

The Island Fox Jigsaw: Twelve Cards, Five Solutions, One Recovery

Learning target: I can work with a team to trace how an invasive species and a pesticide led to the near loss of the island fox, evaluate five real solutions against shared criteria, and explain why a combination of solutions worked.

Collaborative investigation

About 55 min

Jigsaw

MS-LS2-5 · assesses

MS-LS2-4 · practice

MS-ETS1-3 · supports

collaboration

reading

discussion

Standards connections

MS-LS2-5 (assesses, evaluating competing solutions; teams do not design new ones): Teams and individuals evaluate five competing solutions that were actually used to maintain the island fox and its ecosystems, using jointly agreed criteria and scientific, economic and social constraints, which is the PE as written.

MS-LS2-4 (practice): Teams build an evidence-based causal chain showing how changes to biological components (feral pigs, the loss of bald eagles, arriving golden eagles) changed the fox population.

MS-ETS1-3 (supports): Comparing the strengths and weaknesses of each solution and explaining why their combination succeeded uses the same reasoning engineers use to combine the best features of several designs.

Purpose: practice · **Time:** about 55 minutes · **Format:** jigsaw

Answers with reasoning

Twelve evidence cards: the Channel Islands fox

1 Card 1 (Set A): The island fox

A small fox, about the size of a house cat, that lives on six of California's eight Channel Islands and nowhere else. The foxes on each island are a separate subspecies with their own genetic differences. Island foxes eat insects, deer mice, birds, fruits and seeds, and they are active in daylight as well as at night. For thousands of years they had few predators.

2 Card 2 (Set A): The crash

In the 1990s, fox numbers collapsed on the three northern islands. San Miguel Island fell from about 450 foxes to 15. Santa Rosa Island fell from about 1,780 to 15. Santa Cruz Island fell from more than 1,400 to about 55. In 2004, four island fox subspecies were listed as endangered under the U.S. Endangered Species Act.

3 Card 3 (Set A): Evidence about the killer

Biologists fitted foxes with radio collars and found the bodies of the ones that died. Most had been killed by golden eagles. Golden eagles live on the mainland and were not known to nest on the islands until the 1990s. Biologists found no sign that disease, a food shortage or habitat change caused the crash on the northern islands.

4 Card 4 (Set B): Why the golden eagles stayed

Ranchers brought pigs to Santa Cruz Island in the 1800s, and some went wild. Thousands of feral pigs rooted up native plants and loosened soil on hillsides, and their piglets gave golden eagles a plentiful meal all year. Non-native deer and elk on Santa Rosa Island added more food. Eagles that stayed to eat piglets also hunted foxes, which are about the size of a piglet and active in daylight.

5 Card 5 (Set B): The missing guards

Bald eagles once nested on the Channel Islands. They eat mostly fish and seabirds, and they drive other eagles out of their nesting areas. The pesticide DDT, released into the ocean near Los Angeles in the mid-1900s, built up in fish and made bald eagle eggshells so thin that they broke. By the early 1960s bald eagles had disappeared from the islands, leaving an empty niche that golden eagles moved into.

6 Card 6 (Set B): Catalina's different problem

Foxes on Santa Catalina Island also crashed in the late 1990s, but golden eagles were not the cause there. Canine distemper, a virus that infects dogs, foxes and their relatives, probably arrived with an animal from the mainland and killed most of the foxes on much of the island.

7 Card 7 (Set C): Solution 1, captive breeding

Starting in 1999, biologists caught surviving foxes and bred them in pens on the islands. Over the program, 226 foxes raised this way were released into the wild. Strengths: stopped the slide toward extinction quickly, and pens kept foxes safe from eagles. Weaknesses: foxes released while golden eagles remained could be killed; a few captive foxes hold only part of their subspecies' genetic diversity; pens need staff and money every day.

8 Card 8 (Set C): Solution 2, moving golden eagles

From 1999 to 2006, biologists captured 44 golden eagles on the islands and released them on the mainland. Strengths: removes the main cause of fox deaths directly, without killing the eagles, which are a protected native species. Weaknesses: the eagles were hard to trap, so it took years; as long as piglets remained, new golden eagles could arrive to replace the ones removed.

9 Card 9 (Set C): Solution 5, vaccinating foxes

On Catalina, biologists vaccinated captive and wild foxes against canine distemper and also bred foxes in pens. Strengths: targets the real cause on that island. Weaknesses: new pups are born every year and need vaccinating too, and the virus could still arrive with pets or stowaway animals from the mainland.

