Where are all the fish going? Identifying patterns of genetic connectivity across the Hawaiian Archipelago

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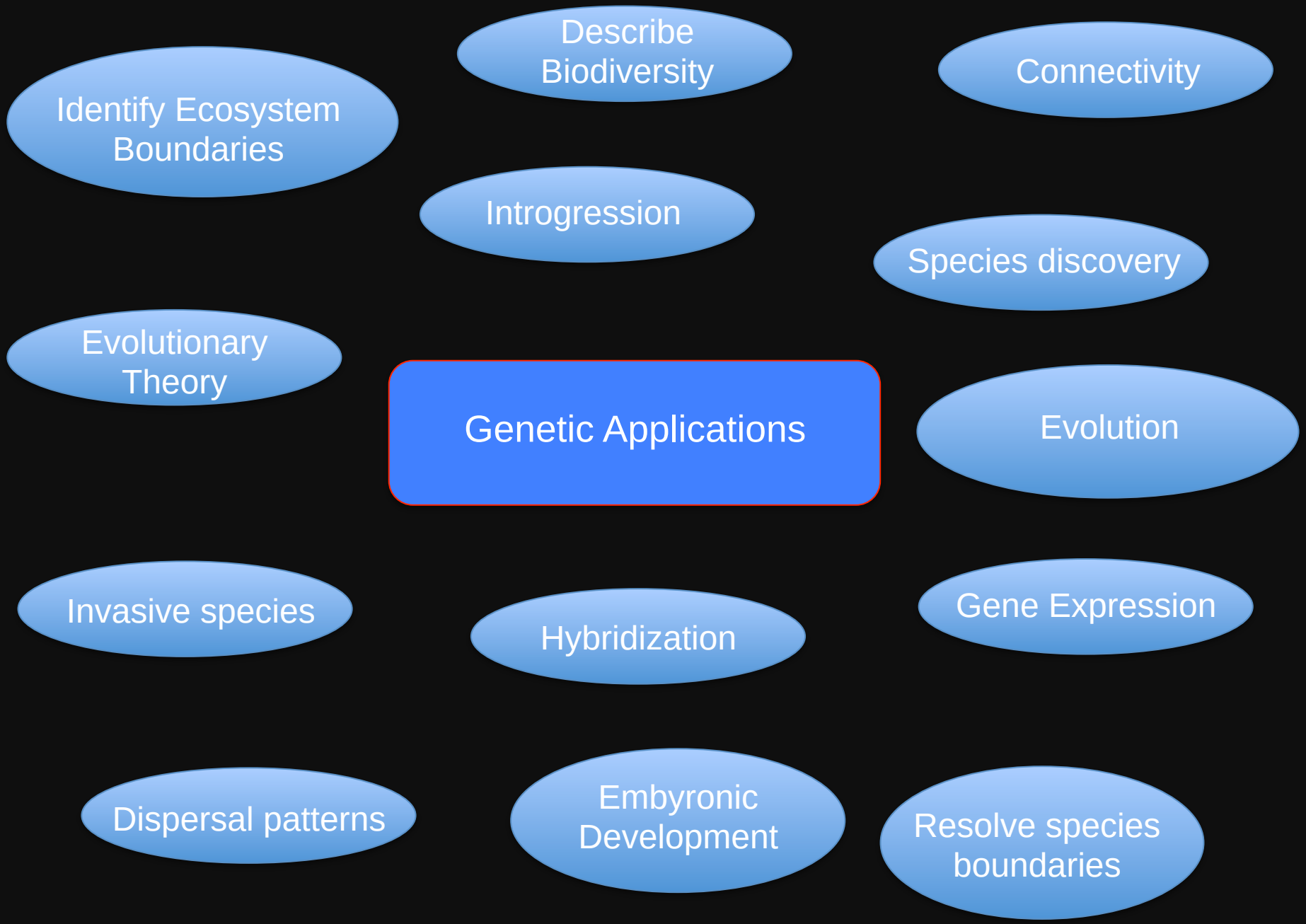
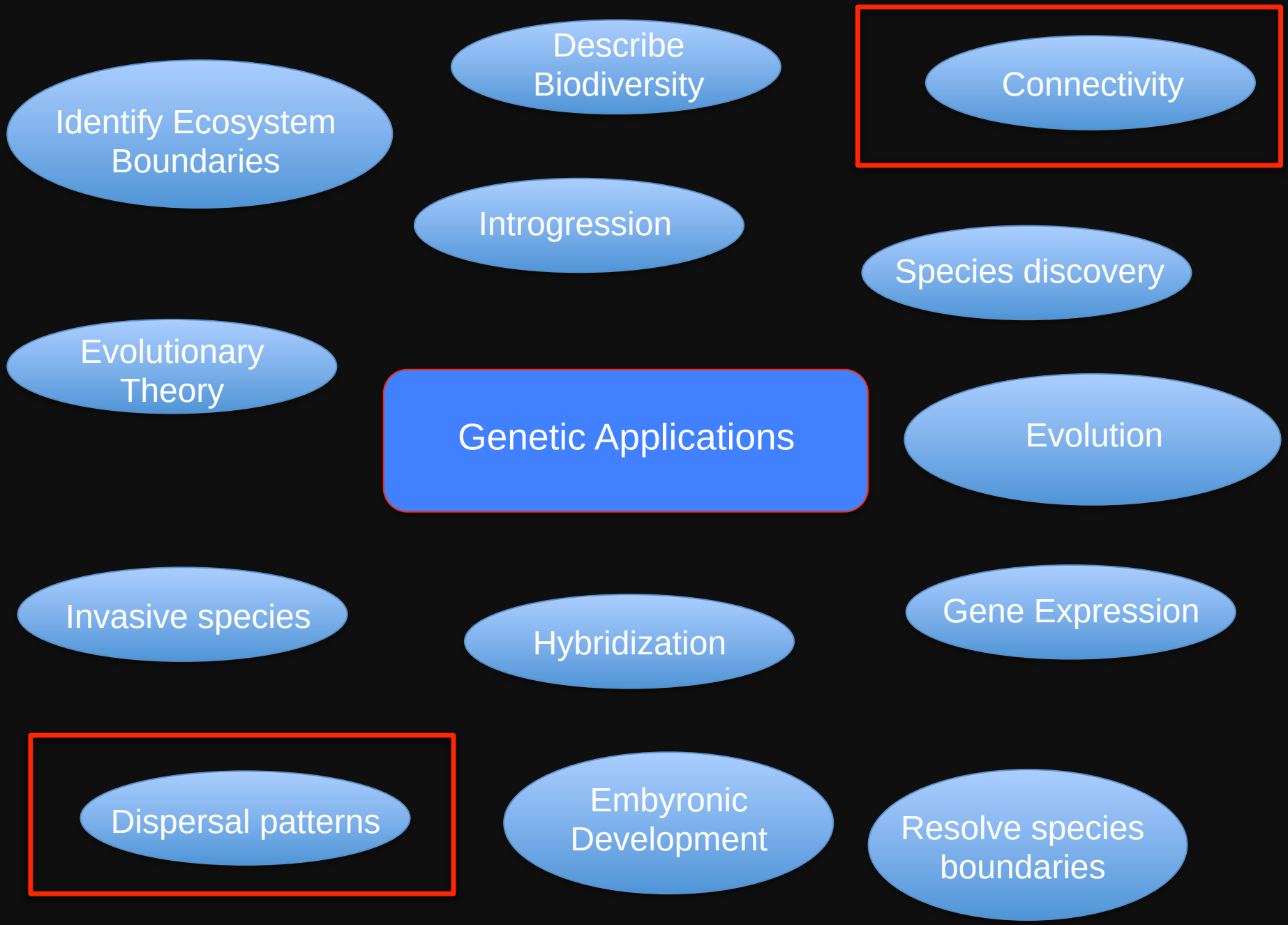
24 September 2019
National Marine Sanctuaries Webinar Series


Describe Biodiversity
Connectivity
Identify Ecosystem Boundaries
Introgression
Species discovery
Evolutionary Theory
Genetic Applications
Evolution
Invasive species
Hybridization
Gene Expression
Dispersal patterns
Embyronic Development
Resolve species boundaries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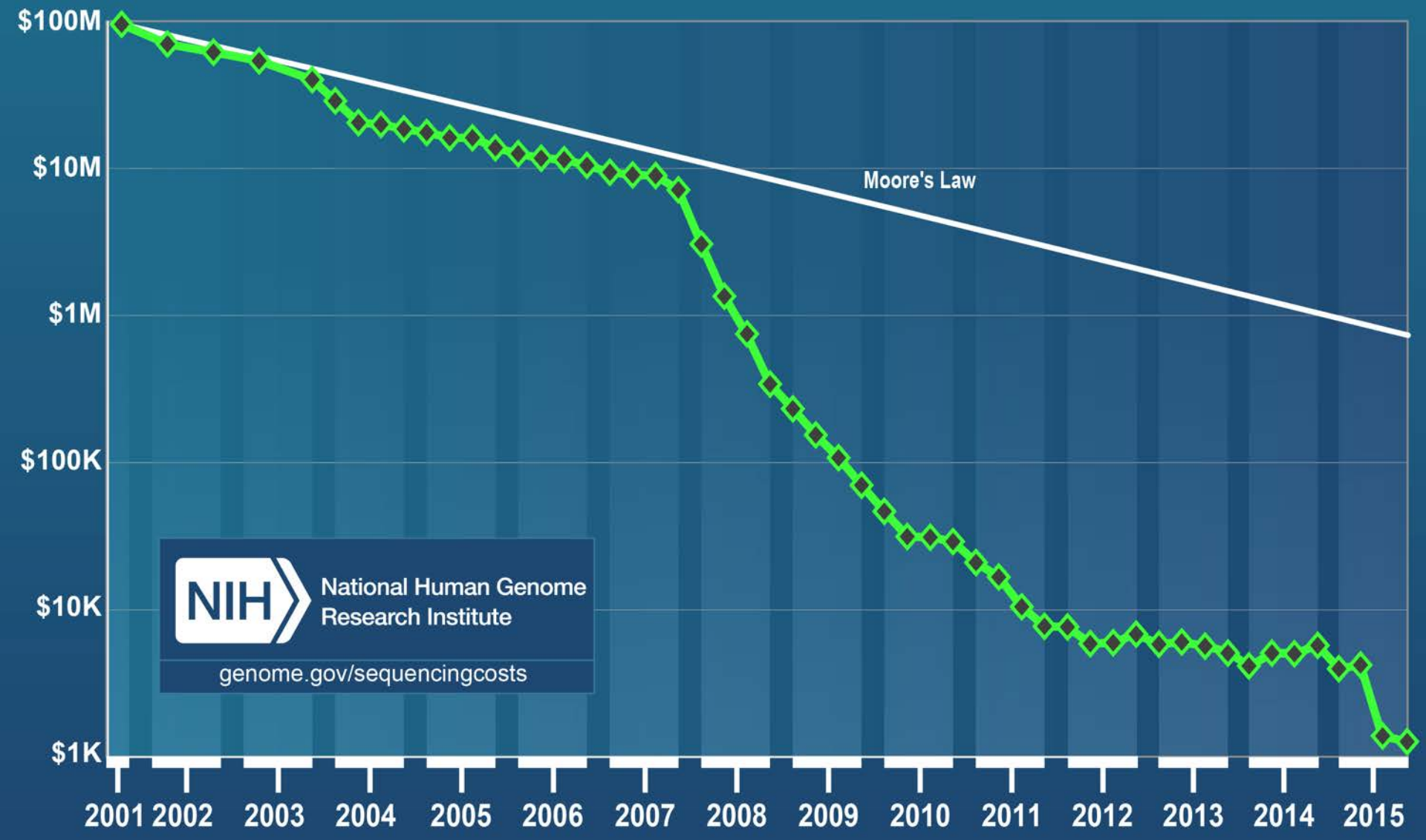
Brief History of Genetics

- 1859 – “On the origin of species” Theory of Evolution by Natural Selection
- 1865 – Gregor Mendel’s pea experiments
- 1869 – DNA isolated
- 1953 – DNA double helix described (Watson, Crick, Franklin, Wilkins)
- 1966 – Genetic code cracked
- 1975 – DNA Sequencing
- 1983 – PCR invented
- 1995 – First genome sequenced
- 2002 – First mammal genome sequenced
- 2003 – Human genome sequenced
- 2005 – Second generation sequencing (Roche 454)
- 2006 – Illumina sequencing (accounts for >70% of the market)

