown noddies, Christmas shearwaters, Tropical shearwaters, and Polynesian storm-petrels. They negatively affected the seabirds' populations that remained on the islands as well. Use the time table of events and the table of bird numbers from the three islands to prepare a brief, 5-minute presentation about how bird numbers have changed since cats have been removed. Use the life history traits page to think about how species might vary in recovery. Include at least one visual in your presentation, discuss similarities and differences with Palmyra, and make a prediction for the future of birds on Palmyra based on this data.

Table 1 Historical timeline of introduction and eradication of predators, and selected human activities at Howland, Baker and Jarvis Islands.

Year	Howland	Baker	Jarvis
Pre-history	*Rattus exulans* introduced		
Early 1860s	Guano miners and whalers brought rodents. Species and islands not specified		
1858 - 1878	104,000 tons guano taken	300,000 tons guano taken	300,000 tons guano taken
1935	All three islands colonised, cats introduced		
	Norway rats named as present		
Post WW II	Cats probably exterminated Pacific rats	Cats probably exterminated Norway rats. Mice remain	
1963 -– 64	Cats removed from these two islands		211 cats killed (80% of popn)
1965	Cats allegedly introduced to these two islands by military		
1965		Mosquitoes introduced, island sprayed with DDT	
1982	Cats present	Cats died out naturally by now	118 cats killed (99% of popn)
1986	Final 17 cats killed		
1990			Last cat killed
2010	No introduced predators		Mice still present

Table 2 Seabird counts at the time of cat eradication for Jarvis, Baker, and Howland Islands and subsequent seabird counts on each island several years after cat eradication. The numbers represent the largest count of birds documented on a single trip but not the total population, as birds nest throughout the year.

Scientific Name	Common Name	Jarvis 1982	Jarvis 2004	Baker 1965	Baker 2002	Howland 1986	Howland 2007
Phaethon rubricauda	Red-tailed tropicbird	2500	2500	15	72	122	496
Sula dactylatra	Masked booby	3000	7000	400	3134	2387	3763
Sula leucogaster	Brown booby	500	2000	10	375	15	275
Sula sula	Red-footed booby	550	1000	1	714	41	825
Fregata minor	Great frigatebird	50	2400	3	900	0	550
Fregata ariel	Lesser frigatebird	1500	4000	0	16,200	0	3850
Onychoprion fuscatus	Sooty tern	1,000,000	+1,000,000	6000	1,600,000	0	150,000
Onychoprion lunatus	Grey-backed tern	6	1100	25	2000	0	2000
Anous stolidus	Brown noddy	1	10,000	1000	3600	50	1000
Procelsterna cerulea	Blue noddy	1	650	0	26	0	11
Gygis alba	White tern	12	11	0	38	2	50
Nesofregetta fuliginosa	Polynesian storm-petrel	1*	3	0	0	1	0
Puffinus nativitatis	Christmas shearwater	0	20	0	0	0	0
Puffinus bailloni	Tropical shearwater	0	20	0	0	0	0
Puffinus pacificus	Wedge-tailed shearwater	100	41	0	10	0	1*

*Birds found dead
Sources: Clapp and Sibley 1965; Forsell and Berendzen 1986; Sibley and Clapp 1965; Skaggs 1994; US Fish and Wildlife Service 2007

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Grade Level

- 7-12

Timeframe

- 1.5 – 2 hours

Materials

- Computer with internet access
- Google Earth
- Student worksheets and case studies
- Audio Visual Materials: Projector

Key Words

- Life History Traits
- K Selected Species
- R Selected Species
- Invasive Species
- Recolonization

Pacific Remote Islands Marine National Monument: Seabird Biology

Activity Summary

In this lesson students will learn about the islands and atolls that are a part of the Pacific Remote Islands Marine National Monument (PRIMNM). They will get a basic introduction to the location and size of the islands and atolls. They will examine some of the wildlife of the islands, specifically seabirds, and learn the basic requirements of these organisms for living and reproducing. They will make and/or analyze a graph using data, and learn to interpret data to make predictions about trends or anomalies. Last, data of seabird populations will demonstrate how invasive species have affected seabirds and case studies of conservation successes show how people are helping populations recover.