10 Card 10 (Set D): Solution 3, removing feral pigs

In 2005 and 2006, professional hunters removed 5,036 feral pigs from Santa Cruz Island. Strengths: takes away the food that drew golden eagles, and native plants recover once pigs stop rooting up hillsides, which also reduces soil erosion. Weaknesses: costly and slow to plan; some people objected to killing so many animals; it does nothing for foxes that have already died.

11 Card 11 (Set D): Solution 4, bringing back bald eagles

Beginning in the early 2000s, young bald eagles were released on the Channel Islands. In 2006, the first bald eagle chick in more than 50 years hatched there without human help. Strengths: restores a native species that keeps golden eagles out of its nesting area, and once established it needs little help.

Weaknesses: slow; DDT still buried in ocean mud near Los Angeles can harm eggs.

12 Card 12 (Set D): The results

As of 2015 there were about 700 foxes on San Miguel, 1,200 on Santa Rosa, 2,100 on Santa Cruz and 1,800 on Catalina. In August 2016, the San Miguel, Santa Rosa and Santa Cruz foxes were removed from the endangered species list, the fastest recovery of any U.S. mammal listed under the Endangered Species Act. The Catalina fox was moved from endangered to threatened because disease is still a risk.

Criteria and constraints for judging a solution — Criteria (what a good solution does): A. acts fast enough to prevent extinction; B. removes a root cause rather than only a symptom; C. keeps working without constant human help; D. restores native species and the ecosystem services the islands provide, such as soil held in place by native plants. Constraints (limits every solution must respect): scientific (it must be possible with the tools and knowledge available), economic (money and staff are limited), and social (the public and the agencies involved must accept it). Your group may add one criterion if everyone agrees.

Part A: Expert round (one set per person)

1. Your expert set: _____. Write the two most important facts from your three cards, including at least one number, and one question your cards raise that another set might answer.

Answer: Set A: the island fox is endemic to six Channel Islands, with a separate subspecies on each; northern island foxes crashed in the 1990s (San Miguel about 450 to 15, Santa Rosa about 1,780 to 15, Santa Cruz more than 1,400 to about 55); radio collars showed golden eagles killed most of them. Set B: feral pig piglets fed golden eagles all year; DDT removed the bald eagles that once kept golden eagles away; Catalina's crash was caused by canine distemper. Set C: 226 captive-bred foxes were released; 44 golden eagles were moved to the mainland from 1999 to 2006; Catalina's foxes were vaccinated. Set D: 5,036 pigs were removed in 2005-2006; a bald eagle chick hatched on its own in 2006 for the first time in more than 50 years; three subspecies were delisted in 2016.

Why: Each expert should bring back the causal or outcome facts their set contributes, with at least one number.

Also acceptable: Accept any two accurate facts from the set with a number.

- Two important facts from the set
- At least one number
- A question that connects to another set

Part B: Home group task

1. Teach your cards in order, Set A first. Listeners write one fact from each set.
2. Build a cause-and-effect chain on scrap paper from DDT and the feral pigs to the fox crash, using arrows. Every arrow must be supported by a card number.
3. Score each of the five solutions against criteria A to D in the decision table.

4. Decide as a group which combination of solutions explains the recovery on the northern islands, and why Catalina needed something different.
 5. Every member must be able to explain one arrow in the chain and one score in the table.
2. Group answer: Write your cause-and-effect chain from DDT and feral pigs to the fox crash on the northern islands. Put the card number that supports each link in brackets, for example [Card 5].

Answer: DDT in the ocean near Los Angeles → thin bald eagle eggshells → bald eagles gone from the islands by the early 1960s [Card 5] → no bald eagles to drive golden eagles away [Card 5]. Feral pigs on Santa Cruz Island → plentiful piglets all year [Card 4] → golden eagles move in and nest [Cards 3, 4] → golden eagles also hunt foxes, which are active in daylight [Cards 3, 4] → northern fox populations crash to 15, 15 and about 55 [Card 2].

Why: Two causes combine: an empty niche (no bald eagles) and a new food supply (piglets) let golden eagles settle, and the eagles' predation caused the crash. Disease is ruled out on the northern islands by Card 3.

Also acceptable: Accept chains that include the deer and elk on Santa Rosa Island as an extra food source [Card 4].

- Includes the DDT and bald eagle branch
- Includes the pig and piglet branch
- Golden eagles connect both branches to the fox crash
- Each link cites a card

3. Group answer: Score each solution 2 (meets the criterion well), 1 (partly) or 0 (not at all). In the last column, name the constraint (scientific, economic or social) that makes the solution hardest to carry out.