Cost per Genome



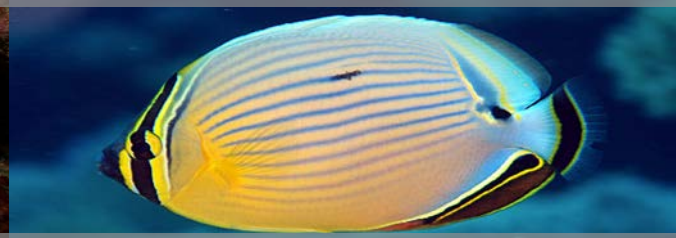
Skillings et al. 2014

Timmers et al. 2012

Andrews et al. 2010

Ahti et al. 2016

Johnston et al. 2017



Waldrop et al. 2016

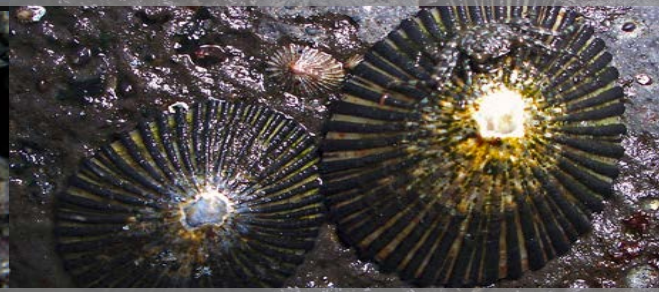
Gaither et al. 2013

Iacchei et al. 2015

Fernandez-Silva et al. 2016

Puritz & Toonen 2011

DiBattista et al. 2013



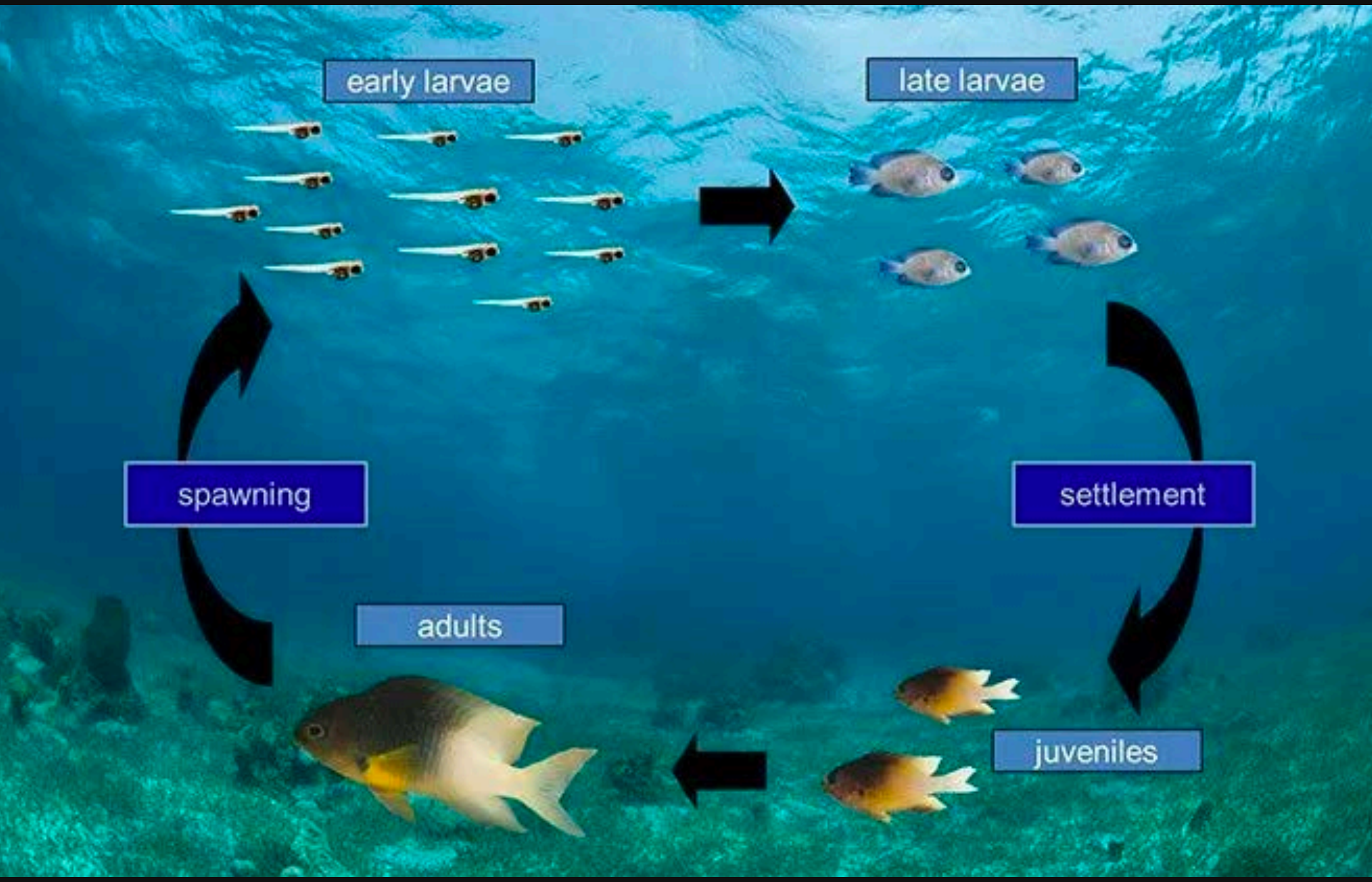
Bird et al. 2013

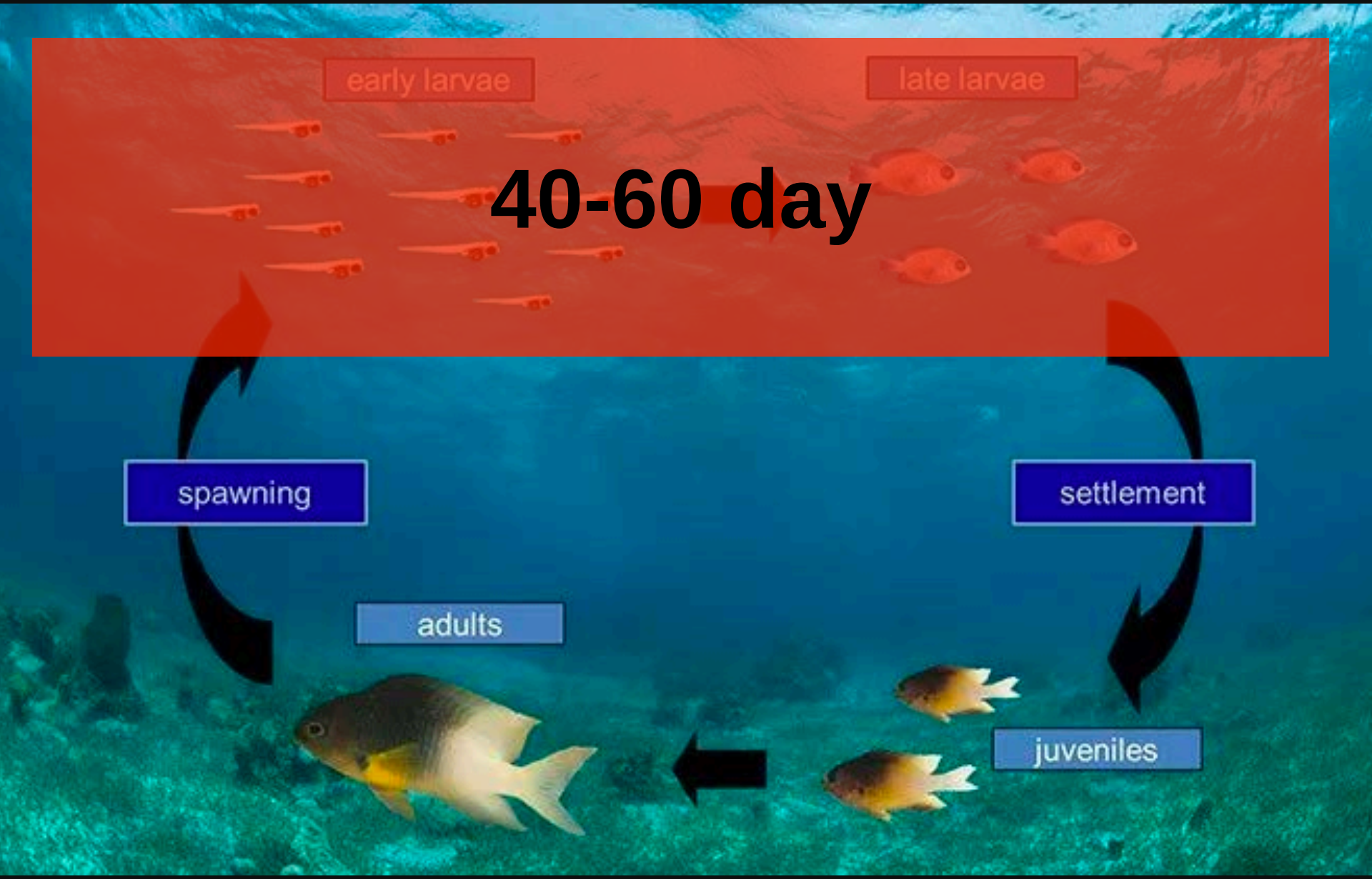
Importance of Understanding Connectivity

- Provides insights into the mechanisms that influence evolution
- Information can be used to inform management and conservation strategies

Informing proper management

- Barriers to dispersal
- Identify vulnerable areas and management units
- Characterize source-sink populations
  - “Source” populations
    - Populations that are responsible for seeding other areas
  - “Sink” populations
    - Regions that are dependent on other populations


early larvae
late larvae
settlement
juveniles
adults
spawning


early larvae
late larvae
40-60 day
spawning
settlement
adults
juveniles

Population Connectivity

Population Connectivity

Population Connectivity

Population Connectivity

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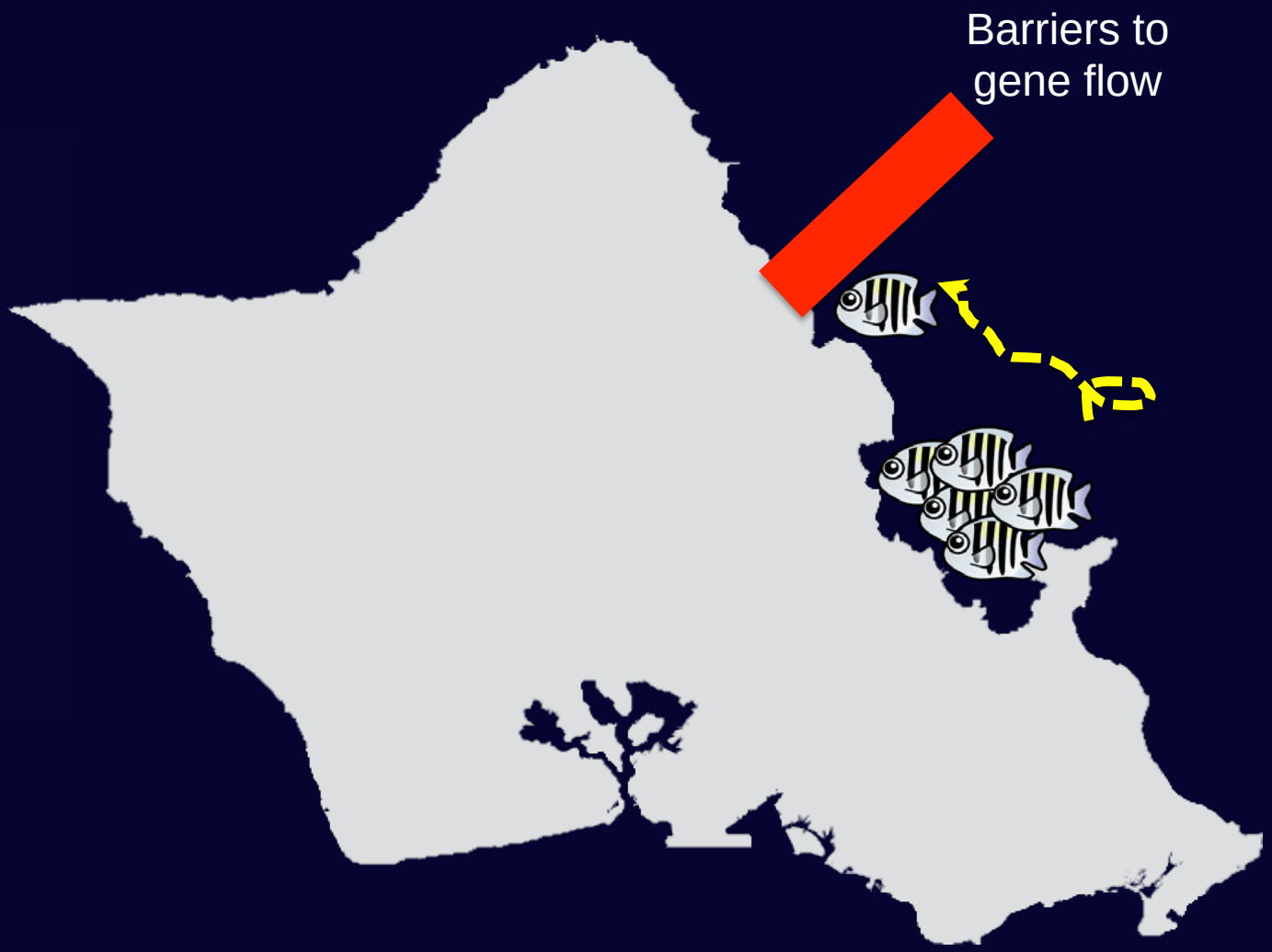
Population Connectivity

Population Connectivity



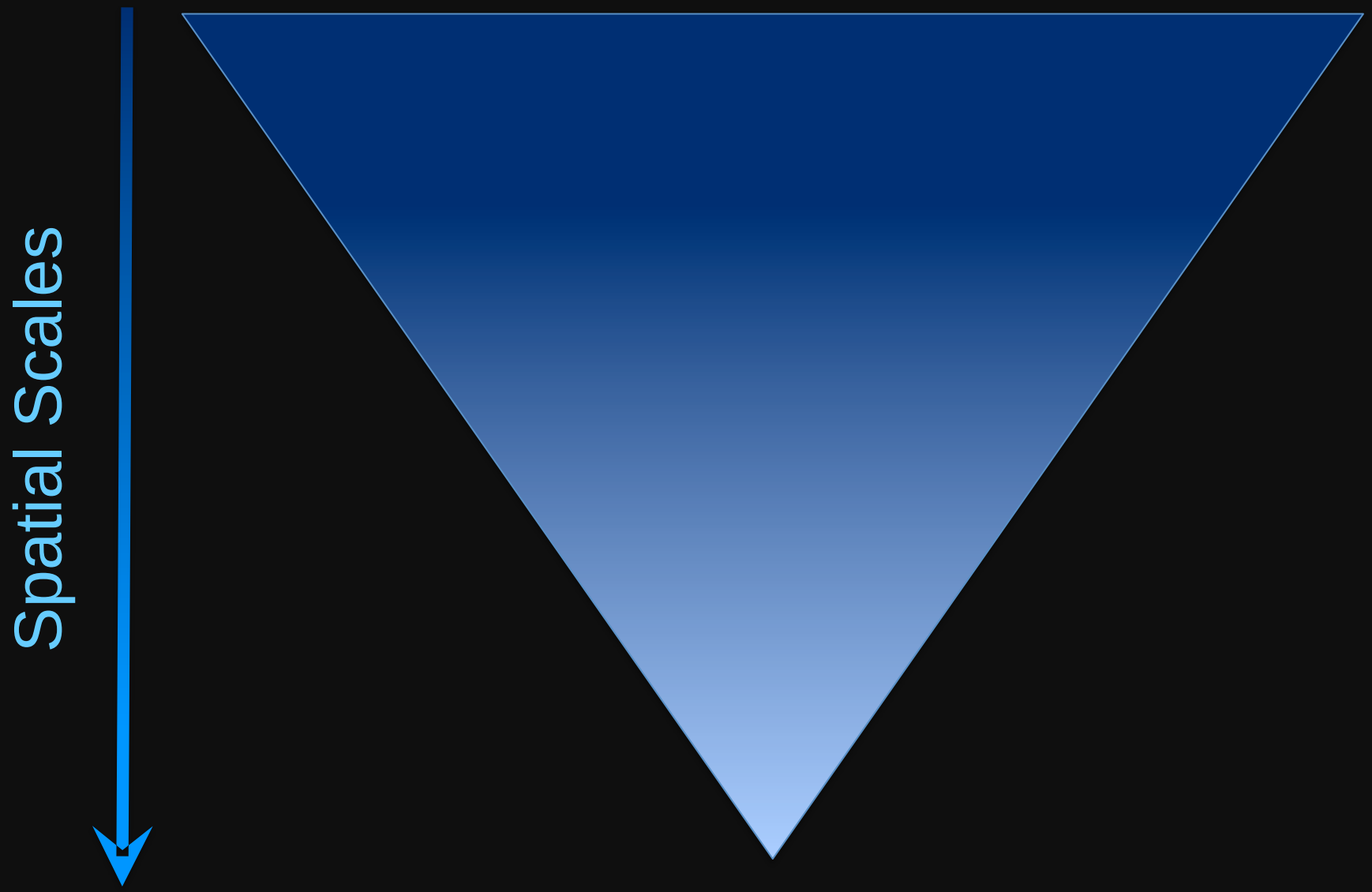
Barriers to dispersal in terrestrial systems

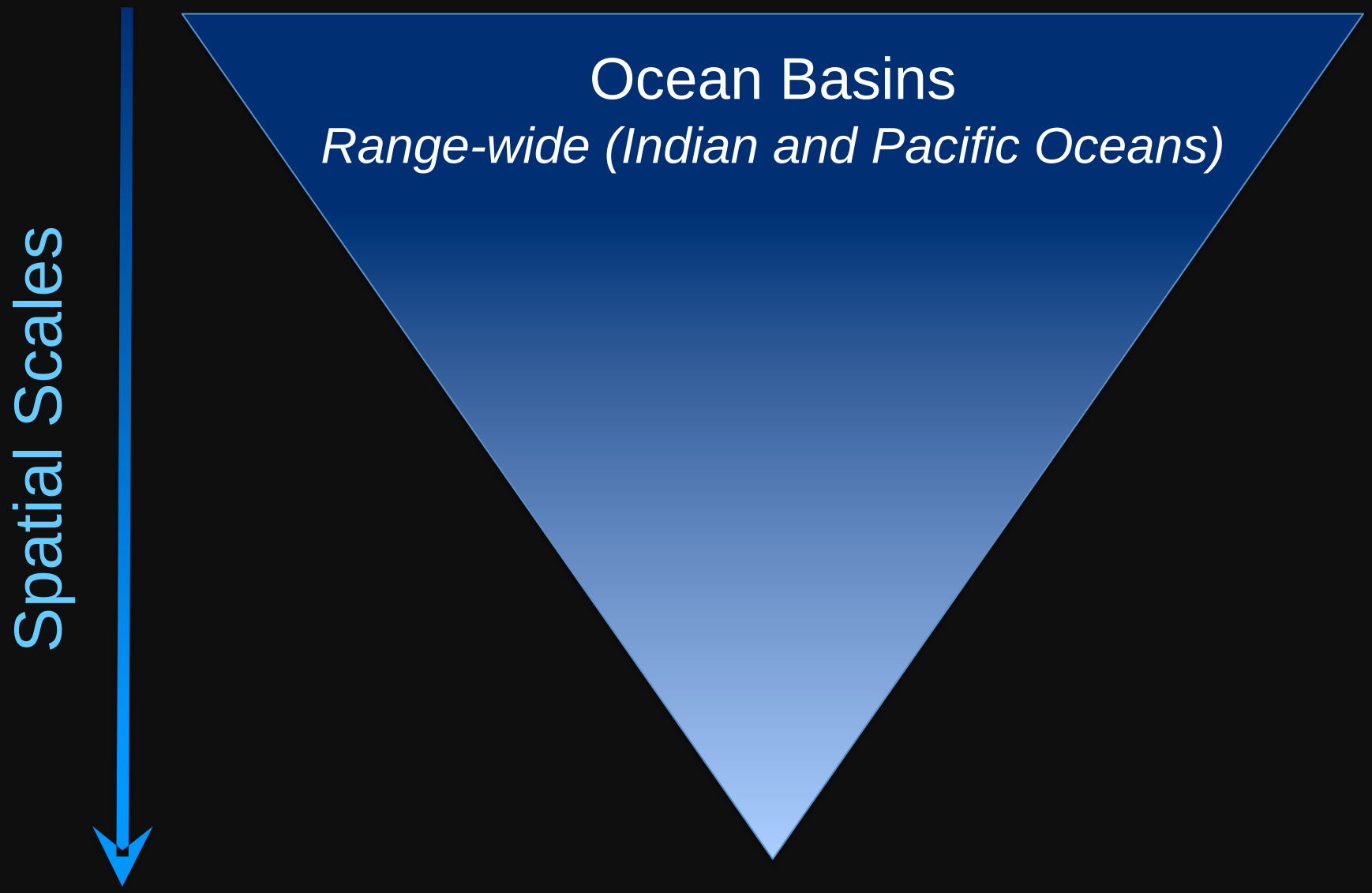
wallpaperswiki.com

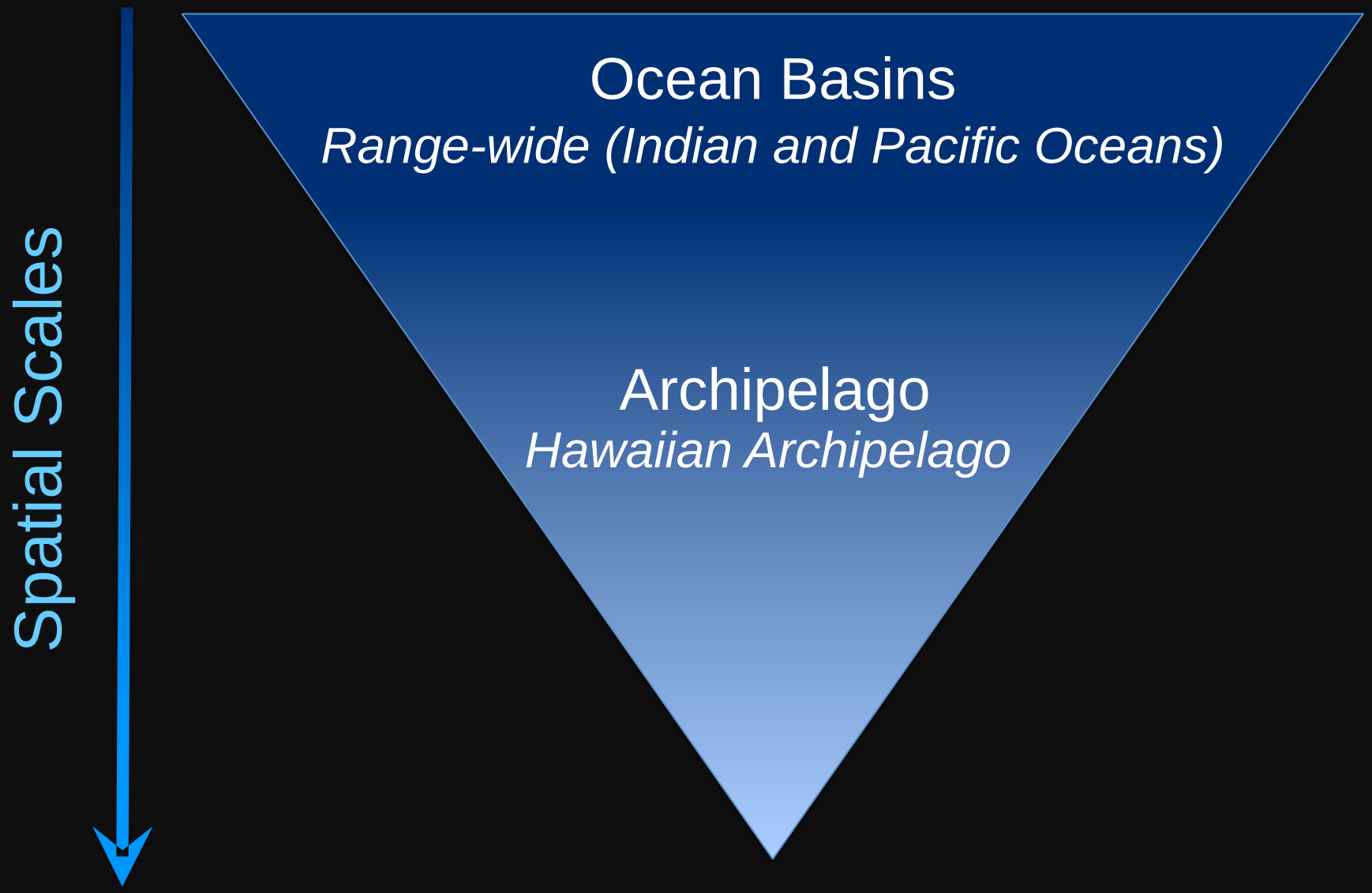
- Often easy to identify
- Examples:
  - Rivers
  - Mountain Ranges
  - Islands

