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To Tell the Truth:

Students Use DNA Barcodes to Unmask "Mislabeled" Fish at Grocery Stores, Restaurants

First students to apply DNA barcodes in public marketplace

One-quarter of 56 fish samples from 14 stores, restaurants in Upper Manhattan revealed to be cheaper or endangered fish species

Mozambique Tilapia sold as "White Tuna" in sushi

Students Kate Stoeckle and Louisa Strauss, together with barcoding experts, are available for advance interviews. The girls' article, to appear in the September edition of U.S. journal Pacific Fishing, is available for media preview, together with high-resolution photos, at http://phe.rockefeller.edu/mislabeledfish

Two New York City high school friends, curious about new DNA barcoding technology, discovered that fish at local stores and restaurants are commonly mislabeled and sold for far more than regular market price.

Worse, in two cases DNA barcode tests revealed that filleted fish sold as the popular Red Snapper (caught mostly off the southeast U.S. and in the Caribbean) was instead the endangered Acadian Redfish (which swims in the North Atlantic).

The report details the first known student use of the four-year-old DNA barcoding technology in a public marketplace. Based in part on the results, barcode scientists are developing sampling kits for schools – an educational program that could contribute to consumer protection at the same time.

Classmates Kate Stoeckle, 18, and Louisa Strauss, 17, of New York's Trinity School sent 60 fish samples from 14 restaurants and grocery stores in their Upper Manhattan neighbourhood to Canada's University of Guelph to obtain their genetic "barcodes," a quick, accurate identifier of a species based on a small portion of its DNA sequence.

Fifty-six barcode results, provided by the university, were compared against references in the Barcode of Life Data Systems library at Guelph's Biodiversity Institute of Ontario. Four of the samples were unidentifiable.

A quarter (14 of 56) of the usable samples were mislabeled – in all cases as higher-priced or more-desirable fish species.

The DNA of fish from a sushi restaurant, mislabeled "White Tuna" (also known as Albacore tuna) matched the barcode for Mozambique Tilapia, commonly raised on fish farms. Farmed, freshwater tilapia sells for a fraction of the price of wild tuna.

A restaurant menu entrée, said to be "Mediterranean Red Mullet," matched the DNA barcode of Spotted Goatfish, which inhabits the Caribbean.

Seven of nine samples said on packaging to be the popular "Red Snapper" were mislabeled. The DNA of those mislabeled fish matched these species:

- **Acadian Redfish** (www.fishbase.org/summary/speciessummary.php?id=3969)
  This species is listed as endangered by the International Union for Conservation of Nature. It comes from the Gulf of St. Lawrence and the shelf waters off Nova Scotia, as well as off Iceland and western Greenland.

- **Nile Perch (www.eol.org/taxa/17063361)**
  A freshwater fish widespread throughout Africa.
  (While small pieces of flesh from a Red Snapper and a Perch might be hard to distinguish by eye, visual comparison of the entire fish – see *http://phe.rockefeller.edu/mislabeledfish* – gives a comic dimension to Kate and Louisa's report.)

- **Lavender Jobfish (www.eol.org/taxa/17154528)**
  A sea fish from the Indo-Pacific (East Africa to Hawaii, and north to Japan); and

- **Slender Pinjalo (www.eol.org/taxa/17056441)**

  Also from the Indo-Pacific (Laccadive Islands to Fiji, north to the Ryukyu Islands).

The girls do not publicly identify the retailers and restaurants sampled.

"Many fish are hard to tell apart once they've been cut up and packaged," says Louisa Strauss. "We hope our work helps to get mislabeled and endangered fish species out of grocery store refrigerators and restaurant frying pans. We think there should be routine DNA barcoding of fish to make sure consumers get what they pay for and to make sure that protected fish are not sold illegally."

"We first learned about DNA barcoding from my Dad but had no idea we were the first students to use it to test what restaurants and fish stores are selling," said Kate, whose father, Dr. Mark Stoeckle, MD, is a bird barcoding expert and Adjunct Faculty Member of the Program for the Human Environment at New York's Rockefeller University. "We hope to get schoolmates interested in doing a larger investigation of fish markets and restaurants in other parts of New York City."