Learning Objectives

Students will be able to:

- Explore the geography of the PRIMNM;
- Understand the size of the PRIMNM and relative ratios of land to water;
- Describe the basic requirements of seabirds and how they fill those needs;
- Examine the impacts of introduced species and how people are working to lessen those impacts; and

Internet Resources

Fact sheet on the NOAA Fisheries National Seabird Program: http://alaskafisheries.noaa.gov/protectedresources/seabirds/seabird_factsheet.pdf

NOAA Fisheries PRIMNM Website http://www.fpir.noaa.gov/MNM/mnm_prias.html

Fish and Wildlife Service PRIMNM Website - clicking on the links to individual islands or atolls on the left will give you information about all the birds found at each place. http://www.fws.gov/pacificremoteislandsmarinemonument/

Slideshow of Birds of Palmyra Atoll http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/hawaii/slideshow-birds-of-palmyra-atoll.xml

You Tube Videos
Kingman Reef: about 2 minutes, made by Environmental Defense Fund https://www.youtube.com/watch?v=I8m5_aeq4tQ&feature=player_embedded#at=52

All of these websites are supplementary information and current at the time of lesson publication. If they do not work, a quick Google search of the prompt will likely lead you to the correct site.

- Make predictions based on data from studies of islands recovering from invasive species.

Background Information

An estimated 14 million seabirds from 21 species use the small area of emergent land in the PRIMNM for nesting (MCBI, 2010). Jarvis Island alone is home to an estimated 1 million sooty terns and Palmyra Atoll is home to the second largest red-footed booby breeding colony in the world with an estimated 6,250 breeding pairs (TNC, 2013). These small areas of land are extremely important for seabirds foraging and breeding. While many species of seabirds spend large amounts of time at sea, nesting requires that they come ashore. Seabirds have several adaptations for life at sea. Their wings can be long for pelagic species that fly over great distances, shorter for those that are diving species, and most have webbed feet for better propulsion while on the surface or diving. Most seabirds also have salt glands that allow them to excrete excess salt that they consume by eating and drinking from a saline environment. Seabirds have three primary methods of feeding: surface feeding, pursuit diving, and plunge diving. Some seabirds, such as frigatebirds, also get some of their food by stealing it from other birds. There is a large range for how far seabirds will forage from their nesting area. Blue noddies forage close to shore typically staying within 1-2 km of their nesting site, whereas masked and red-footed boobies will forage 100-200 km from their nesting sites and red-tailed tropicbirds have a range of 1,500 km.

In addition to physiological adaptations for life at sea, the life history of seabirds also differs from their land relatives. Seabirds usually live longer than land birds and are K-selected species, meaning they live longer, have fewer offspring and typically give more parental care than R-selected species, which tend to be small, quickly reproducing organisms with short generation time. Most seabirds breed in colonies, leading to the incredible amounts of seabirds that gather on the islands and atolls of the PRIMNM. Palmyra Atoll is the only seabird nesting area in roughly 1,165,495 square kilometers of ocean, so the protection offered by being part of the national monument system is crucial for the birds that nest there and on the other remote islands. Just as they feed in a variety of ways, seabirds also have different preferences for nesting. Some like to nest in trees, some on the ground in the open, and others will make burrows on the ground. White terns are well known for laying eggs in precarious places like rocks, rock ledges, or bare branches. Additional information on all species found in the PRIMNM can be found on the websites listed in the internet resources section of the lesson.

Though seabirds greatly benefit from the islands and atolls of the PRIMNM and their associated ecosystems, they also give benefits back to those ecosystems. Seabirds play important roles in tropical food webs

Outline

ENGAGE – Introduction to Pacific Remote Island Marine National Monument

EXPLORE – Seabird nesting strategy discussion

EXPLAIN – Seabird and rat interactions at Palmyra Atoll

ELABORATE- Seabird and invasive species interaction case studies

EVALUATE- Presentation of case study

Vocabulary

LIFE HISTORY TRAITS – major characteristics that affect the rate, timing, and other aspects of growth, reproduction, and resource gathering

K SELECTED SPECIES – species that tend to have a lower number of offspring but invest more energy in individual offspring, mature more slowly and/or are older at the time of first reproduction, and have a longer lifespan