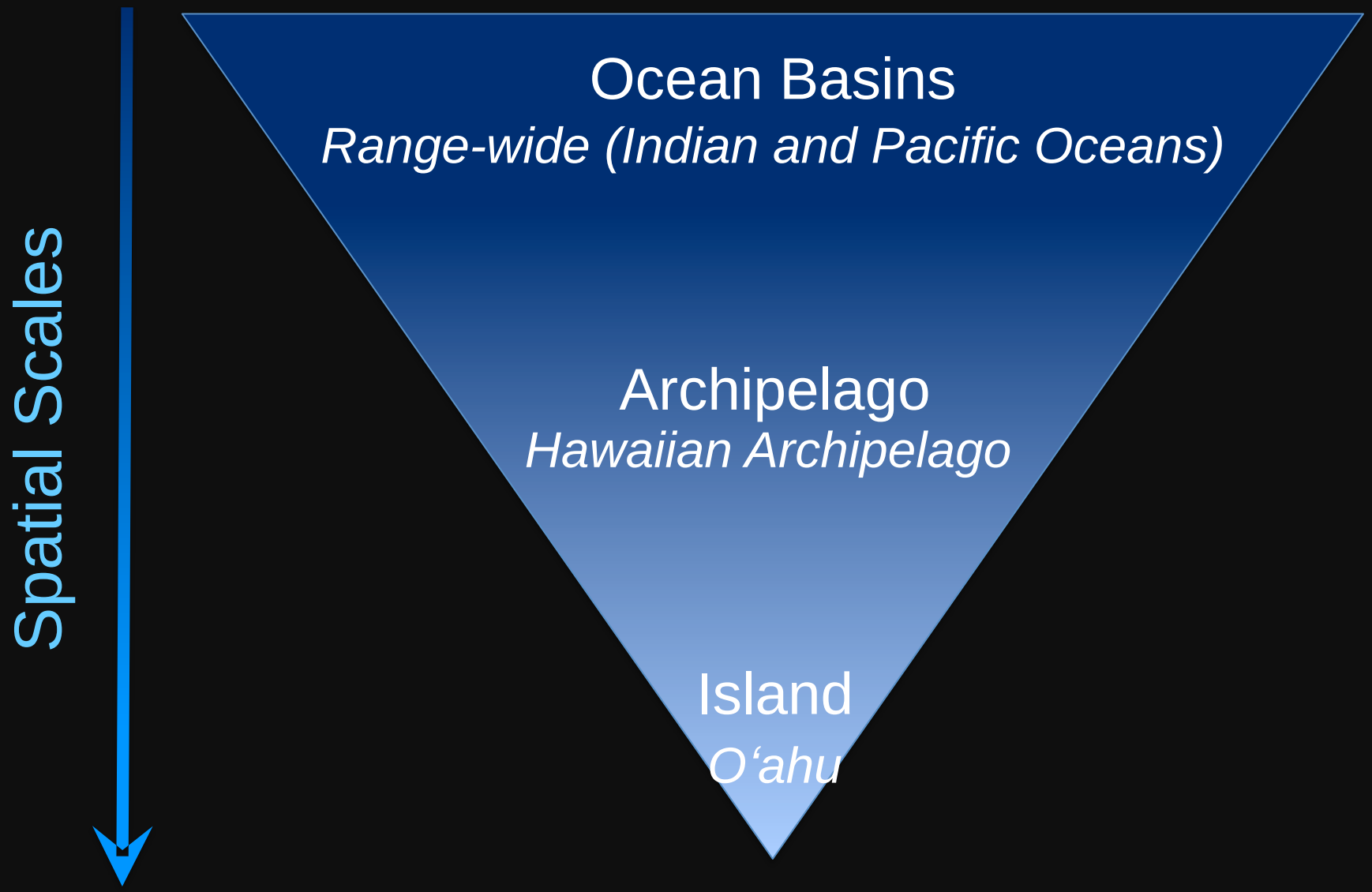
Barriers in marine systems

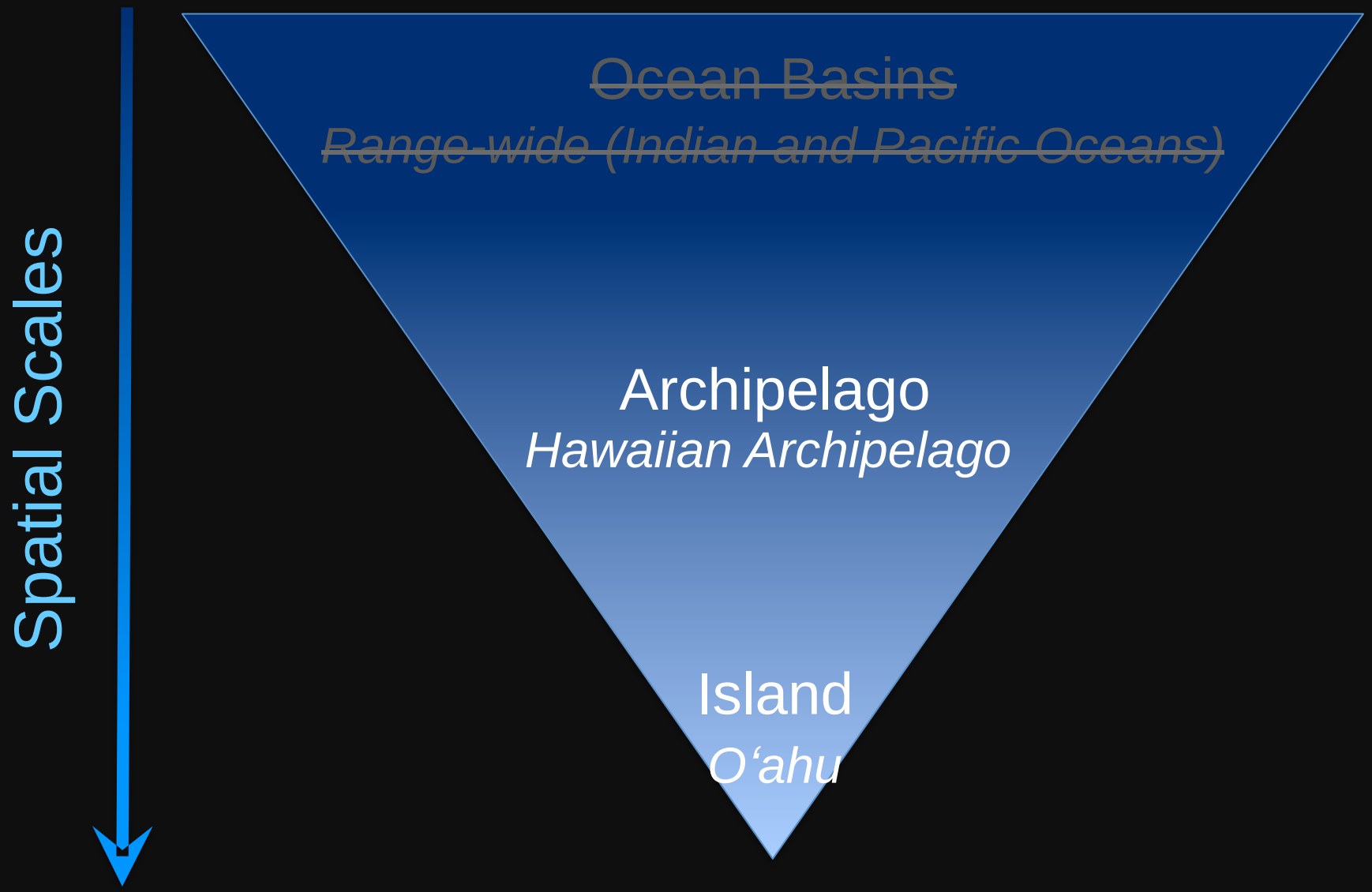
Most marine organisms have larvae that can drift for weeks to months


Spatial Scales


Spatial Scales
Ocean Basins
Range-wide (Indian and Pacific Oceans)


Spatial Scales
Ocean Basins
Range-wide (Indian and Pacific Oceans)
Archipelago
Hawaiian Archipelago


Spatial Scales
Ocean Basins
Range-wide (Indian and Pacific Oceans)
Archipelago
Hawaiian Archipelago
Island
O‘ahu


Spatial Scales
~~Ocean Basins~~
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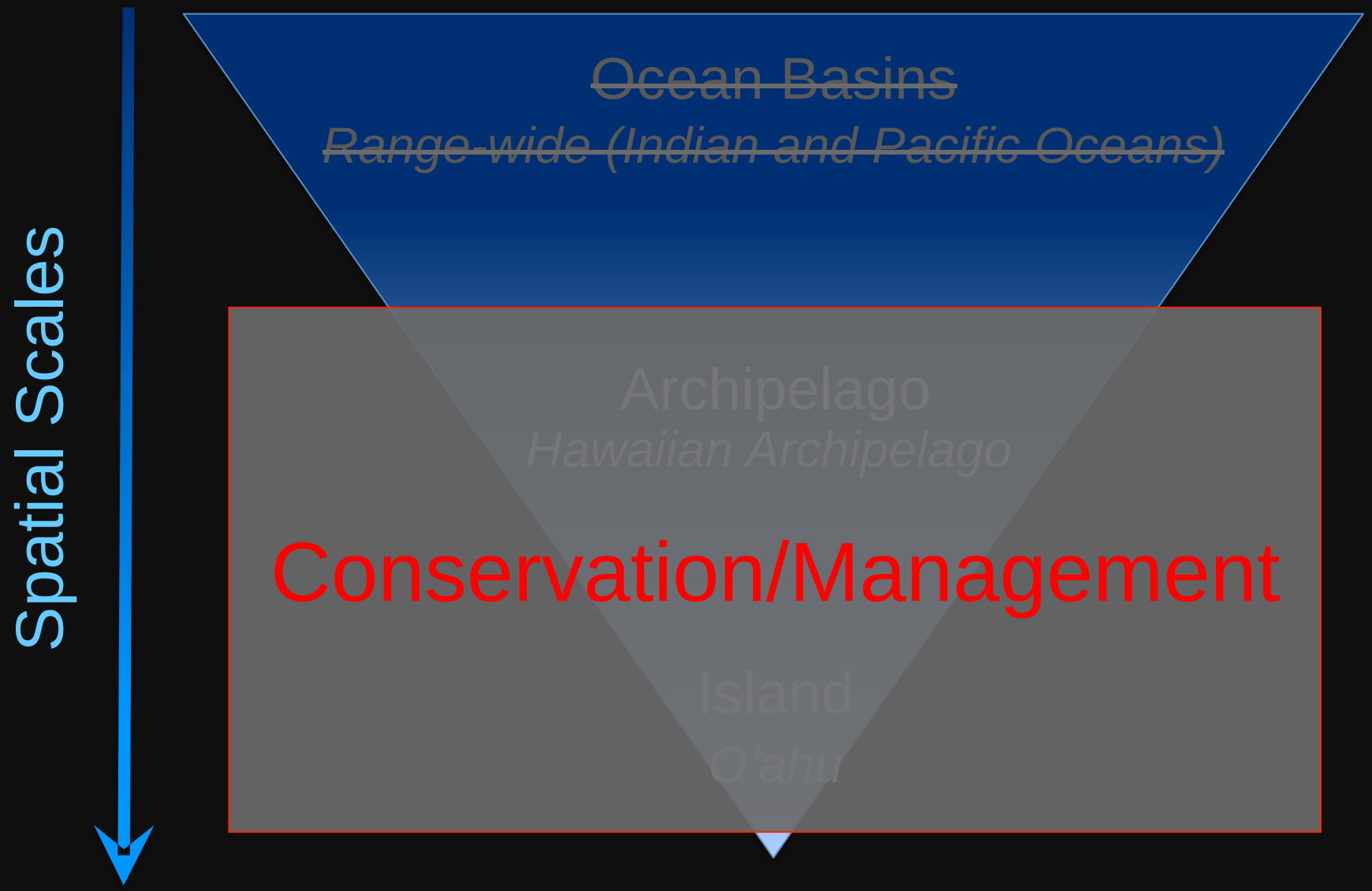
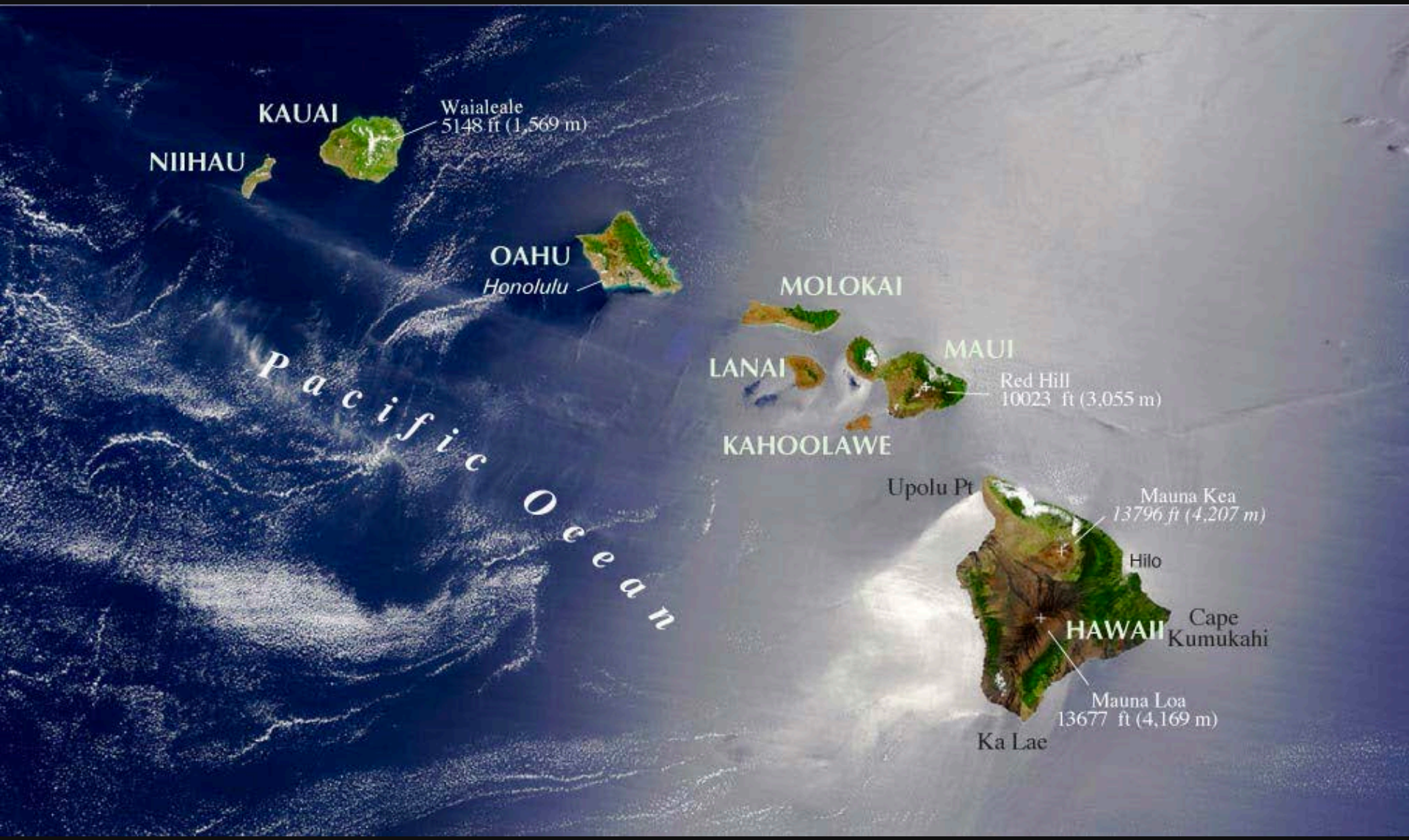
Archipelago
Hawaiian Archipelago
Island
O‘ahu

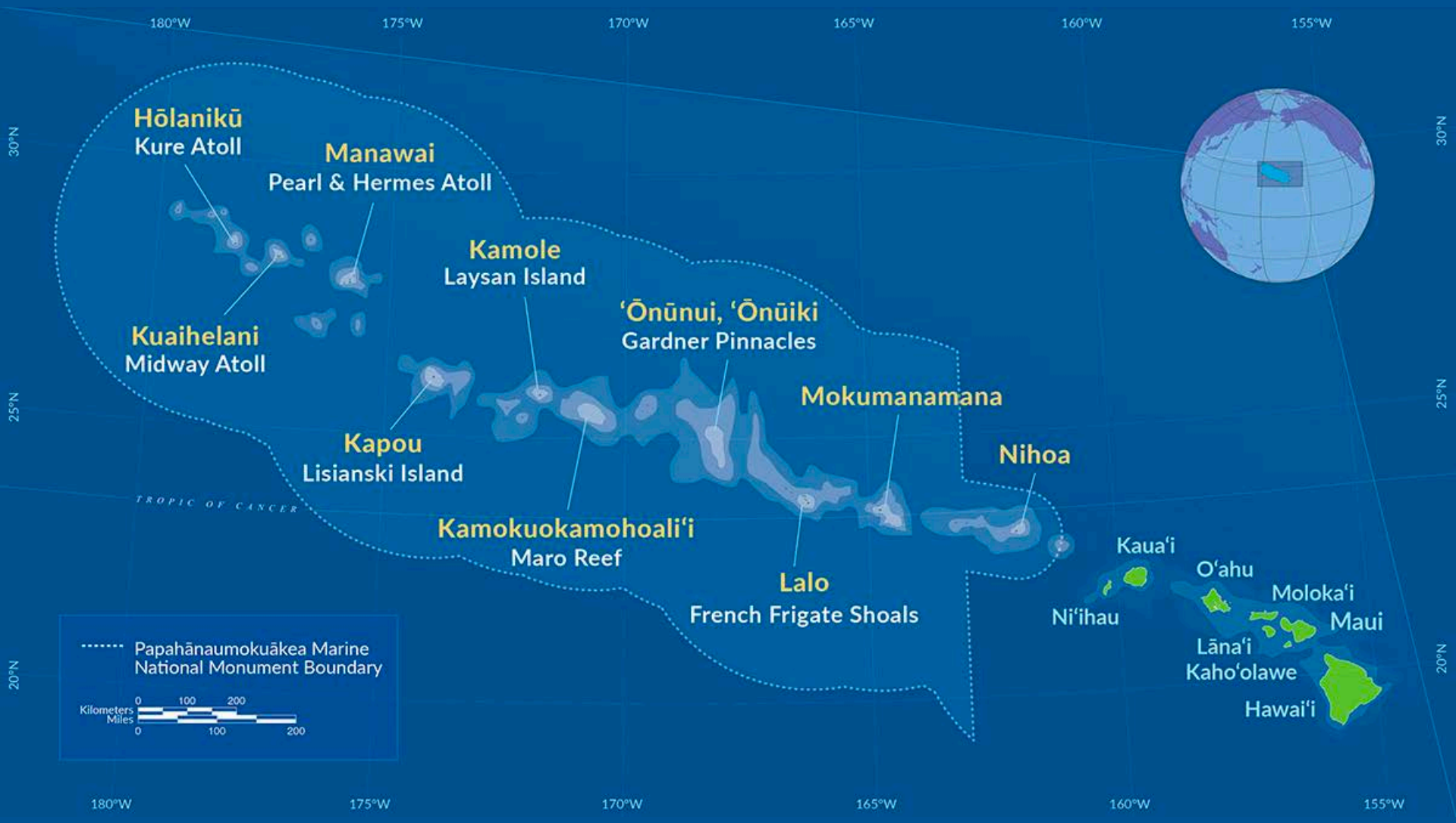

Spatial Scales
~~Ocean Basins~~
~~*Range-wide (Indian and Pacific Oceans)*~~
Archipelago
Hawaiian Archipelago
Conservation/Management
Island
O'ahu