Adds Kate "I think this sleuthing project may be part of a family tradition; my grandmother, Kitty Carlisle Hart, was a panelist for many years on the TV game show ***To Tell The Truth***."

The pair prepared a short paper on their research, published by the U.S. trade journal Pacific Fishing (including a short article explaining how they did it, step-by-step).

In it they write: "We are not certain where the mislabeling occurs, but it seems it is not the fishermen, since the mislabeled fish are from completely different parts of the world. For example, if a fishing boat arrives at a dock in Florida, it is unlikely that it carries fish from Southeast Asia. Perhaps the mislabeling occurs somewhere in the middle, when the fish are filleted and no longer easily identifiable."

The do-it-yourself materials required to sequence the DNA from a piece of fish cost less than $10 and "it's easy to do," say Kate and Louisa. "And, once you have your DNA sequences it is easy to copy and 'paste' these into the 'Identification Engine' on the Barcode of Life Database. However, because some closely-related species have similar DNA barcodes, you need an expert to help with analyzing the data."

“This report signals to food and health authorities worldwide how simple and easy it is today to spot check and certify fish in the market, which would protect both consumers and depleted species,” says Meryl Williams, former Executive Director of the WorldFish Center in Malaysia and a leader of the Census of Marine Life research program, which is inventorying all the world’s fish species.

“We can’t call the findings by these students a fire alarm for consumers but they have certainly pointed to significant smoke.”

Barcode factories

“From the beginnings of DNA barcoding, scientists have envisioned moving the technology out of laboratories and into the protection of consumers, health, endangered species and borders,” says Dr. Bob Hanner of Guelph, who oversaw the samples analysis by student Eugene Wong.

In June, Dr. Hanner and colleagues published an article on DNA barcoding of Canadian freashwater fish, which elaborates the scientific underpinning of Kate and Louisa’s investigation (see www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0002490). He has also co-authored an upcoming article on using DNA barcodes to reveal the substitution of seafood in North American markets, describing the potential use of barcodes to harmonize across jurisdictions various names for the same fish.

At the Guelph “barcode factory,” and at a sister facility at the Smithsonian Institution in Washington, D.C, researchers can identify and distinguish known and unknown species of fish and other animals quickly, cheaply, easily and accurately based on a short portion of its full DNA sequence. Their work uncovers much hidden diversity, some of which has led to the description of new species.

A single research paper in 2003 by Guelph Professor Paul Hebert and colleagues spawned a burgeoning global initiative, co-ordinated by the Consortium for the Barcode of Life (CBOL) with 160 member organizations from 50 countries (up from 42 member organizations from 18 countries in 2005).

Says David Schindel, Executive Secretary of the CBOL, based at the Smithsonian Institution: "Substituted, mislabeled fish offered in supermarkets and restaurants may be endangered species or pose health problems – toxic pufferfish sold as something else, for example. Barcoding could help close important markets to fish illegally caught and marketed."

Barcoders anticipate many requests from all over the world as government agencies and others apply the technology to consumer protection, food safety, environmental monitoring and detecting the spread of invasive species.

The US National Oceanic and Atmospheric Administration, for example, envisions such potential barcode uses as:

- Reliable identification of catch and by-catch on vessels and at the dock;
- Analysis of gut contents to understand food chains in the ocean; and
- Assessment of fish stocks by identifying fish larvae as well as juveniles and adults.

DNA barcodes may also help slow invasions of pests via international trade, reduce bird-plane collisions, and pinpoint the breeding hideouts of disease-spreading mosquitoes. DNA barcoding of trees is expected to help get illegal timber out of global markets.

Scientists have cataloged barcodes for about 46,000 animal species of all types so far (www.barcodinglife.org). Whenever possible, scientists have used museum specimens to create the barcode reference library, enabling them to check and verify puzzling results.