R SELECTED SPECIES – species that tend to have a shorter life span, mature rapidly and reproduce early; they typically have lots of offspring but low levels of parental investment leading to high offspring mortality

and ecosystems. Seabirds consume an estimated 7% of ocean primary productivity and the guano they produce fertilizes terrestrial and tidal zones. It is critical that people recognize the importance of seabirds to these ecosystems because many seabird species are listed as threatened. There are 326 species of seabirds identified, 102 are threatened or endangered and five are considered extinct by the IUCN. (Jones, 2010). NOAA Fisheries has a National Seabird Program that monitors and tries to reduce seabird bycatch from fisheries. They also use seabirds as ecosystem indicators when conducting research.

Preparation

- Read the background section and the PRIMNM Factsheet to familiarize yourself with the area and its seabirds; should take about 10 minutes.
- Familiarize yourself with Google Earth or Google Maps Satellite view, whichever you choose to use in class. The time it takes for this will depend on your familiarity with the programs. If you've never used Google Earth, plan to spend 20-30 minutes to get comfortable before using it in class.
- Print out enough individual worksheets and case studies for your class. Each student needs their own "student worksheet." They should work in groups for the case studies. There are three case studies, you can either split the class into three groups or have multiple groups do the same case study depending on your class size. Each group should have a few copies of their case study.
- Decide how you would like to share the table on page 8 (numbers of seabirds on Jarvis) with your class; it could be shown in a projector or printed out.
- Have appropriate materials or space for the students to present their case studies in groups such as dry erase board space and markers, or large newsprint and markers. Each group will need enough space/paper to make a visual and a few comments.

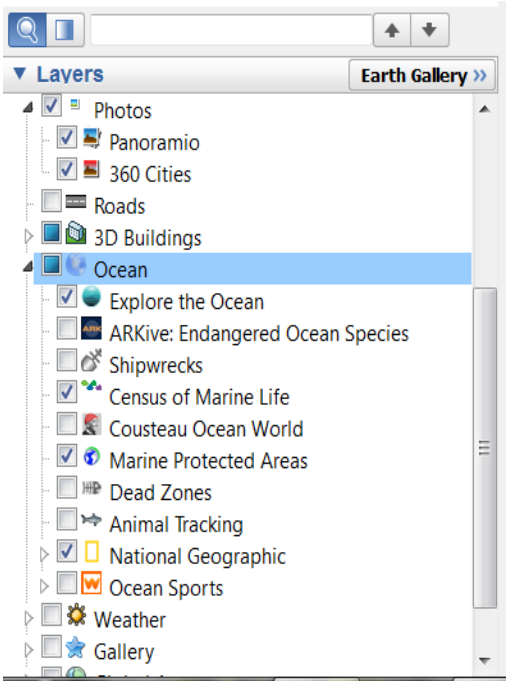
Learning Procedure

Engage

Show students an overview of PRIMNM. Use Google Earth or Google Maps satellite view to show close ups of the individual islands and zoom out to show how far they are from your school or other major landmarks, like Hawaii or Australia. Talk about the differences that you can see among the islands and atolls. The islands (Jarvis, Howland, and Baker) do not have center lagoons while the atolls (Palmyra, Wake and Johnston) have center lagoons and are made up of small islets that surround the lagoon. On Johnston, there are clear remnants of the air force base that closed in 2004 and there are also visible runways and development on Wake from military activity. The military presence both places dates back to pre-WWII. Kingman Reef has very little emergent land, but the reef can be seen. You can discuss what the different colors

of water mean and that darker water indicates that it is deeper. After viewing the individual locations, zoom out and look at the entire area.

- From each island or atoll, the water out to 50 nautical miles is part of the Monument.
- Ask your students to estimate something equivalent to the size of the Monument. It's roughly 225,039 square kilometers or roughly the size of Minnesota (225,062 square kilometers).