Answer: Suggested scores (A, B, C, D, total; hardest constraint). Captive breeding: 2, 0, 0, 1, total 3; economic (daily staff and money). Moving golden eagles: 1, 1, 1, 1, total 4; scientific (eagles are hard to trap; new ones arrive while pigs remain). Removing feral pigs: 0, 2, 2, 2, total 6; social (some people objected to killing the pigs) and economic. Bringing back bald eagles: 0, 2, 2, 2, total 6; scientific (slow, and DDT in ocean mud can harm eggs). Vaccinating foxes: 1, 1, 0, 1, total 3; economic (new pups every year).

Why: The pattern matters more than exact scores: captive breeding and eagle removal were fast but needed constant effort, while pig removal and bald eagle restoration were slow but removed root causes and restored native species and soil-holding plants.

Also acceptable: Accept scores that differ by 1 if the group's reasoning cites the cards; for example, moving eagles can earn 2 on B if the group argues that the eagles were the direct cause.

- Fast solutions (captive breeding, eagle moving) score higher on A
- Root-cause solutions (pig removal, bald eagles) score higher on B and C
- Each hardest constraint is named and fits the card
- Scores are consistent with card evidence

4. Group answer: No single solution scored 2 on every criterion. Explain why the northern islands needed a combination, and say which solutions handled the emergency and which handled the root causes.

Answer: Captive breeding and moving golden eagles handled the emergency: with only 15 foxes left on two islands, waiting years for pigs to be removed and bald eagles to return would have meant extinction. But those fast solutions treated symptoms; as long as piglets fed golden eagles and no bald eagles defended the islands, new eagles would keep arriving and released foxes would keep dying. Removing the pigs and bringing back bald eagles removed the root causes, so the recovery could last without constant help. Together they produced the fastest recovery of any U.S. listed mammal (Card 12).

Why: The combination pairs fast symptom treatment with slow root-cause removal, mirroring the engineering idea of combining the best features of several designs.

Also acceptable: None.

- Names captive breeding and eagle moving as the emergency response
- Names pig removal and bald eagle return as root-cause solutions
- Explains why either group alone would fail
- Uses card evidence

5. Group answer: Why would moving golden eagles and removing pigs have done little to save Catalina's foxes? Which solutions fit Catalina's problem?

Answer: Catalina's foxes crashed from canine distemper, not golden eagles (Card 6), so moving eagles or removing pigs would not touch the cause. Vaccinating foxes and captive breeding fit Catalina's problem (Card 9).

Why: A solution must match the cause; the same species needed different solutions on different islands.

Also acceptable: None.

- Identifies disease as Catalina's cause
- Names vaccination and captive breeding as the fitting solutions

Part C: Individual accountability (complete alone)

6. Feral pigs never ate a fox. Explain how pigs, an introduced species, still caused fox deaths. Is this a direct or an indirect effect?

Answer: Pigs supplied piglets that fed golden eagles all year, so eagles moved in and stayed, and those eagles also hunted foxes (Cards 3 and 4). The pigs harmed foxes through a third species, the golden eagle, so this is an **indirect effect**.

Why: An indirect effect passes through another population; here, the invasive pigs increased a predator that then reduced the foxes.

Also acceptable: Accept 'the pigs fed the fox's predator' as the core explanation.

- Explains the piglet to eagle to fox link
- Labels the effect indirect
- Cites card evidence

7. Santa Rosa Island's foxes went from about 15 to about 1,200 by 2015. How many times larger was the 2015 population? Then explain why the recovered foxes may still carry less genetic diversity than the foxes before the crash.

Answer: $1,200 \div 15 = 80$ times larger. The recovered population descends from only about 15 survivors (plus captive-bred foxes from the same few animals), so it carries only the gene varieties those few foxes had. Many gene varieties in the larger pre-crash population were probably lost, and they cannot come back from other islands because each island has a separate subspecies.

Why: This links a population bottleneck to lasting low genetic diversity, the same issue as the kākāpō.

Also acceptable: Accept 'about 80 times' with the division shown.

- Calculates 80 times
- Explains that the population descends from few survivors
- Connects few ancestors to lost gene variety

8. Predict what would most likely have happened if managers had removed the pigs but had **not** started captive breeding or moved any golden eagles. Use card evidence about timing.

Answer: The foxes on San Miguel and Santa Rosa would most likely have gone extinct. Pig removal did not happen until 2005-2006 (Card 10), but by the end of the 1990s only about 15 foxes were left on each of those islands (Card 2), and golden eagles were killing most of the foxes that died (Card 3). Without captive breeding to protect survivors and without moving the eagles, the remaining foxes would probably have been killed before the pigs were gone.

Why: Timing evidence shows that slow root-cause solutions could not have arrived in time on their own.

Also acceptable: Accept 'Santa Cruz foxes might have survived because about 55 remained' as a nuanced addition.