Marine Barcode of Life Campaign Coordinator Dirk Steinke emphasizes the increasing importance of completing the world's collection of fish barcodes.

"To date, barcodes from about 5,400 fish species have been recorded. Some 30,000 fish species are described in the scientific literature, however, so there is a long way to go," says Dr. Steinke.

The barcoders are looking to raise US $150 million to create 5 million records from 500,000 animal species by 2014 via the International Barcode of Life Project. The Governments of Ontario and Australia recently committed more than $6.7 million to the effort, and the Alfred P. Sloan Foundation $3.25 million.

Experts predict that in a few years researchers in the field, indeed any interested citizen, could employ hand-held DNA devices to identify species almost instantly.

Says Jesse Ausubel, Director of Rockefeller University's Program for the Human Environment: "For Kate and Louisa, DNA barcoding seemed as natural as instant messaging. In 10 years no one will believe there was a time before DNA was used for species identifications."

"The initiative and the intellectual curiosity that Kate and Louisa exhibited by pursuing this project is an inspiring example of what this generation has to offer," said Suellyn Preston Scull, acting head of school at Trinity. "The increasingly interconnected world in which we live requires citizens who exercise rigorous and passionate intellectual inquiry, using the best tools to get the job done. Their work demonstrates how essential a liberal education is for our future and the Trinity School community celebrates their achievement."

Kate and Louisa will enroll at Johns Hopkins University this fall.

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About Rockefeller University: Please see: www.rockefeller.edu/about.php

About Trinity School: Founded in 1709 as a charity school for the parish of Trinity Church, Wall Street, Trinity School is the oldest continuously operating educational institution in New York City. Celebrating its 300th year in 2008-2009, the School is deeply committed to the conversation between student and teacher, to rigorous and passionate intellectual inquiry, and to engaging fully in the city, nation, and world of which we are a part. www.trinityschoolnyc.org

Annex 1: **Mislabeled fish (14 of 56 samples)**

a) = Package label / menu name
b) = DNA barcode match:

1a) Mediterranean Red Mullet
1b) Spotted Goatfish (*Pseudupeneus maculates*), a Caribbean fish

2a) White Tuna sushi
2b) Mozambique Tilapia (*Oreochromis mossambicus*)

3a) Sea Bass sushi
3b) Striped Bass (*Morone saxatalis*). According to the U.S. Food and Drug Administration: "Sea Bass" can refer to various fishes; none are in Morone genus, however.

4a) Sea Bass
4b) White Bass (*Morone chrysops*), a freshwater fish, often farmed.

5a) Red Snapper sushi
5b) Atlantic Cod (*Gadus morhua*).

6a and 7a) Red Snapper fillet
6b and 7b) Acadian Redfish (*Sebastes fasciatus*) **IUCN Red List status: endangered**

8a and 9a) Red Snapper fillet, U.S. caught wild
8b and 9b) Lavender Jobfish (*Pristipomoides sieboldii*)

10a) Red Snapper fillet, frozen-thawed
10b) Slender Pinjalo (*Pinjalo lewisi*)

11a) Red Snapper fillet
11b) Nile Perch (*Lates niloticus*)

12a) Tobiko Flying Fish Roe
12b) Smelt or Capelin (*Mallotus villosus*)

13a) White Snapper
13b) White Hake (*Urophycis tenuis*) (hakes are in a different Order from snappers)

14a) Kingfish
14b) King Mackerel (aka Spanish Mackerel), (*Scomberomorus cavalla*) – not an FDA approved market name for this fish; Kingfish should refer to various "Whitings" (Menticirrhus sp)

Useful links:

- Barcode of Life Database : www.barcodinglife.org
- Consortium for the Barcode of Life: barcoding.si.edu
- Barcoding marine species: www.marinebarcoding.org
- FishBol: www.fishbol.org
- Barcoding blog: http://phe.rockefeller.edu/barcode/blog
- Ten Reasons for Barcoding Life: http://phe.rockefeller.edu/barcode/docs/TenReasonsBarcoding.pdf