Archipelago | Island



Archipelago	Island

Hawaiian Archipelago



Archipelago	Island

Main Hawaiian Islands

Archipelago | Island

Papahānaumokuākea Marine National Monunment

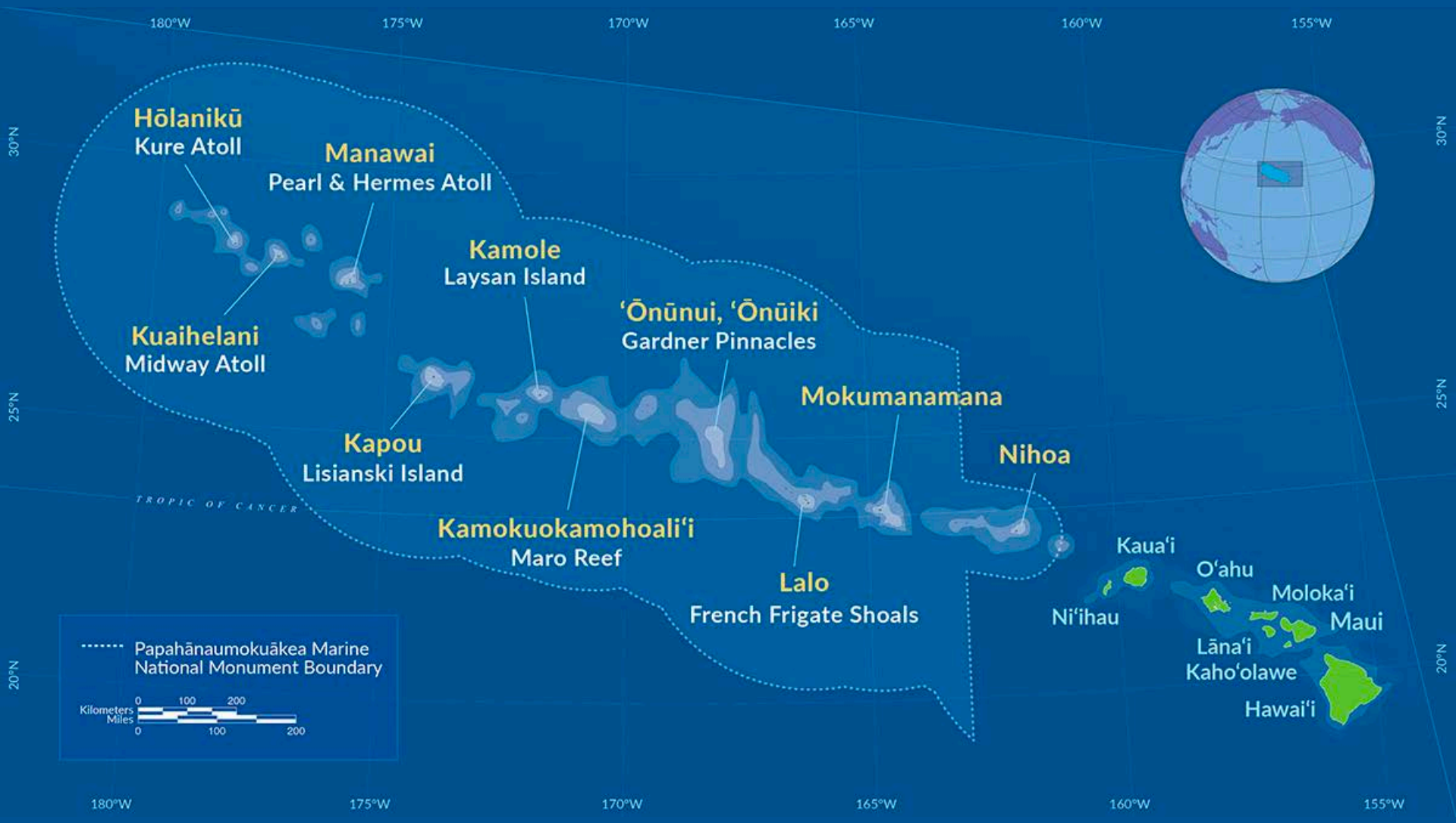
Archipelago | Island

Archipelago | Island

Map of the USA with the Hawaiian Archipelago overlaid. Black outline shows the boundary of the Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve, which is 1200 Nautical Miles long by 100 Nautical Miles wide and has an area roughly the same size as Florida and Georgia combined, or 131,800 square statute miles.