- Predicts likely extinction or near extinction
- Uses the pig removal dates
- Uses the population low or the eagle predation evidence

9. A classmate says, 'Captive breeding saved the island fox, so it was the best solution.' Evaluate this claim using at least two criteria and evidence from at least three different cards.

Answer: The claim is only partly correct. Captive breeding scores well on criterion A: it acted fast, protected the last foxes in pens from 1999, and returned 226 foxes to the wild (Card 7). But it scores poorly on criteria B and C: it removed no cause, needed staff and money every day, and released foxes could be killed while golden eagles remained (Card 7). Recovery became lasting only after the root causes were removed: 44 golden eagles were moved (Card 8), 5,036 pigs were removed so eagles had no reason to stay (Card 10), and bald eagles returned to guard the islands (Card 11). The best solution was the combination, not captive breeding alone, which is why the foxes could be removed from the endangered list in 2016 (Card 12).

Why: Students must weigh a solution against more than one criterion and use evidence from several cards.

Also acceptable: A student who argues captive breeding was the most essential single piece because nothing else could have prevented extinction in time can earn full credit if they also explain why it was not sufficient alone.

- Takes a position (partly correct, correct or incorrect)
- Uses at least two criteria by name
- Cites at least three different cards
- Concludes about the role of the combination

Scoring rubric

Criterion	4 • Exemplary	3 • Proficient	2 • Developing	1 • Beginning
Cause-and-effect chain	Both branches (DDT and bald eagles; pigs and piglets) lead through golden eagles to the fox crash, every link supported by a card number, and disease ruled out for the northern islands.	Both branches present with one link missing or unsupported.	Only one branch, or links stated without card evidence.	Chain missing, or it blames the wrong cause (for example, disease on the northern islands).
Evaluation of solutions	All five solutions scored with reasons drawn from the cards; fast symptom treatments and slow root-cause solutions are clearly distinguished; a fitting constraint is named for each.	All five scored with mostly card-based reasons; one constraint missing or weakly matched.	Some solutions scored without reasons, or scores contradict the cards.	Table incomplete or unrelated to the criteria.
Combination and Catalina reasoning	Explains why the northern islands needed both emergency and root-cause solutions and why Catalina needed different ones, using card evidence and timing.	Explains the combination correctly but the Catalina contrast or the timing evidence is thin.	Names solutions without explaining why they were combined.	Claims a single solution was enough, with no evidence.
Individual accountability (Part C)	All four answers accurate, with the indirect effect, the 80-times calculation and genetic-diversity link, a timing-based prediction and a multi-criteria evaluation citing three cards.	Three of four accurate with evidence; one thin or partly incorrect.	Two accurate; others restate the group result without reasoning.	Part C mostly blank or inaccurate.

Teacher notes

Print and cut the twelve cards; each set mixes facts students need to share. All facts were checked against the U.S. Fish and Wildlife Service's August 2016 announcement of the delisting (population lows and 2015 numbers, 226 foxes released from captive breeding, vaccination against canine distemper, bald eagle restoration), the U.S. Department of the Interior's tally of 44 golden eagles relocated from 1999 to 2006, the National Park Service and The Nature Conservancy report of 5,036 pigs removed from Santa Cruz Island in 2005-2006, and Channel Islands National Park materials (golden eagle predation as the cause of the northern decline; DDT and the loss of bald eagles; captive breeding begun in 1999; listing in 2004). The first bald eagle chick hatched without human help on the islands in 2006. The criteria in the callout were written for this worksheet as a fair framework; they are not the agencies' official recovery criteria. Keep the expert-round question in q1 short so groups have time for q3. Groups often over-credit captive breeding (the visible solution) and under-credit pig removal; q8 and q9 are designed to surface that. This sheet assesses the evaluation half of MS-LS2-5; the chapter's Lab 3 and Worksheet 9 ask students to design and justify their own combinations.

Scaffold offered to students: Root cause or symptom?

A symptom is what you see going wrong: foxes dying. A root cause is what keeps making it happen: golden eagles that stay because piglets feed them, and an empty bald eagle niche. A solution that treats a symptom works quickly but must keep going. A solution that removes a root cause may be slow but can stop the problem for good. For each solution card, ask: 'If we stopped doing this tomorrow, would the problem come back?'

Extension: Write card 13

Today, island fox managers worry most about disease, ticks and other threats arriving from the mainland. Write a thirteenth card in the same style as the others that proposes a new solution for keeping a disease such as canine distemper off the islands. Include its strengths and weaknesses and the constraint (scientific, economic or social) that would make it hardest to carry out. Then score it against criteria A to D and explain whether it should be combined with vaccination.