Have the students predict what percentage of the Monument is exposed land. It is only roughly 29 square kilometers or 0.013% of the area of the Monument truly making this a marine preserved area as opposed to a terrestrial one. If you would like to compare your home state to the area of the Monument, data on the area of every US state can be found here: http://en.wikipedia.org/wiki/List_of_U.S._states_and_territories_by_areathe

Explore – Seabird Nesting

What kinds of wildlife can be found in the PRIMNM? Despite the relatively small amount of land, these islands and atolls are home to a very large seabird population. Seabirds and shorebirds have some of the same requirements for living, but their challenges can be different.

- Brainstorm with your students the need of seabirds, and how living primarily at sea requires different adaptations than living on land. They may come up with things like ability to swim (seen in different wing shape and webbed feet), and dealing with the fact that their primary source of water is saline. Steer the discussion towards nesting behavior; even though adult seabirds can spend extended time at sea they must nest on land.
- Lead a discussion with your students on the different types of nesting behaviors in seabirds (information in background section). Ask you students questions like:
  - Where and how do your local birds nest? Do they nest on the ground or in trees, alone or in groups?
  - Why might the behaviors vary for the seabirds out on these islands?

- What are the challenges for nesting?
- Did you see many trees or foliage when looking at the images of the islands? What might that mean for where birds nest?
- Why might nesting on the ground be hazardous?

As a visual to stimulate discussion, show the table of numbers of seabirds on Jarvis. Even under good conditions there is a lot of variation in nesting numbers from year to year. Aim to have the students leave this discussion with the understanding that nesting on the ground is safe under natural conditions, but if predators are introduced by humans it can lead to negative results for those species. Included in the lesson materials is also a file of pictures of birds from the table so students can visualize what these species of birds look like.

Depkin, F.C. and Kim, J. (2010) USFWS Trip Report, Jarvis Island NWR.

Table 1. Status of seabirds seen on Jarvis Island NWR, 01 – 05 April 2010 with comparisons to 2008, 2004, and 1996[1].

Species Name	Nesting Y/N	Number of Nesting Pairs[1]	Total number of birds seen 2010	Results From 2008 26-28 Mar	Results From 2004 26-27 Mar	Results From 1996[4] 20-23 Mar
Wedge-tailed Shearwater	?	25[2]	35	100	41[3]	0(8)
Christmas Shearwater	Y	1	8	20	20[3]	0(12)
Audubon's Shearwater	N	0	8	20	4[3]	1(20)
Red-tailed Tropicbird	Y	92	400	40[3]	150	13(110)
Masked Booby	Y	935	5,421	2,323[3]	5,000	333(2,515)
Brown Booby	Y	20	≈75	8[3]	200	51(86)
Red-footed Booby	Y	63	>100	17[3]	750	216
Great Frigatebird	Y	293	>500	95[3]	1,600	251
Lesser Frigatebird	Y	744	>900	0	4,000	809
Brown Noddy	Y	68	>600	250	10,000	1,238
Black Noddy	N	0	3	0	NA	0(1)
Species	N	0	95	25[3]	650	4(100)
White Tern	Y	1	6	0	NA	1(5)
Sooty Tern	Y	≥100,000	≈200,000	Na	150,000	117(TMTC)
Gray-backed Tern	N	0	76	300	1,100	90

[1]Yearly comparisons are not intended to express differences in population size but to demonstrate variability of nesting effort in the equatorial region of the Pacific.
[2]Number of nesting pairs resulted from direct counts except where noted.
[3]Number of active burrows encountered.
[4]Indicates actual nest counts, otherwise number of nesting pairs was estimated in 2008 and 2004.
[5]The 1996 results display number of nest sites and (total number of birds seen).

Explain – Seabird and Rats Interaction Worksheet

Nesting on the ground isn't typically a problem because few of these islands have native ground-dwelling predators. These are the conditions

the birds evolved in. When one is introduced, it can be disastrous for native species without ways of defending themselves and their nests. Invasive species are a problem in a lot of ecosystems and the PRIMNM is no exception. Rats were probably introduced to Palmyra Atoll during WWII when it was a military base.

Complete the seabird and rat interaction worksheet. Students will need to examine and interpret the data on Palmyra Atoll seabirds and rats interactions that accompanies their worksheet in order to answer the following questions:

1. Look at the list on the next page of life history traits of central Pacific seabirds and how that affects how they are impacted by rats. Predict three species of birds that would have difficulty coexisting with rats and describe why.