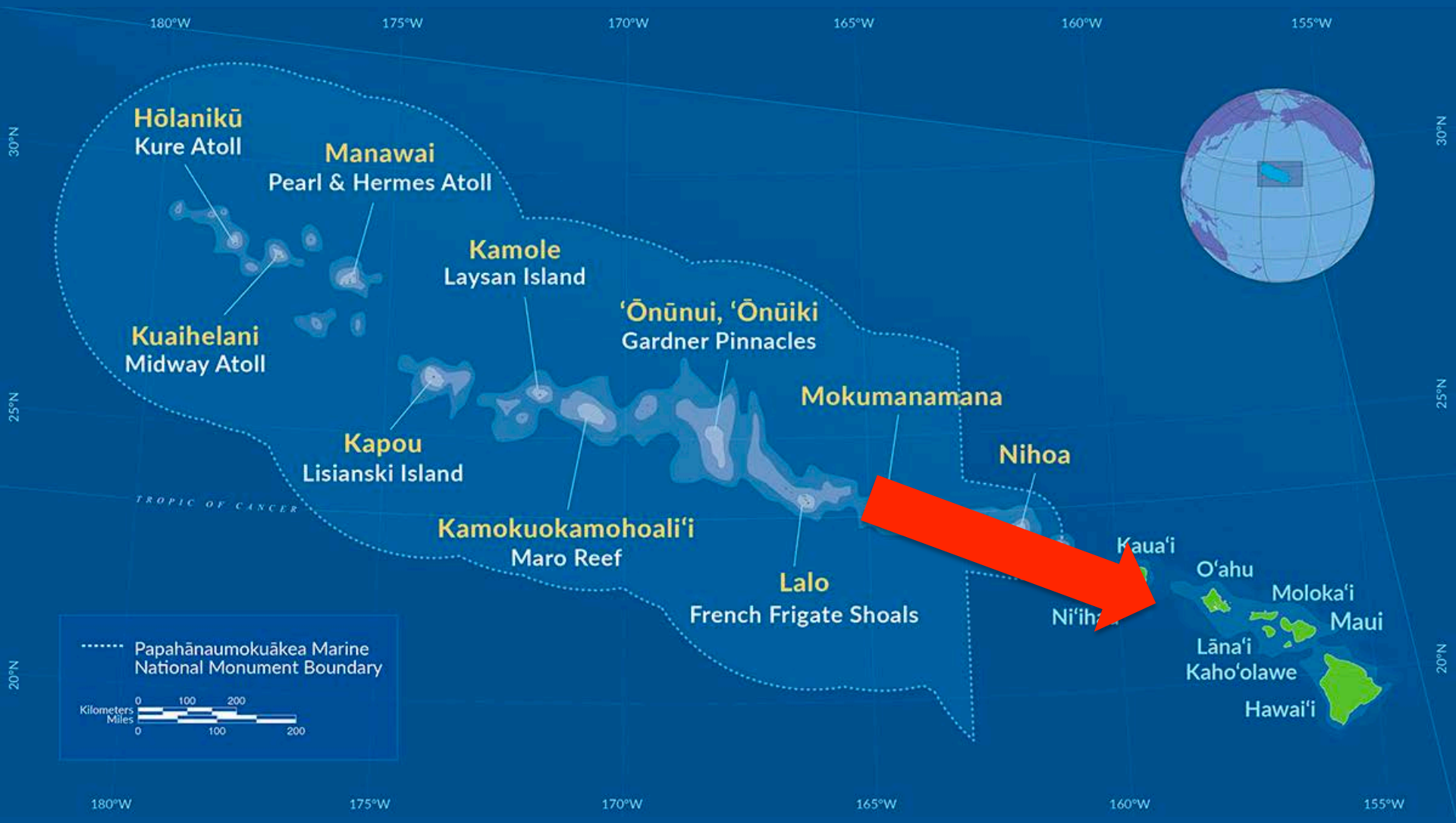
Archipelago	Island

Hawaiian Archipelago



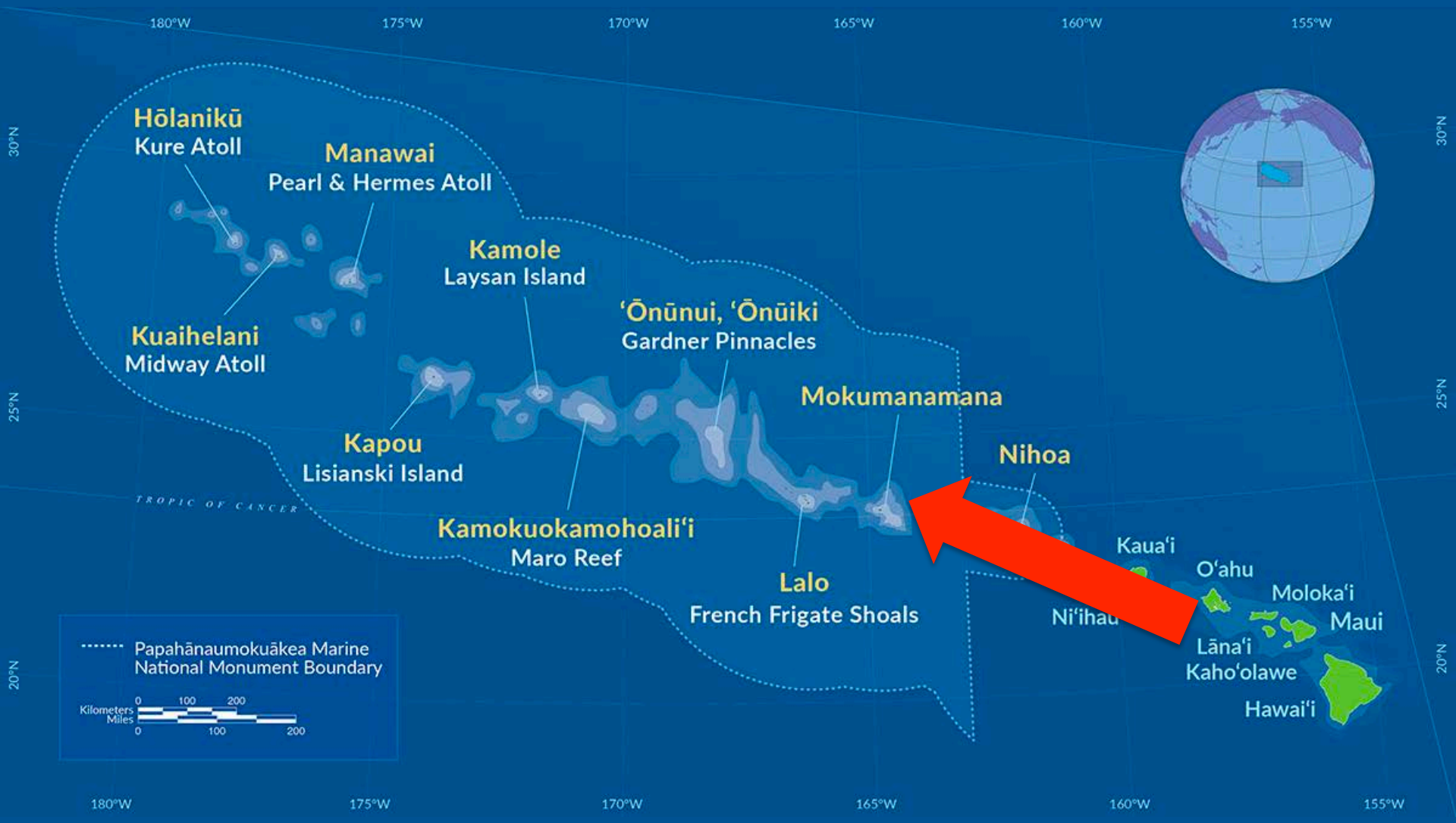
Archipelago	Island

Hawaiian Archipelago



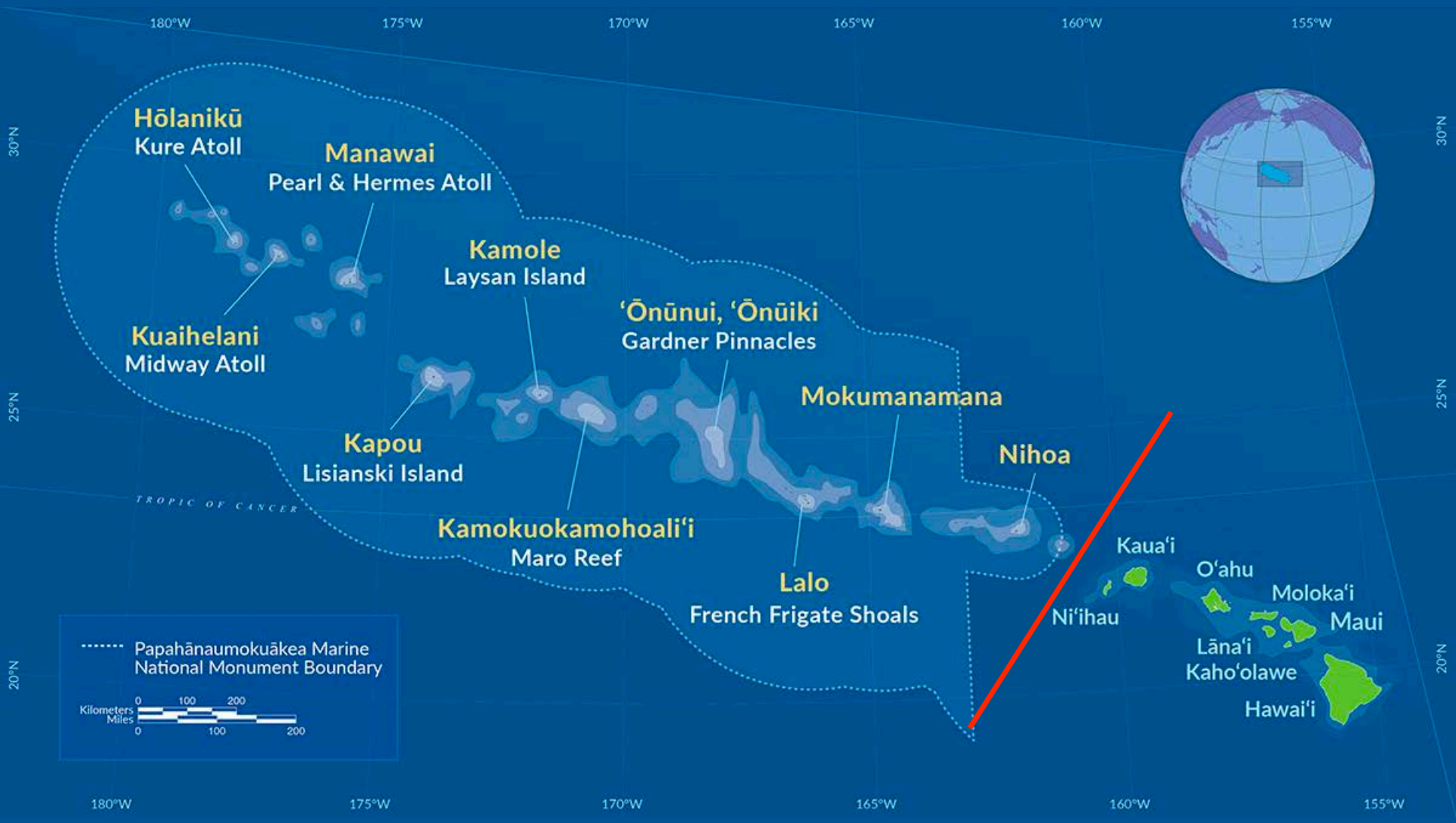
Archipelago	Island

Hawaiian Archipelago



Archipelago	Island

Hawaiian Archipelago



Archipelago	Island

Archipelago

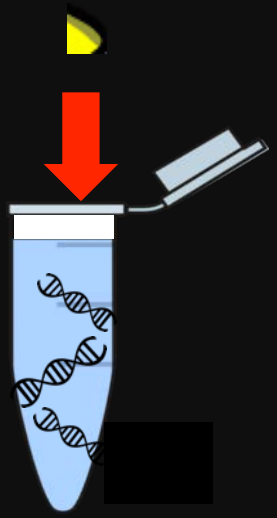
Island

Genetic methods

Collect tissue sample

Genetic methods

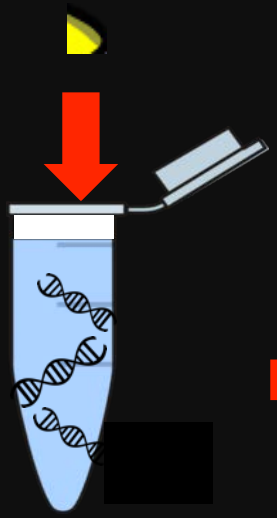
Collect tissue sample



Extract & Isolate DNA

Genetic methods

Collect tissue sample

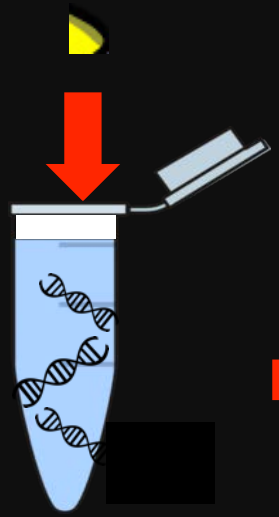


Extract & Isolate DNA

Sequence DNA

Genetic methods

Collect tissue sample



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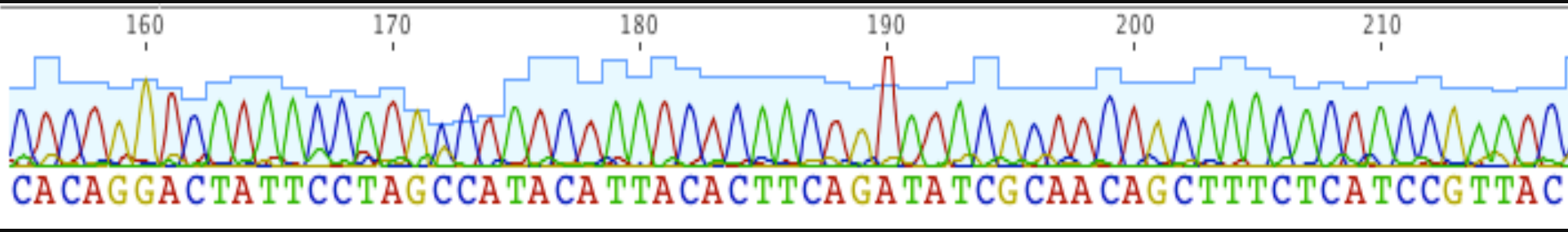
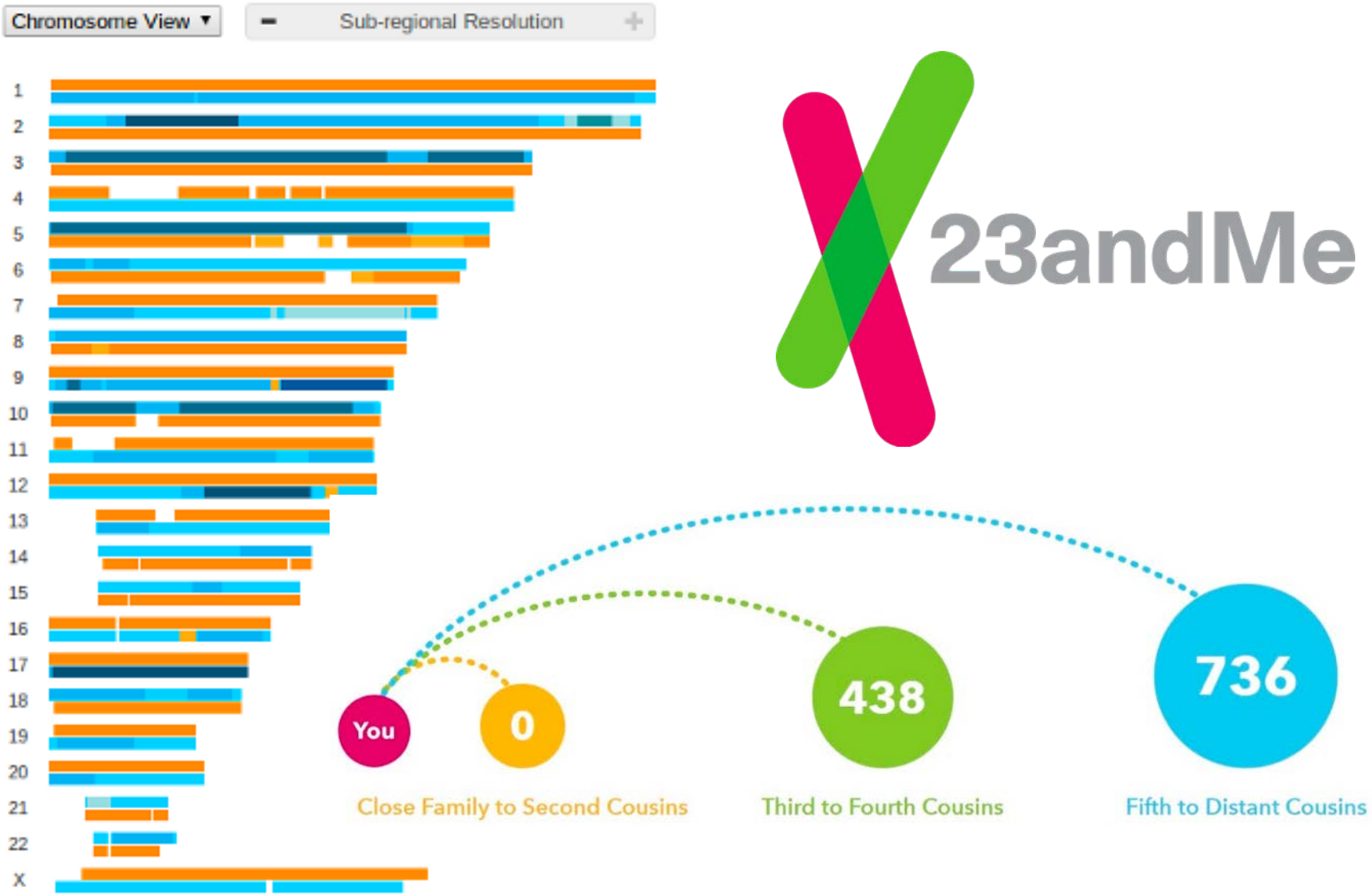


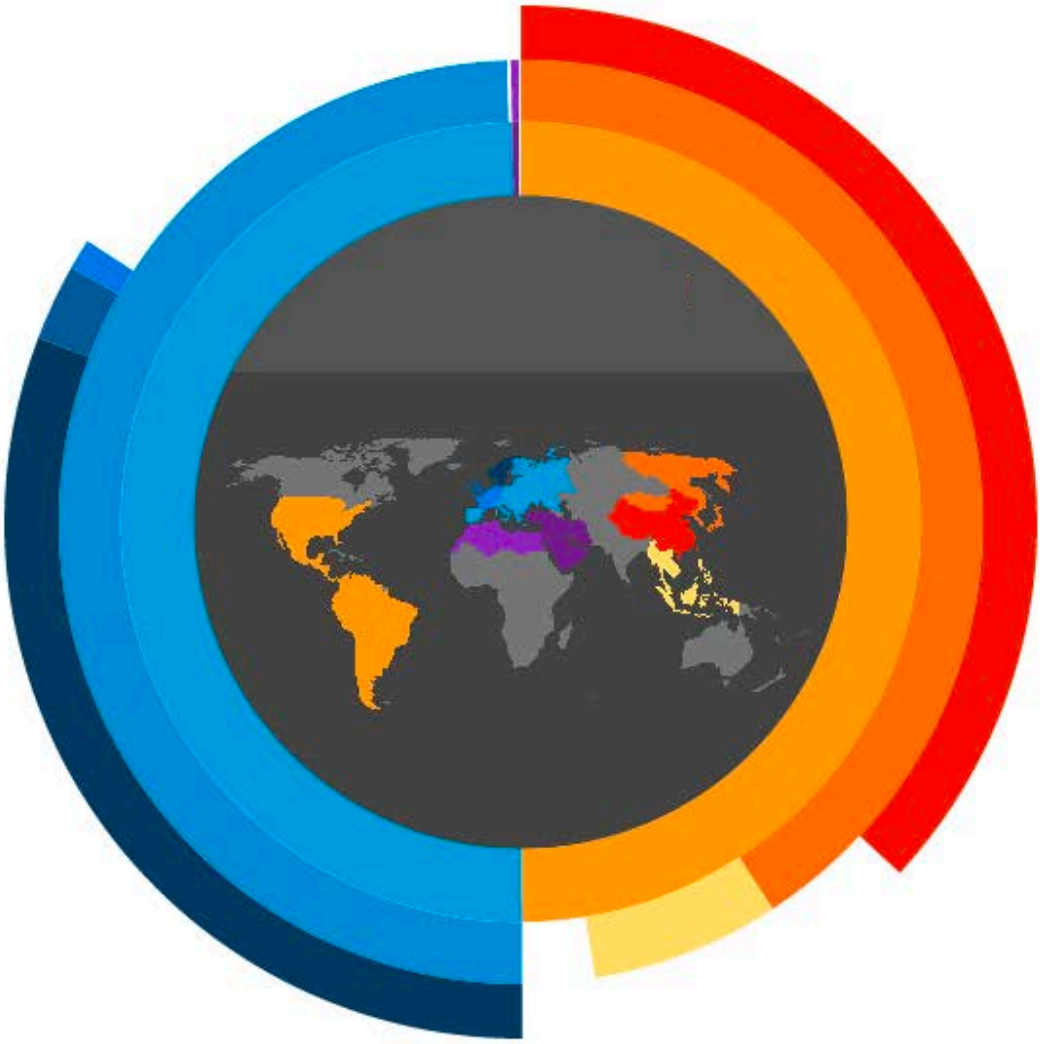
Using genetic methods



Using genetic methods

23andMe

Map View ▾ | Sub-regional Resolution

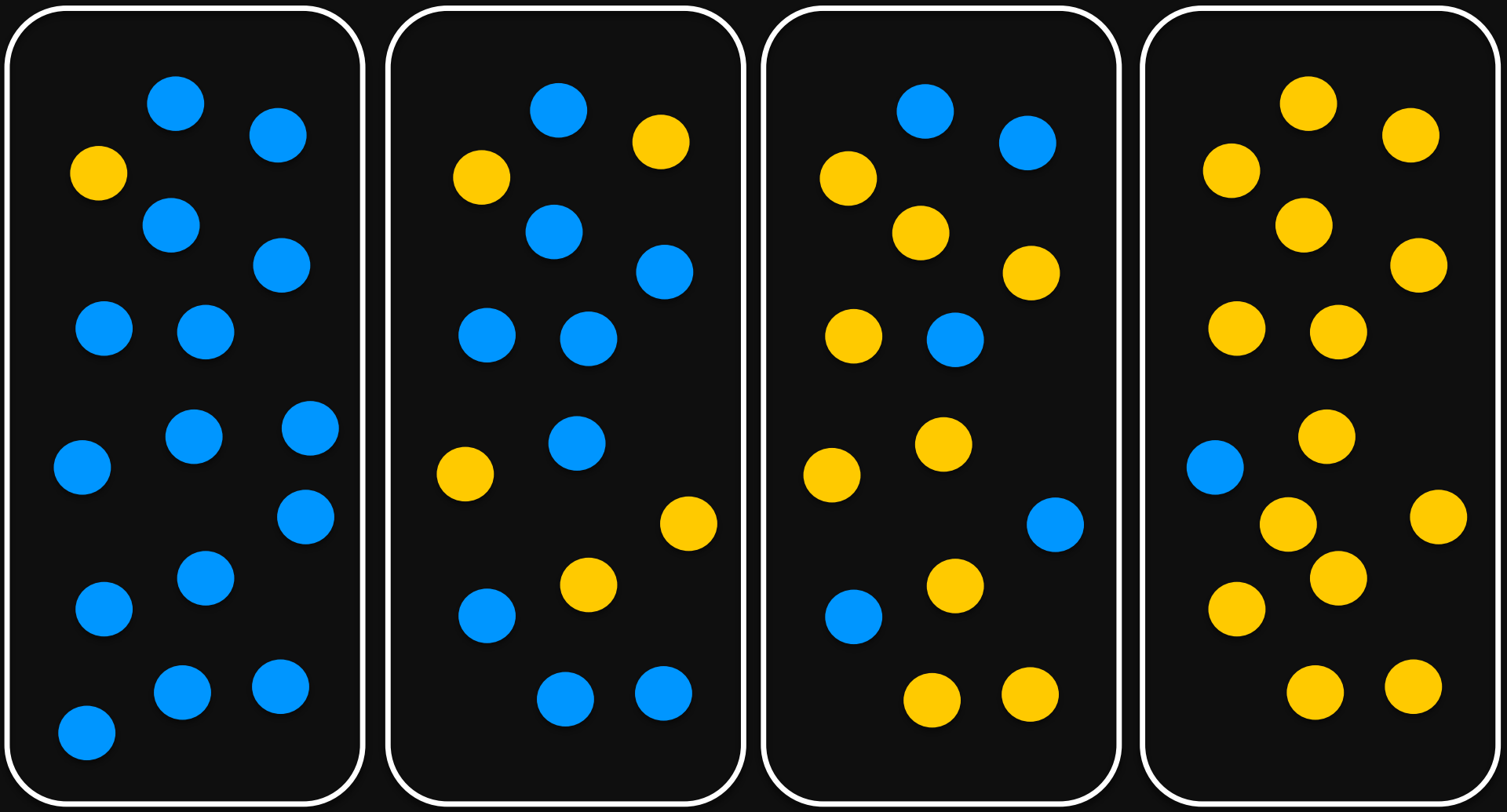


Ancestry Composition tells you what percent of your DNA comes from each of 31 populations worldwide. This analysis includes DNA you received from all of your recent ancestors, on both sides of your family. The results reflect where your ancestors lived before the widespread migrations of the past few hundred years.

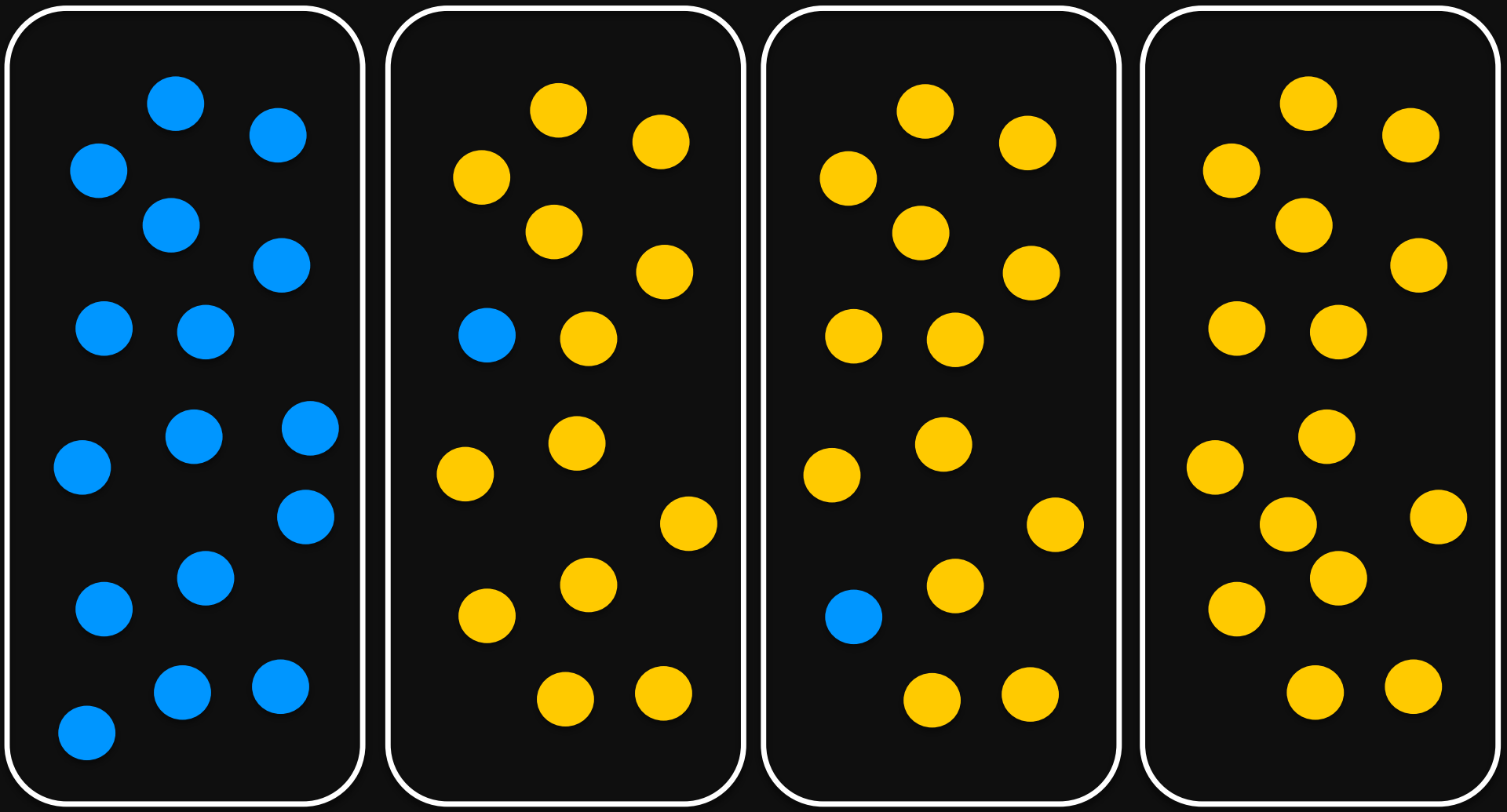
49.9%	East Asian & Native American
	East Asian
36.9%	Chinese
3.9%	Broadly East Asian
6.6%	Southeast Asian
2.5%	Broadly East Asian & Native American
49.7%	European
	Northwestern European
30.9%	Scandinavian
2.4%	British & Irish
1.0%	French & German
15.4%	Broadly Northwestern European
0.1%	Broadly European
0.3%	Middle Eastern & North African
0.3%	North African
0.1%	Unassigned