2. A group monitoring the recovery on Palmyra since the rat removal has found a 130% increase in native tree seedlings. Which species of birds would you predict would benefit from this change in the environment?

3. If seabirds killed off by rats were going to recolonize Palmyra Atoll, where do you think they would come from?

4. Chick translocation (humans moving seabird chicks) or using methods such as playing seabird sounds, using decoys and smells, or creating artificial burrows can help speed up recolonization rates of seabirds. If you were the manager of a recovering island, would you use these techniques? Why or why not?

5. How did rats originally get to the islands? How can we prevent them from getting to new islands or islands where they have been eradicated?

Elaborate – Case Studies

When students have completed the worksheets, form the class into three groups and distribute the case studies giving one study to each group. Depending on your class size, you can have groups complete the same case study to keep group sizes from being too large. Have each group give a short presentation of the observed results and what they think those results mean for the future of Palmyra and the other islands of the PRIMNM. Encourage them to include details in their predictions; which species will see the most benefit from the removal of rats or some sort of timeline for recovery. How will the seabirds on the other islands fare in the continued presence of invasives? Provide them with either

chalkboard/dry erase board space or a large piece of newsprint or paper so the groups can create a visual aid for their presentation.

Evaluate – Group Presentations

Evaluate students' presentations and consider the following metrics:

- Presentation skills – eye contact, clear speaking, everyone contributing;
- Effective visuals;
- Use and interpretation of data from the given case study; and
- Discussing similarities and differences with Palmyra and making informed predictions for the future of birds on the atoll. Specifics for each atoll are included in the worksheet and case study answer key.

Closing

Recap lessons learned and cover any common presentation issues. If you're not going to do any of the extend options as a class, share some of the birding resources for any students who are interested in pursuing them on their own time.

Extending the Lesson

- Do some birding in your area either as part of class or encourage the class to do it after school on their own. If they're interested, students can use http://ebird.org/ebird/eBirdReports?cmd=Start to find good places for birding nearby and to record the birds they see.
- Use data from the Christmas Bird Count organized by the Audubon Society to practice making graphs and interpreting data trends. You can use data from your local area or from Hawaii and the Northwest Hawaiian Islands if you'd like to continue to lookat some of the same species. Data sorted either by species or by location can be downloaded here: http://netapp.audubon.org/CBCObservation/#
- Investigate some cases of invasive species in your area and how they have affected native species.

Connections to Other Subjects

- Ecology
- Biology
- Math

Related Links

EBird Data and Regional Information
NOAA Fisheries Pacific Remote Islands MNM
NOAA Fisheries Pacific Islands Regional Office
NOAA Fisheries Seabird Program
Palmyra Atoll Research Consortium

The Nature Conservancy's Palmyra Site

For More Information

NOAA Fisheries Pacific Islands Regional Office
NOAA Marine National Monument Program
1845 Wasp Blvd., Building 176
Honolulu, HI 96818
(808) 725-5000, (808) 725-5215 (fax) pirohonolulu@noaa.gov

Acknowledgement

This lesson is one in a series exploring the geology, biology, oceanography, and ecology of the Pacific Marine National Monuments. It was developed for the NOAA Fisheries Pacific Islands Regional Office.

This lesson was developed by Mary Engels of the University of Idaho and Laura Nelson of the University of Washington.

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Sources

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Pacific Islands Benthic Habitat Mapping Center, University of Hawaii at Manoa http://www.soest.hawaii.edu/pibhmc/pibhmc_pria.htm

Rauzon, M., D. Boyle, W. Everett, J. Gilardi. (2008). The Status of Birds on Wake Atoll. Atoll Research Bulletin 561: 1-43.