show all populations

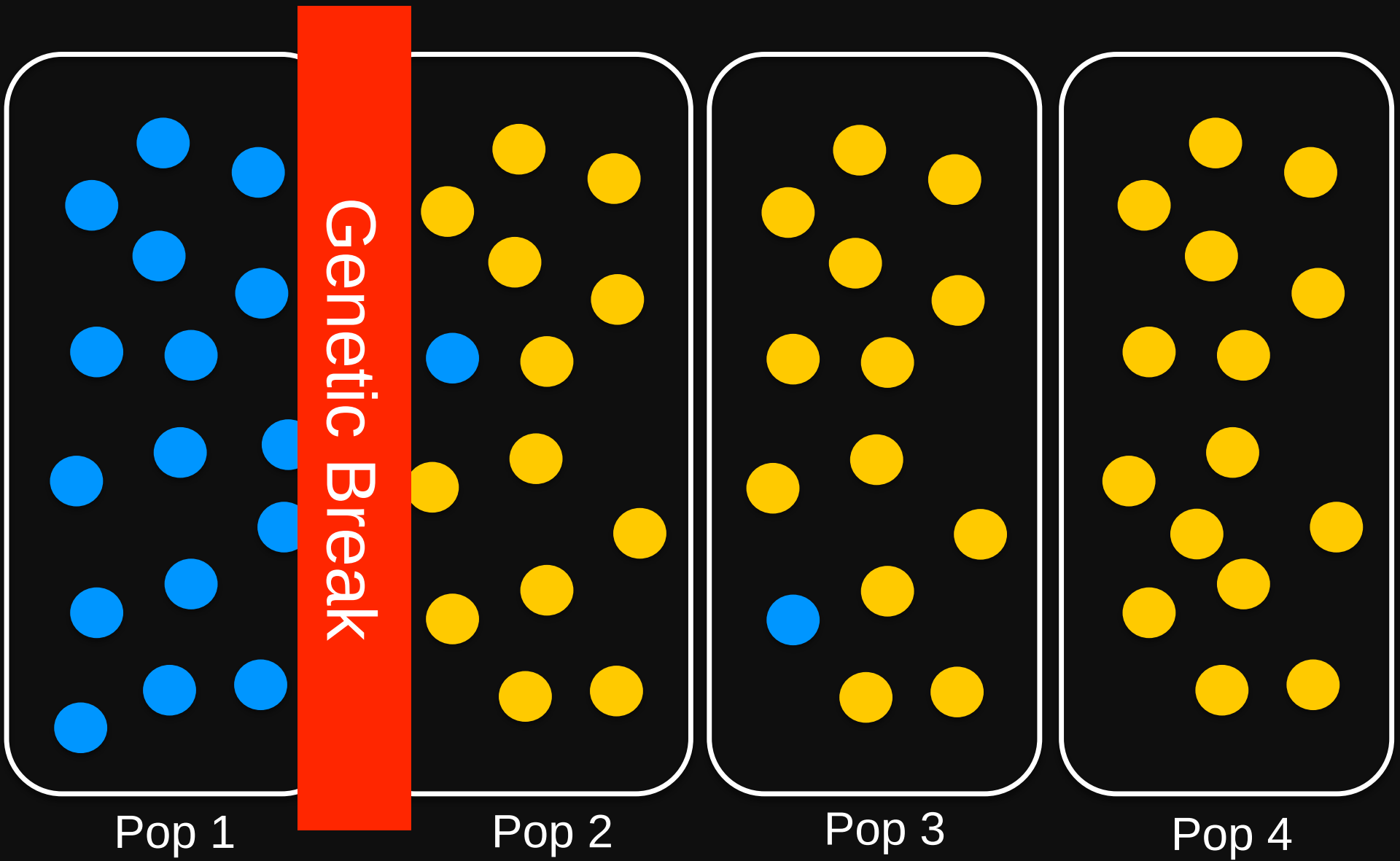
Population Genetics Example



Population Genetics Example 2

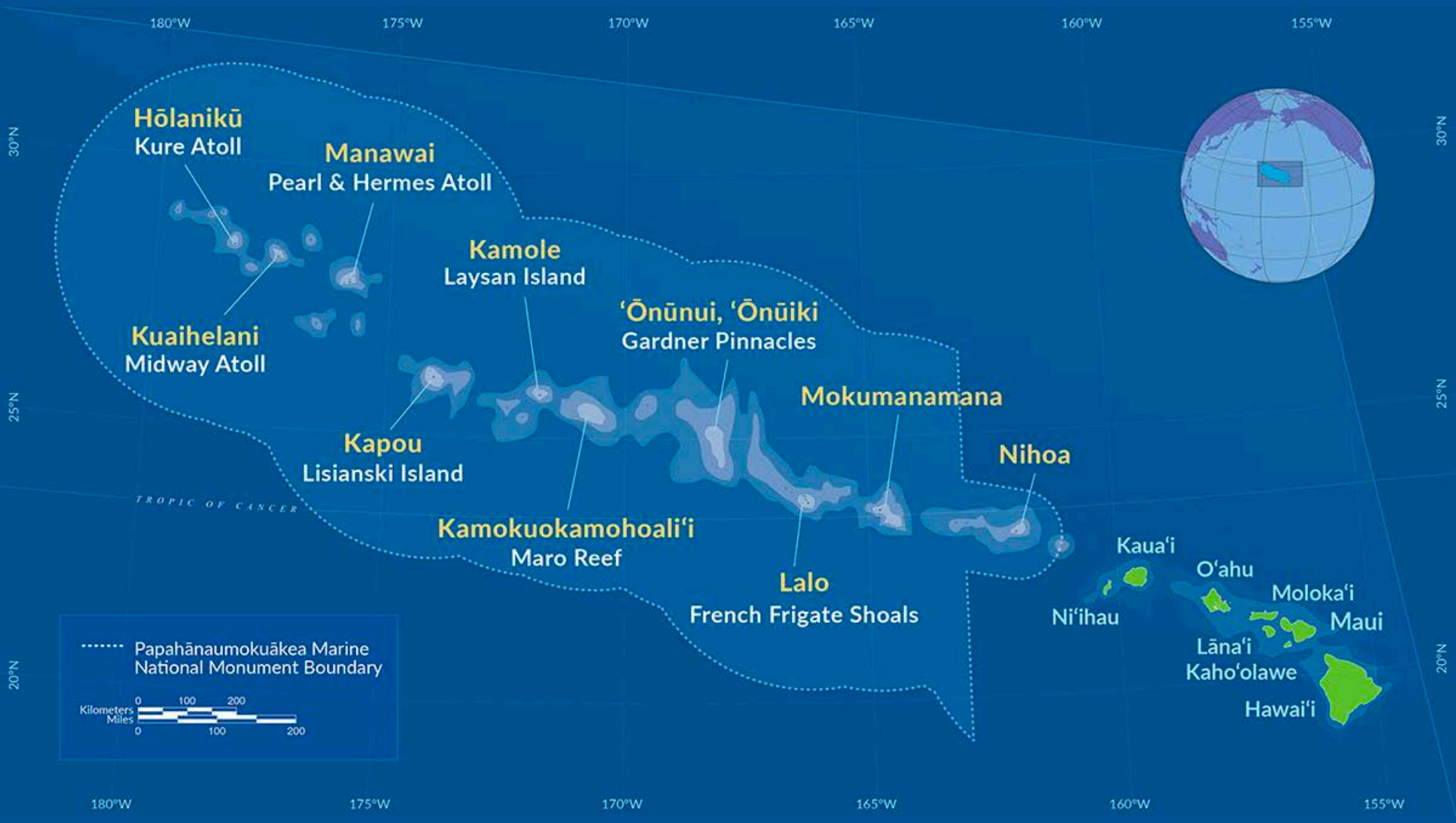


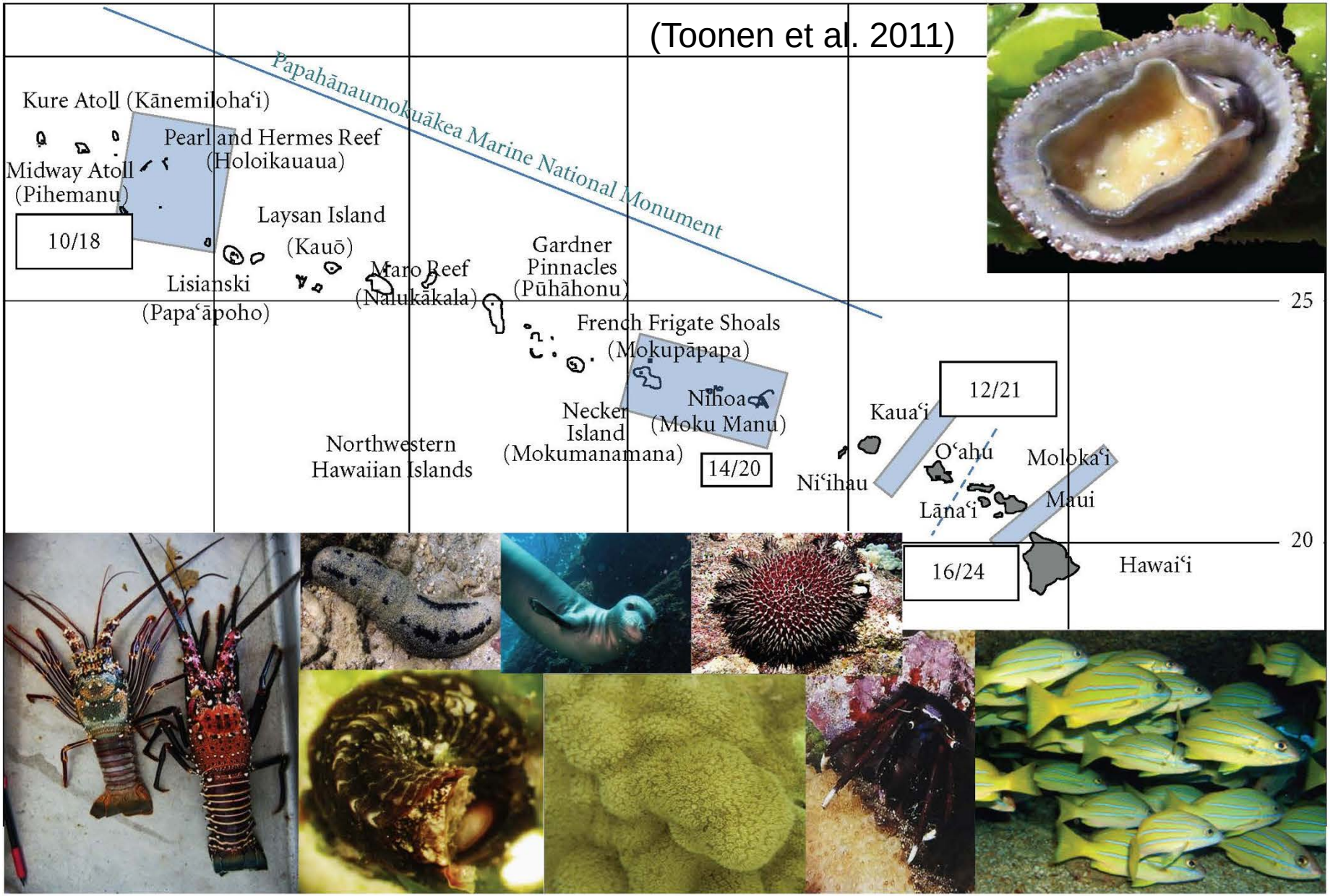
Population Genetics Example 2



Archipelago	Island

Hawaiian Archipelago




(Toonen et al. 2011)
Papahānaumokuākea Marine National Monument
Kure Atoll (Kānemiloha'i)
Pearl and Hermes Reef
(Holoikauaua)
Midway Atoll
(Pihemanu)
10/18
Laysan Island
(Kauō)
Lisianski
(Papa'āpoho)
Maro Reef
(Nalukākala)
Gardner
Pinnacles
(Pūhāhonu)
French Frigate Shoals
(Mokupāpapa)
Nihoa
(Moku Manu)
Necker
Island
(Mokumanamana)
Northwestern
Hawaiian Islands
14/20
12/21
Kaua'i
Ni'ihau
O'ahu
Moloka'i
Lāna'i
Maui
Hawai'i
16/24
25
20

(Toonen et al. 2011)

Do these patterns hold in a genomics framework?

Archipelago	Island

Manini (*Acanthurus triostegus*)

- PLD: 54-70 days
- Indo-Pacific

Kole (*Ctenocheatus strigosus*)

- PLD: 50-60 days
- Hawaiian Endemic

Archipelago	Island

Manini (*Acanthurus triostegus*)

- PLD: 54-70 days
- Indo-Pacific = high dispersal

Kole (*Ctenocheatus strigosus*)

- PLD: 50-60 days
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Archipelago	Island

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Kole (*Ctenocheatus strigosus*)

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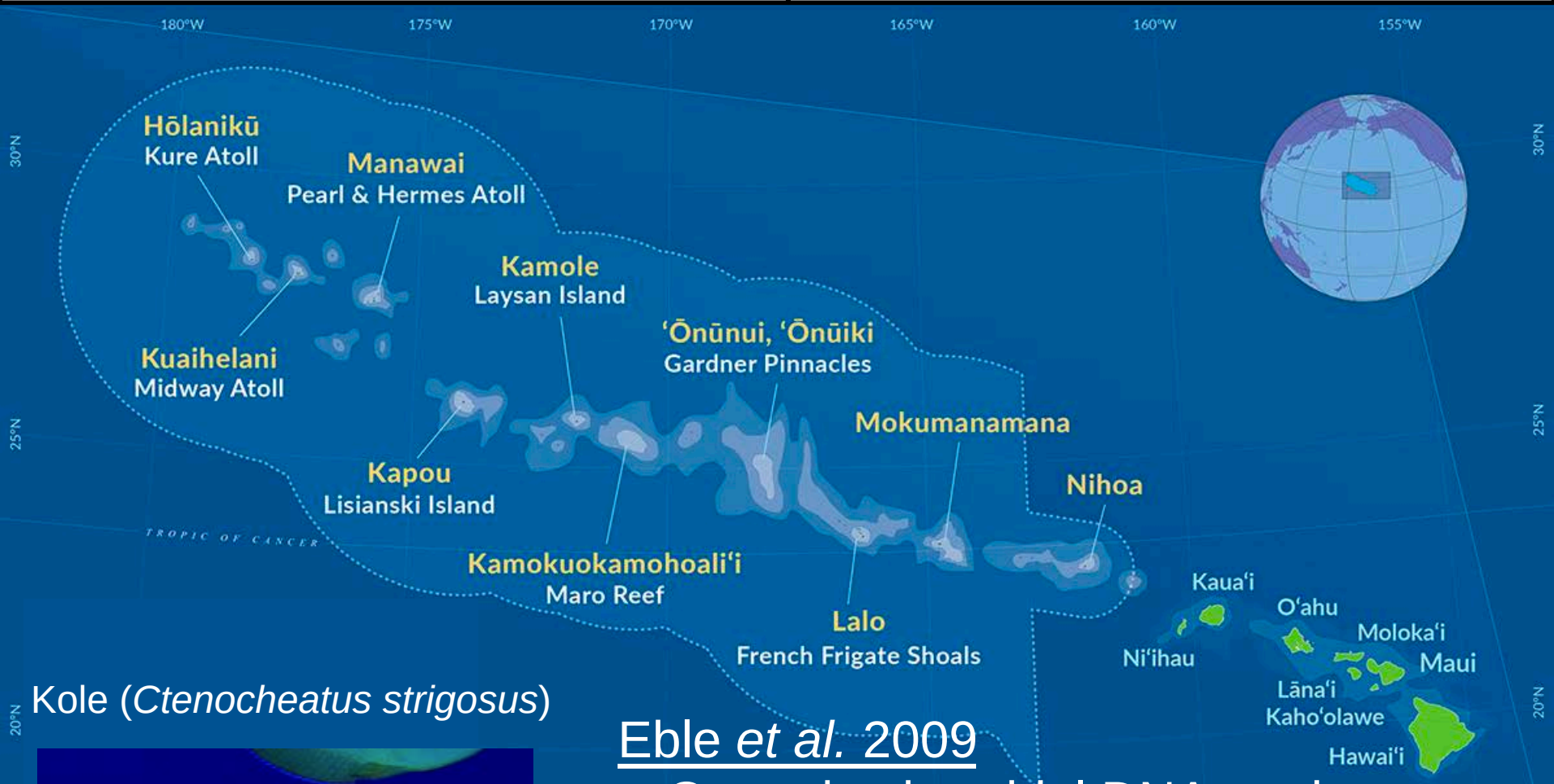
- Hawaiian Endemic = low dispersal

Do these species show similar connectivity patterns across the Hawaiian Archipelago?