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Education Standards

Next Generation Science Standards	• MS-LS2-2. – Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems. • MS-LS2-4. – Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations. • HS-LS2-2. – Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales. HS-LS2-7. – Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity. • HS-LS4-5. – Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species. • HS-LS4-6. – Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.
Ocean Literacy Principles	• 5 – The ocean supports a great diversity of life and ecosystems. • 5D – Ocean biology provides many unique examples of life cycles, adaptations, and important relationships among organisms (symbiosis, predator-prey dynamics, and every transfer) that do not occur on land. • 5F – Ocean ecosystems are defined by environmental factors and the community of organisms living there. Ocean life is not evenly distributed through time or space due to differences in abiotic factors such as oxygen, salinity, temperature, pH, light, nutrients, pressure, substrate, and circulation. A few regions of the ocean support the most abundant life on Earth, while most of the ocean does not support much life. • 6D - Humans affect the ocean in a variety of ways. Laws, regulations, and resource management affect what is taken out and put into the ocean. Human development and activity leads to pollution (point source, nonpoint source, and noise pollution), changes to ocean chemistry (ocean acidification), and physical modifications (changes to beaches, shores, and rivers). In addition, humans have removed most of the large vertebrates from the ocean. • 6G - Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.

Brown Booby (*Sula leucogaster)*

Red-tailed Tropicbird (*Phaethon rubricauda)*

Masked Booby *(Sula dactylatra)*

Red-footed Booby *(Sula sula)*

Photos from USFWS

Great Frigatebird *(Fregata minor palmerstoni)*

Lesser Frigatebird (Fregata ariel)

Brown Noddy *(Anous stolidus)*

Christmas Shearwater *(Puffinus nativitatis)*

Wedge-tailed Shearwater *(Puffinus pacificus)*

Audubon's Shearwater (*Puffinus lherminieri)*

Grey-backed Tern (*Onychoprion lunatus)*

Sooty Tern (*Onychoprion fuscatus)*

White Tern (*Gygis alba)*

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Pacific Remote Islands Marine National Monument: Seabird Biology Worksheet / Case Study ANSWER KEY

Name_____ Date_____

Seabird and Rat Interactions

Use the information on different species of seabirds and how they're impacted by rats to answer the following questions. The list of seabird species includes those found on any island in the PRIMNM, but not all birds are found on every island. The information on how rats affect seabirds comes from a scientist that evaluated studies examining interactions between seabirds and rats all over the world.

1. Look at the list on the next page of life history traits of central Pacific seabirds and how that affects how they are impacted by rats. Predict three species of birds that would have difficulty coexisting with rats.

Audubon's shearwater, Christmas shearwater, wedge-tailed shearwater, bulwer's petrel, blue noddy, grey-backed tern – Though no records exist prior to the introduction of rats, these birds are believed to have been extirpated from Palmyra by rats based on best estimates from scientists. These species are all high risk in two or three of the categories.

In addition to those specie listed above, the phoenix petrel and white-throated storm petrel are also believed to have lived on Palmyra but are not found on other islands in the PRIMNM.

2. A group of scientists monitoring the recovery of *Pisonia grandis* trees on Palmyra since the rat removal has found a 130% increase in the native tree seedlings. Which species of birds would you predict would benefit from this change in the environment?

The arboreal and branch dwelling species: black noddy, red-footed booby, great frigatebird, and white tern.

3. If seabirds that have been killed off by rats were going to recolonize Palmyra Atoll, where do you think they would come from?

Jarvis, Howland, Baker, and Kiritimati (Christmas Island) are the closest to Palmyra.

4. Chick translocation (humans moving seabird chicks) or using methods such as playing seabird sounds, using decoys and smells, or creating artificial burrows can help speed up recolonization rates of seabirds. If you were the manager of a recovering island, would you use these techniques? Why or why not?

More of an opinion question but look for good reasoning to support either a yes or no decision. Potential explanations and rationale against using those techniques include that it would be better left to happen naturally or that there should be less human interference. Potential support for using those techniques includes that it could speed up recovery and helps the seabirds get established rather than leaving it to chance. It's reasonable for students to pick and choose and support some of the less intrusive techniques like creating artificial burrows but that they might not go as far as physically moving seabird chicks.

5. How did rats originally get to the islands? How can we prevent them from getting to new islands or islands where they have been eradicated?

Rats typically arrived by ships that either stopped at the islands or were shipwrecked upon the island or outlying coral reef. By taking precautions with ships that visit the islands, we can prevent the introduction of rats to places they haven't yet been or the reintroduction of them to islands where they have been eradicated.

When you've completed this worksheet, give it to your teacher and get your case study.