Archipelago | Island

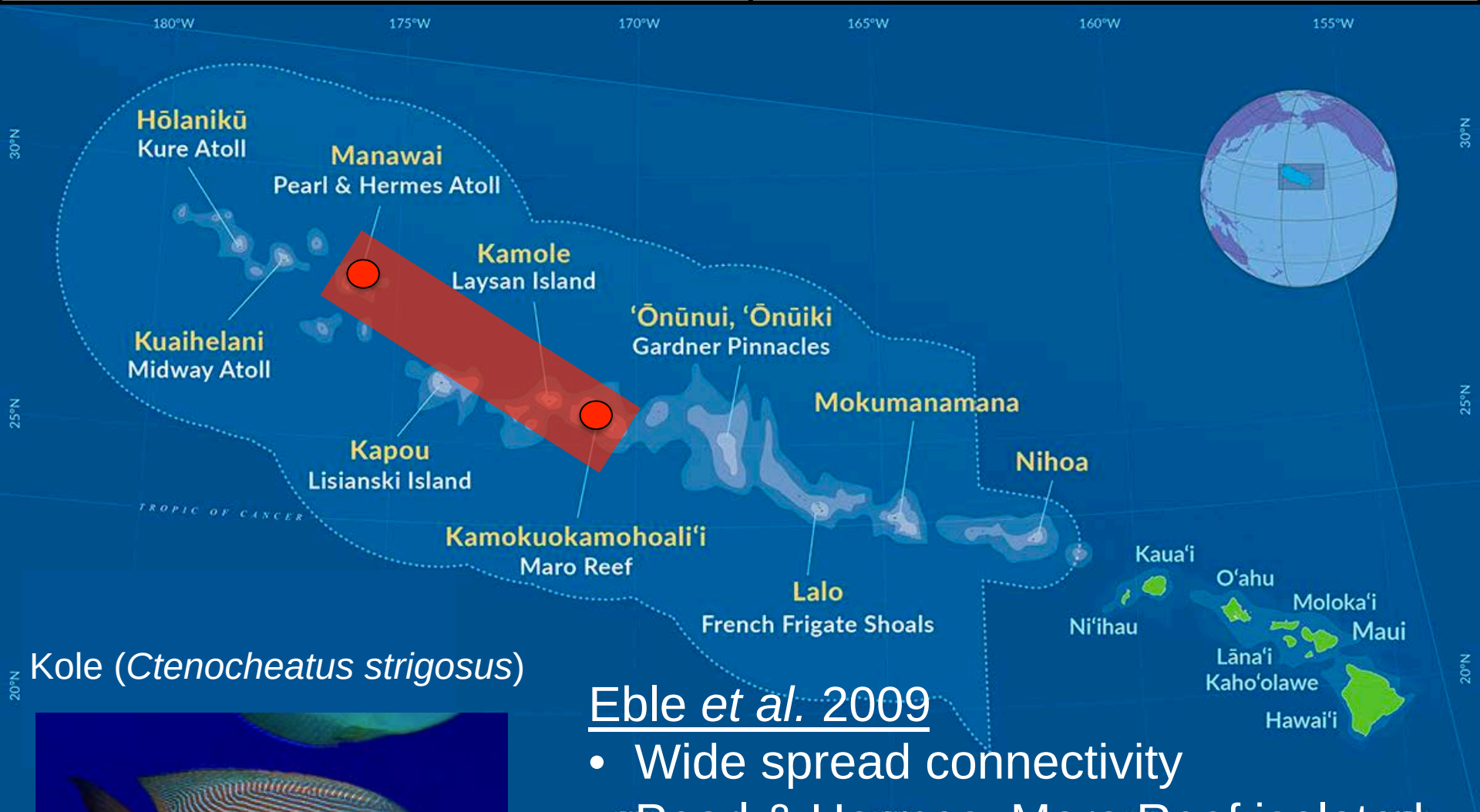


Kole (*Ctenocheatus strigosus*)

Eble *et al.* 2009

- One mitochondrial DNA marker

Archipelago | Island

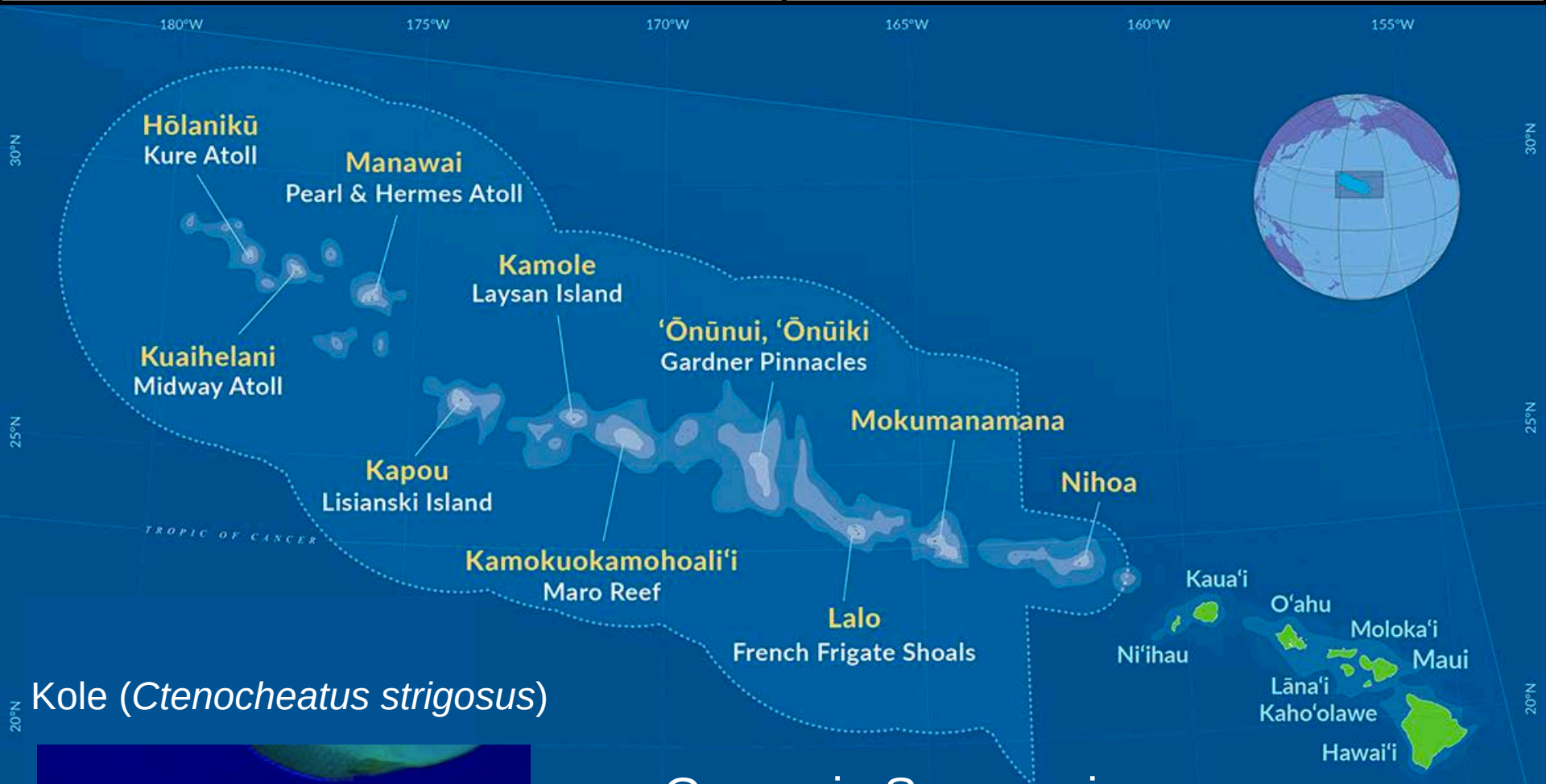


Kole (*Ctenocheatus strigosus*)

Eble *et al.* 2009

- Wide spread connectivity
- Pearl & Hermes, Maro Reef isolated from the rest of the archipelago

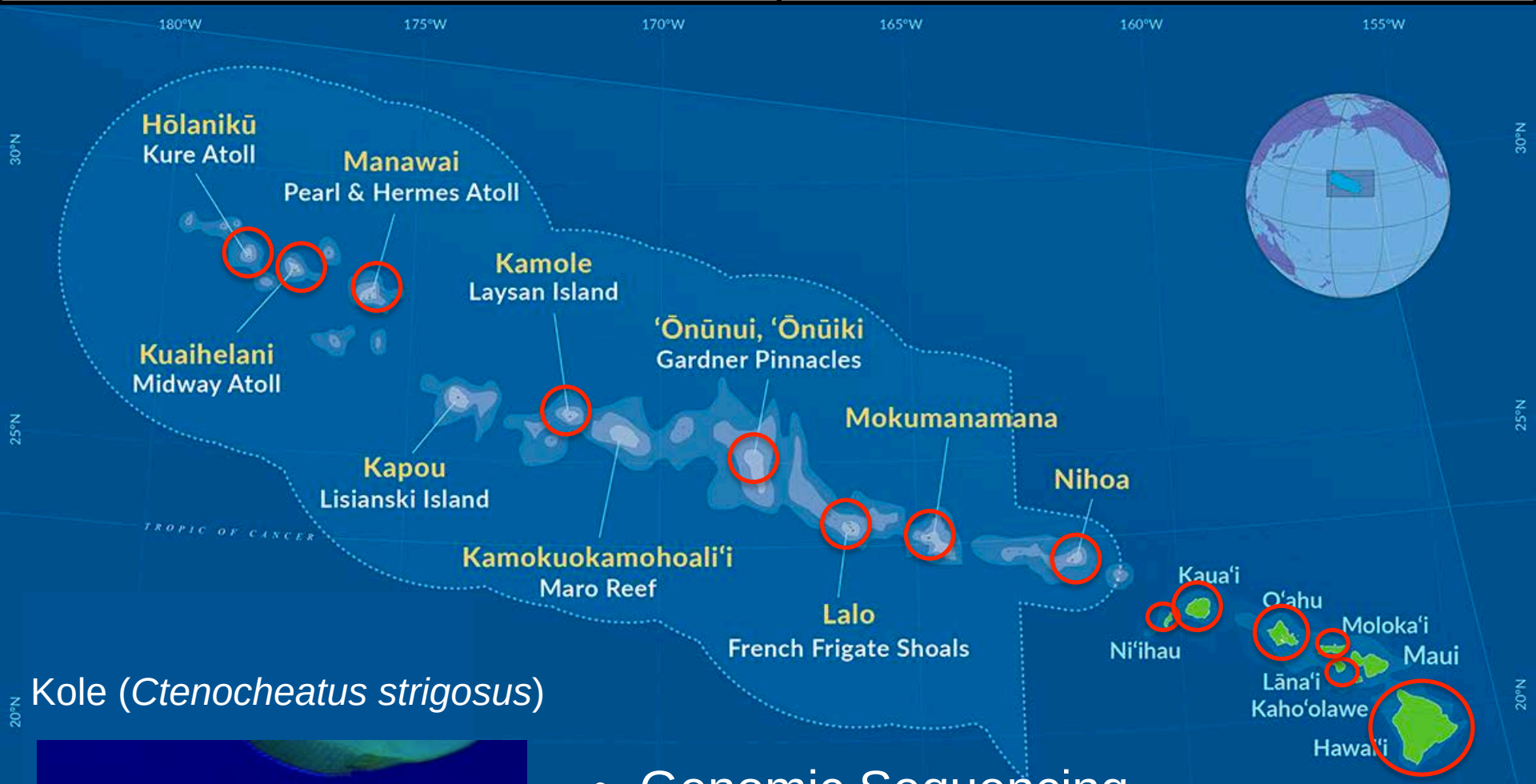
Archipelago | Island



Kole (*Ctenocheatus strigosus*)

- Genomic Sequencing

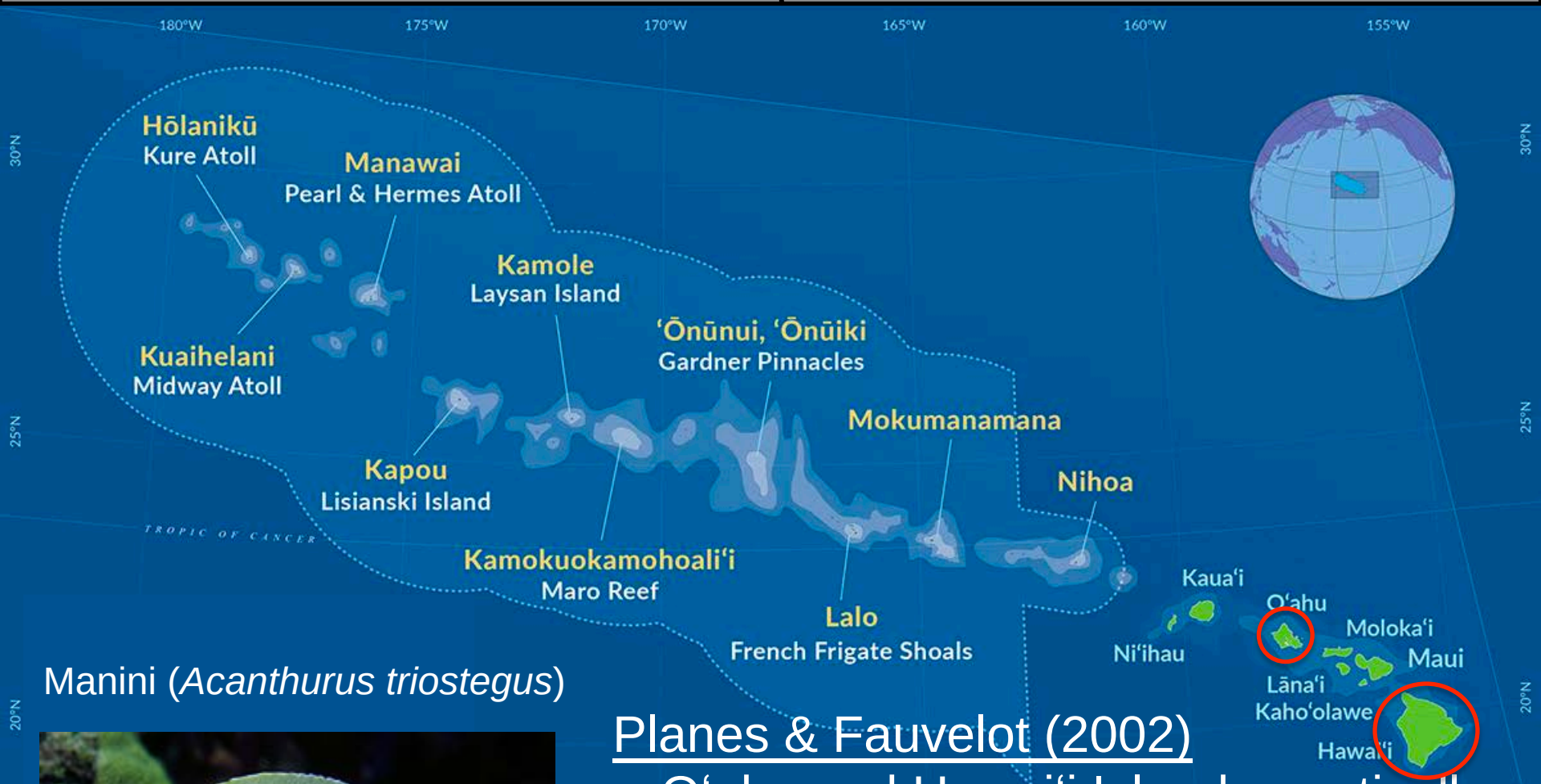
Archipelago | Island



Kole (*Ctenocheatus strigosus*)

- Genomic Sequencing
- Each Island is genetically distinct
- Each island needs to be managed independently

Archipelago | Island

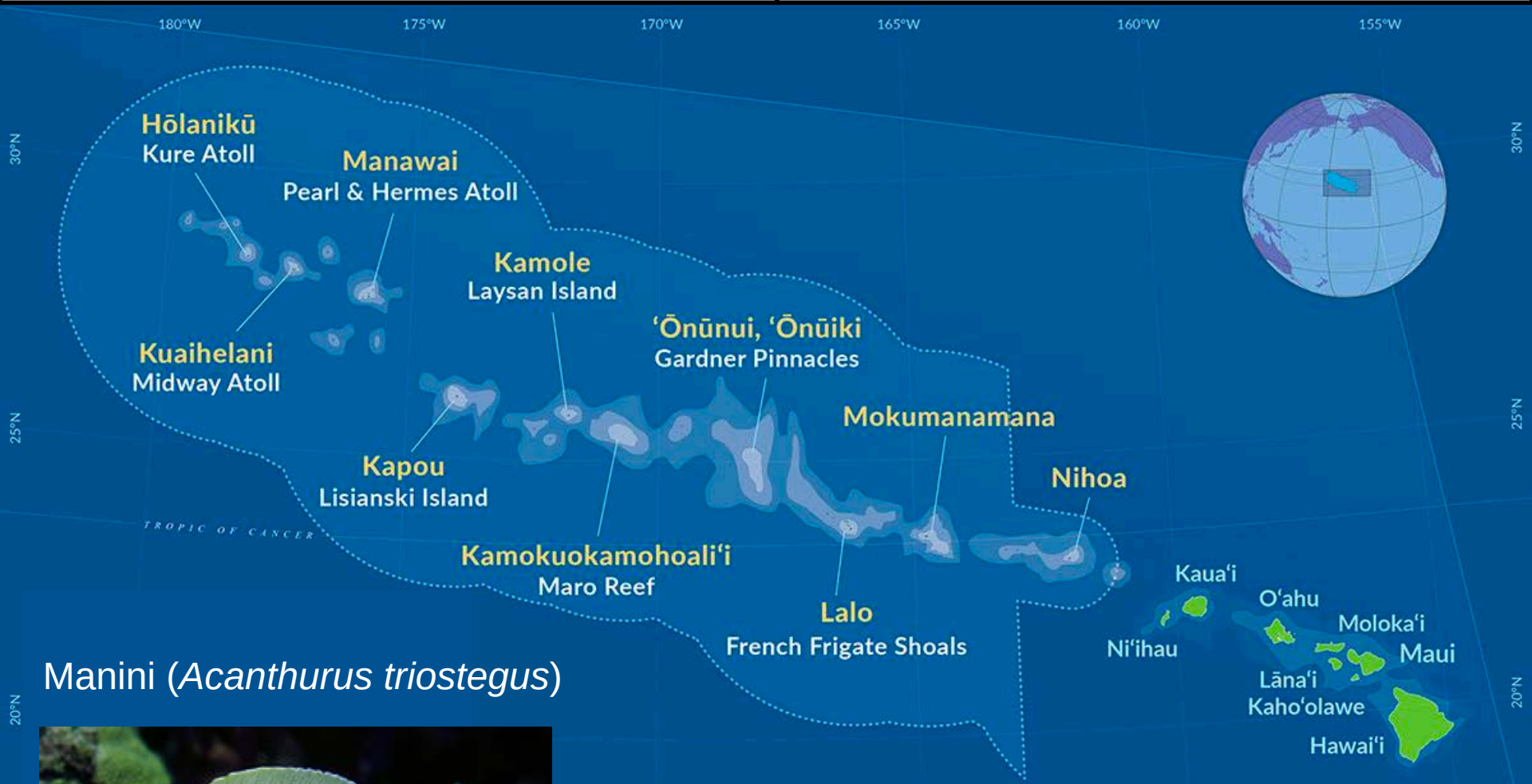


Manini (*Acanthurus triostegus*)

Planes & Fauvelot (2002)