Life History Traits and Level of Rat Impact

Nesting Strategy	Impact
Burrowing	High
Crevice nesting	High
Branch	Low
Ground	Low

Family	Impact
Hydrobadidae	High
Diomedeidae	Low
Fregatidae	Low
Laridae	Medium
Alcidae	High
Sulidae	Low
Phaethontidae	Low
Procellariidae	High
Pelecanoididae	High

Adult Weight/Size	Impact
Small (less than 300 g)	High
Medium (301-600 g)	Medium
Large (601-900 g)	Medium
Very Large (greater than 900 g)	Low

Seabirds of the Pacific Remote Islands Marine National Monument

Species	Family	Nesting	Size (g)
Audubon's Shearwater	Procellariidae	Burrows	170
Black Noddy	Sternidae	Branch	120
Blue Noddy	Laridae	Ground (rocky)	58
Brown Noddy	Laridae	Ground	200
Brown Booby	Sulidae	Ground	1270
Masked Booby	Sulidae	Ground	1855
Red-footed Booby	Sulidae	Arboreal	975
Great Frigatebird	Fregatidae	Branches	1185
Lesser Frigatebird	Fregatidae	Ground	750
Christmas Shearwater	Procellariidae	Ground under dense cover	350
Wedge-tailed Shearwater	Procellariidae	Burrows	455
Grey-backed Tern	Laridae	Ground	230
Sooty Tern	Laridae	Ground	180
White Tern	Laridae	Branches	110
Red-tailed Tropicbird	Phaethontidae	Ground	620
Bulwer's Petrel	Procellariidae	Crevices or burrows	95
Black-footed Albatross	Diomedeidae	Ground	3195
Laysan Albatross	Diomedeidae	Ground	2855

Evaluating Group Presentations

Evaluate the presentations of your students and consider the following metrics:

- Presentation skills – eye contact, clear speaking, everyone contributing
- Effective visuals
- Use and interpretation of the data from the given case study
- Discussing similarities and differences with Palmyra and making informed predictions for the future of birds on the atoll and that might include:

For Wake Atoll

- *Similarities with Palmyra: Invasive vegetation, military presence, many of the same species of birds*
- *Differences: Dealing with cats instead of rats, different species of invasive trees, birds affected by recent storms*
- *For some bird species, lots of variation among all years but most see some sort of increase in population after cats were removed in 2004*
- *After cats were controlled/removed*
    - *Large increase in the population of black and brown noddies*
    - *Return of wedge-tailed shearwaters which had been present before cats but no recognizable population while cats were on the island*
        - *Moderate increase in white terns*
    - *Potential Predictions: Predict an increase in population in some but not all species of birds, predict an increase in the same species that saw large population growth on Wake, recognize natural disasters can still play a role in species recovery and population numbers.*

For Rose Atoll

- *Similarities with Palmyra: Invasive rats, certain species of birds were no longer found on the island due to predation by the rats. On Rose, Christmas and wedge-tailed shearwaters were likely extirpated.*
- *Black noddies, brown boobies, masked boobies, red-footed boobies, and red-tailed tropicbirds showed a positive response to the rat removal*
- *Environmental events have likely also influenced seabird nesting in addition to rats*
- *White-tailed tropic birds occur in such low numbers that it's hard to make any conclusions about how they might have been affected*
- *Potential Predictions: Predict an increase in bird populations that have previously suffered predation by rats on their eggs and young, predict a return of birds that were not able to survive on the island when rats were there, or predict a greater percentage of eggs will hatch.*

For Baker, Howland and Jarvis Islands

- *Similarities with Palmyra: Geography and types of species of birds*
- *Differences: Both cats and rats, large environmental impacts due to guano removal in addition to invasives*
- *After eradiation: increase in almost every bird species but amount varies from island to island, return of great frigatebirds, lesser frigatebirds, sooty terns, blue noddy, and white terns to Howland, both shearwaters to Jarvis, blue noddy, white tern, and lesser frigatebirds to Baker.*

- *Potential Predictions: Predict an increase in most bird species, recognize islands recover differently than even those that are similar based upon varying recovery rates and random events, predict the return of some species that did not live on the island while rats were there*

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