- Oʻahu and Hawaiʻi Island genetically distinct

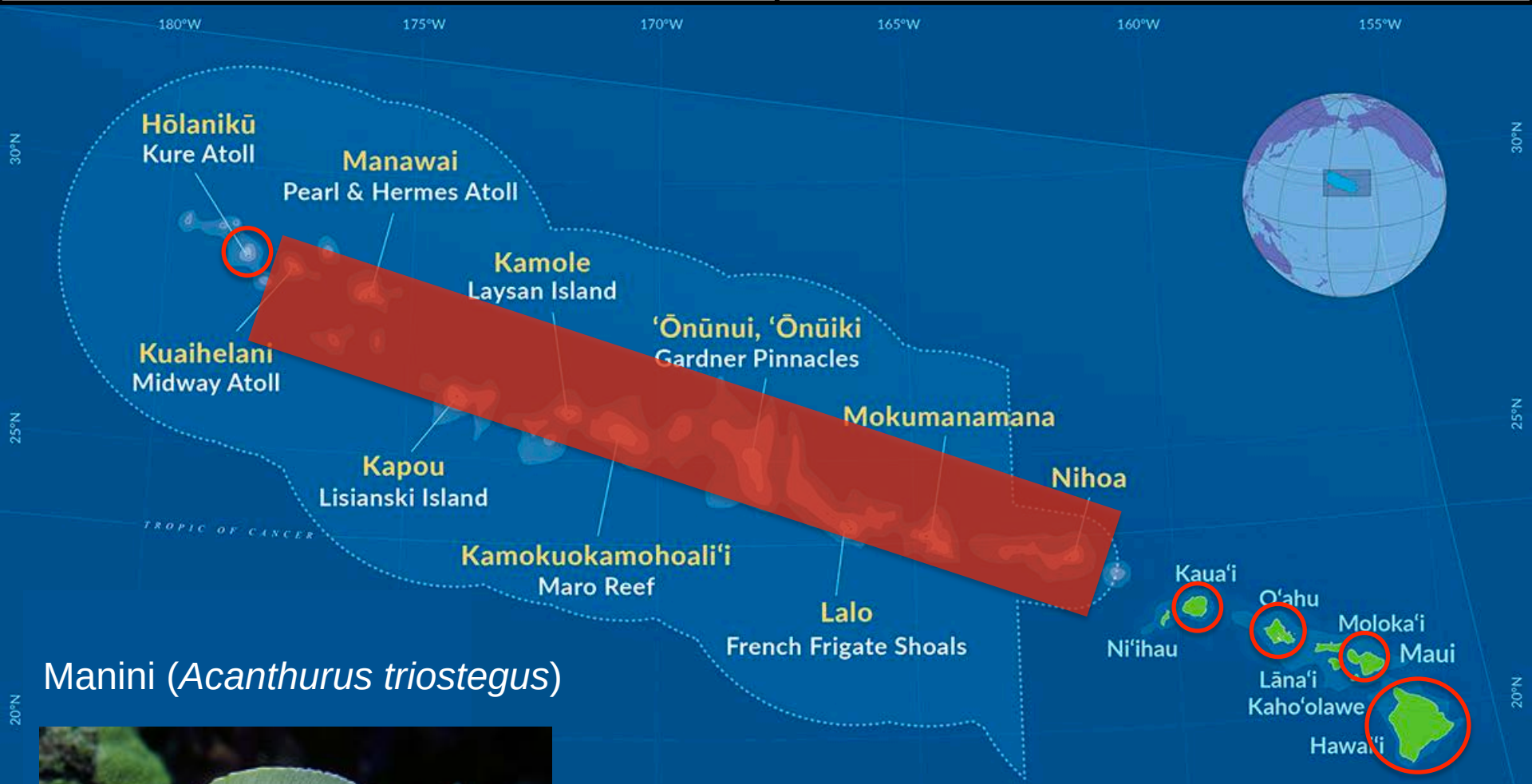
Archipelago | Island



Manini (*Acanthurus triostegus*)

- Genomic Sequencing

Archipelago | Island



Manini (*Acanthurus triostegus*)

- Genomic Sequencing
- Each MHI, Kure; isolated populations
- NWHI + Johnston genetically homogenous

Conclusions: Archipelago

Manini (*Acanthurus triostegus*)

Kole (*Ctenocheatus strigosus*)

Conclusions: Archipelago

Manini (*Acanthurus triostegus*)

Kole (*Ctenocheatus strigosus*)

Genomics provides finer scale resolution for identifying connectivity patterns

Conclusions: Archipelago

Manini (*Acanthurus triostegus*)

Kole (*Ctenocheatus strigosus*)

Genomics provides finer scale resolution for identifying connectivity patterns

- Island-by-island isolation
  - First account in Hawaiian fishes

Conclusions: Archipelago

Manini (*Acanthurus triostegus*)

Kole (*Ctenocheatus strigosus*)

Genomics provides finer scale resolution for identifying connectivity patterns

- Widespread connectivity in NWHI
- Island-by-island isolation
  - First account in Hawaiian fishes

Conclusions: Archipelago

Manini (*Acanthurus triostegus*)

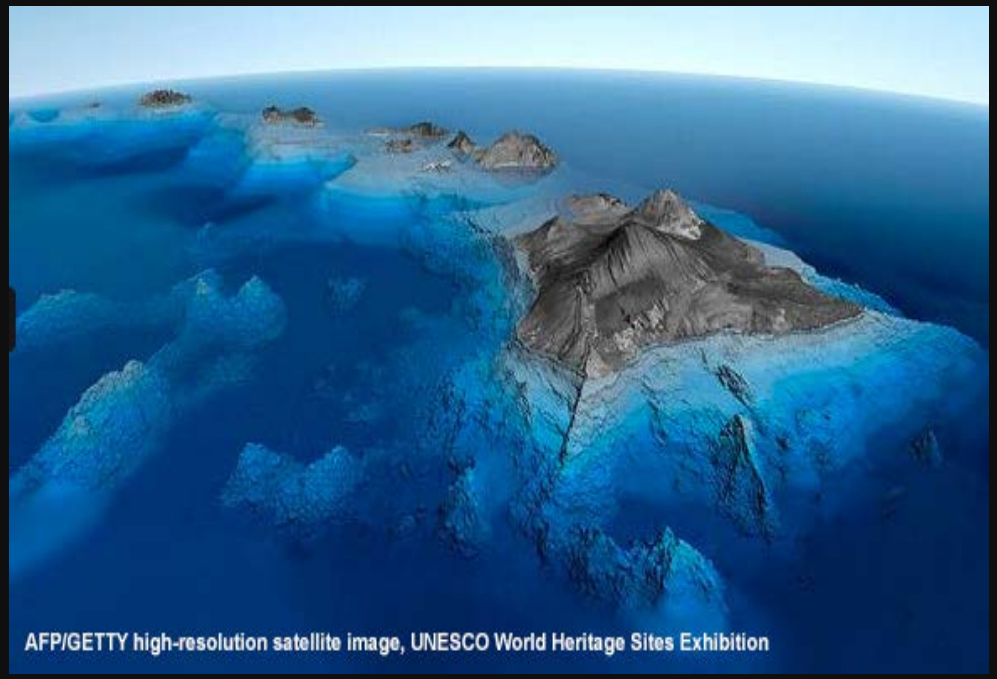
Kole (*Ctenocheatus strigosus*)

Management Implications

- MHI are separate populations from the NWHI

Smaller spatial scales: Island

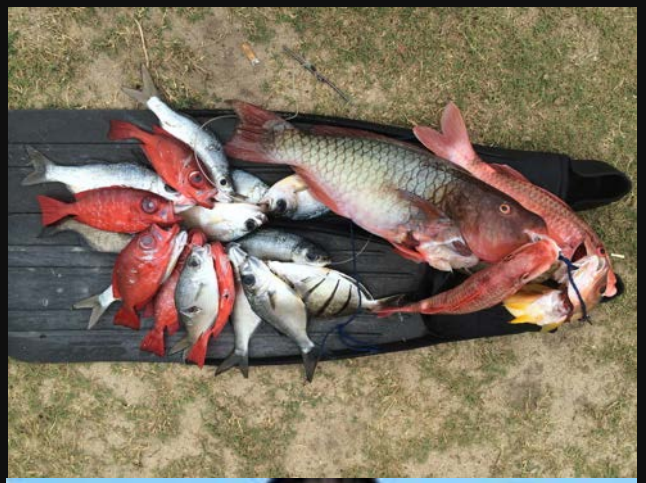
- Archipelago assessment shows that each MHI is distinct
- Island assessment requires finer scale resolution
  - Parentage analysis



Parentage Analysis

Recreational Fisheries in Hawai‘i

- Heavy pressure of fish communities
- Not well regulated
- Estimated that 31% of Hawai‘i residents participate in recreational fishing (Hamnett et al. 2006)
- 36% of the total catch is attributed to recreational harvest (WestPac, 2002)

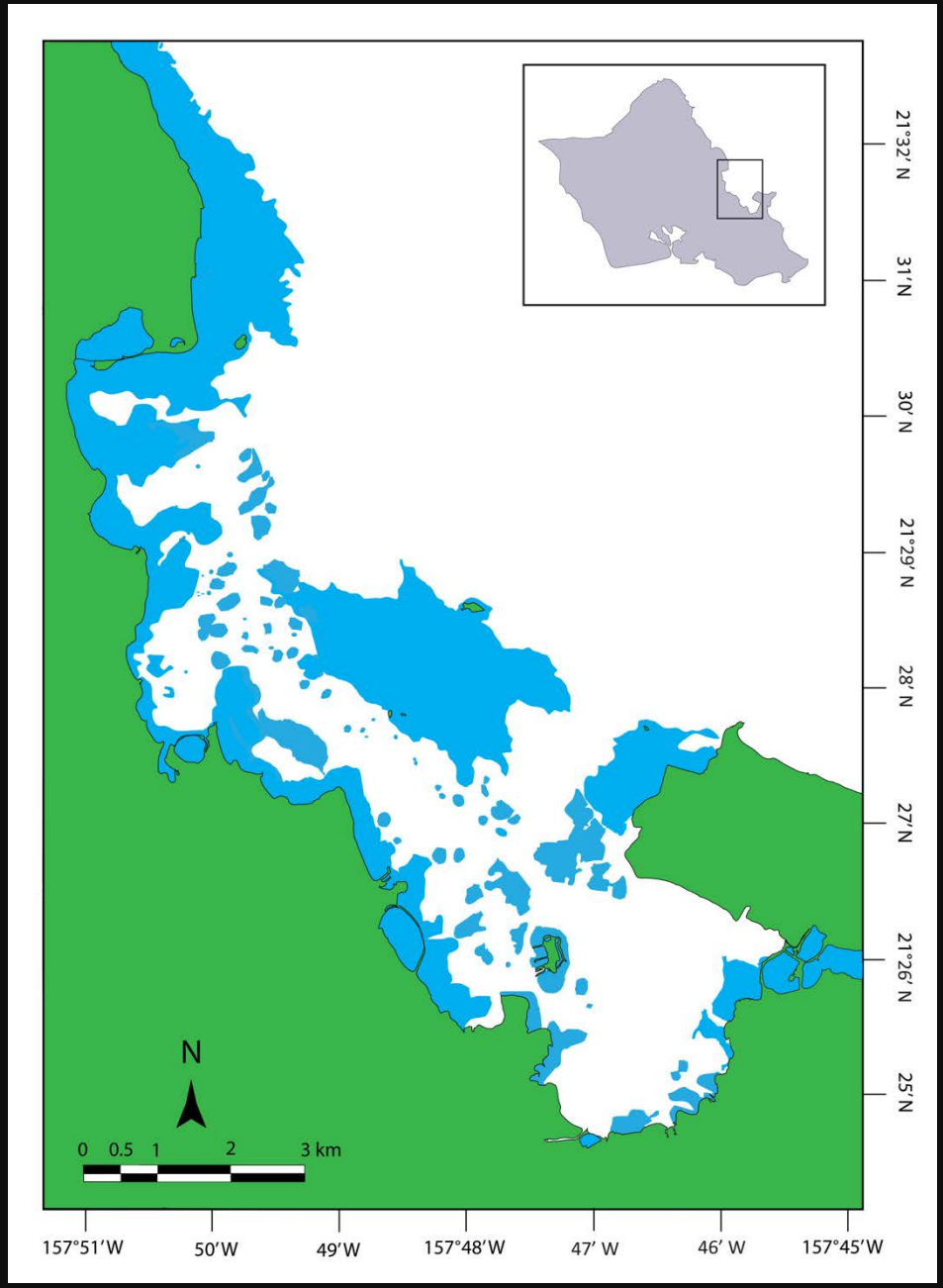


Problems associated with under-managed fisheries

- Lead to overfishing
- Prohibit long-term sustainability
  - Inability to maintain food security

Windward O‘ahu

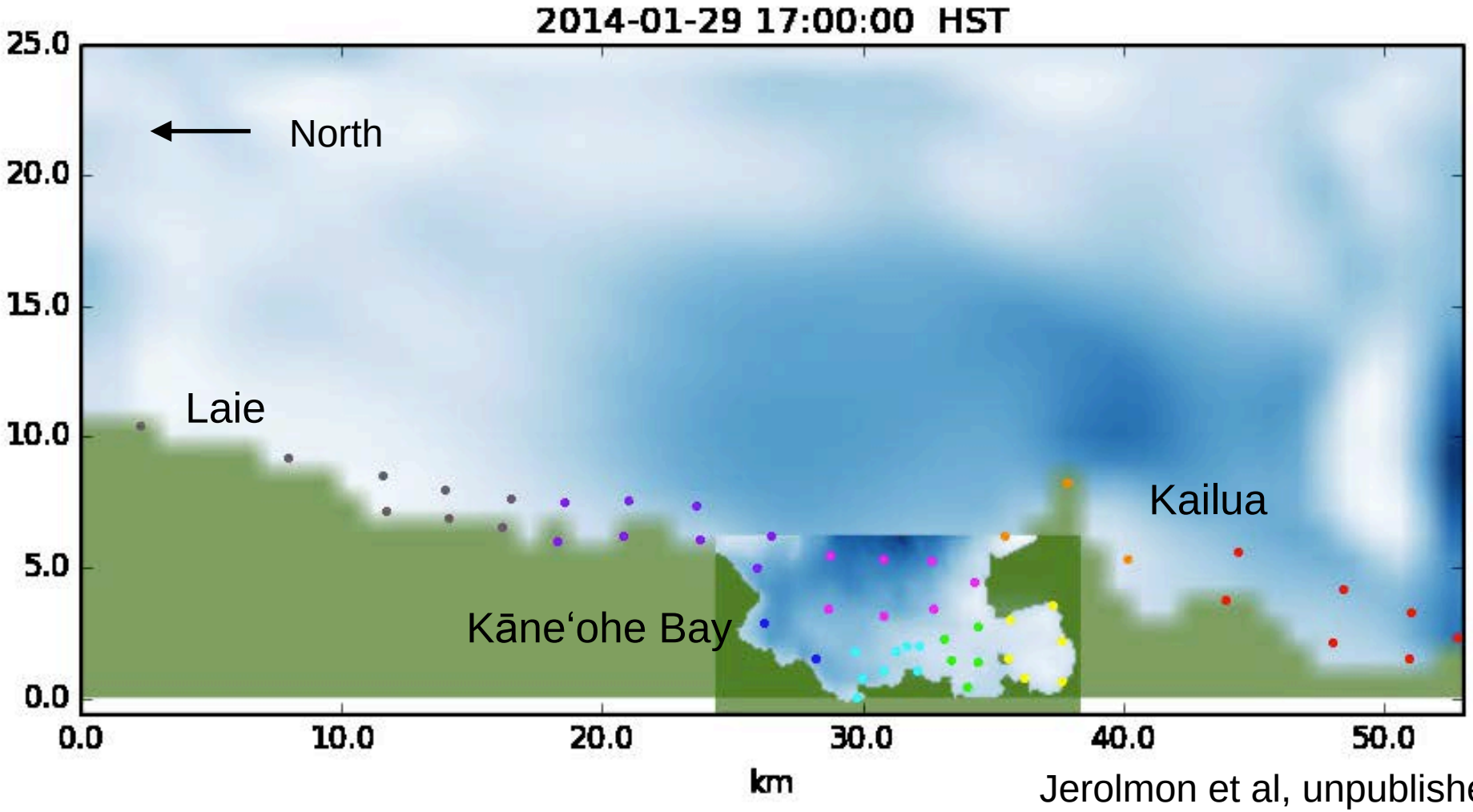
- Identify connectivity and dispersal patterns
- Initiated by Native Hawaiian community leaders to better understand connectivity of resources



Manini, *Acanthurus triostegus*

- Identified by communities leaders as an important fish stock
- Abundant throughout Hawai‘i
- Heavily targeted by recreational fishers

Windward Coast of O‘ahu

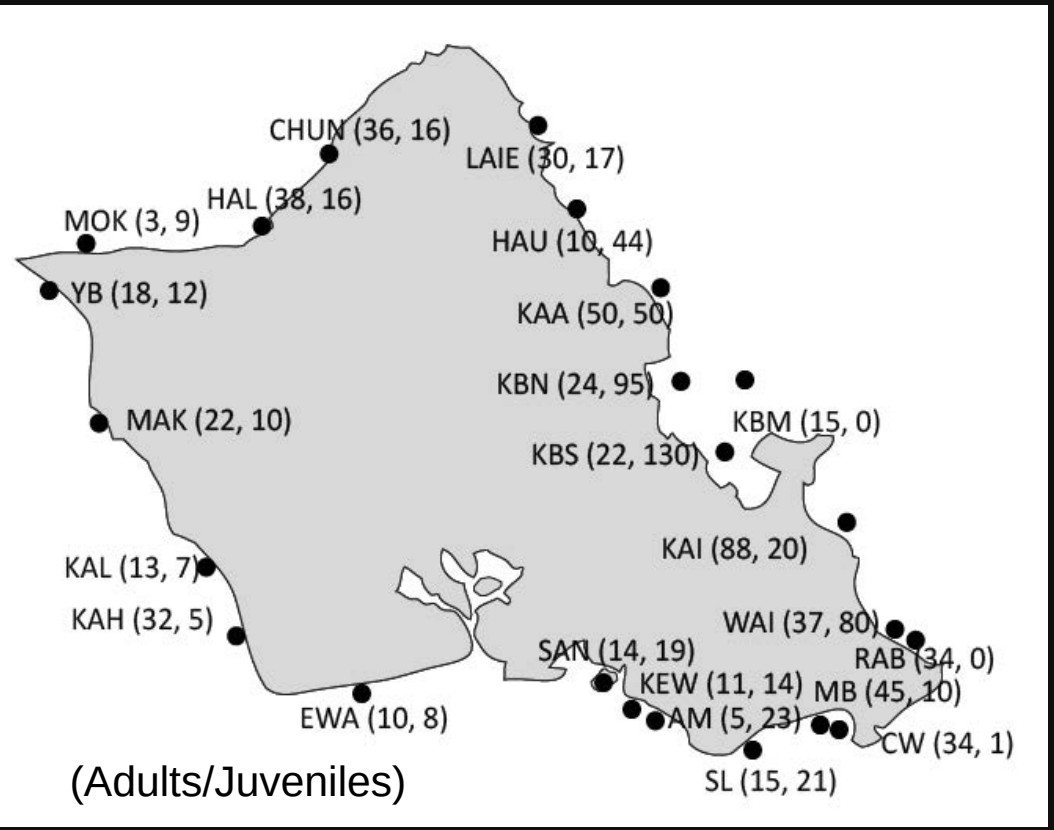


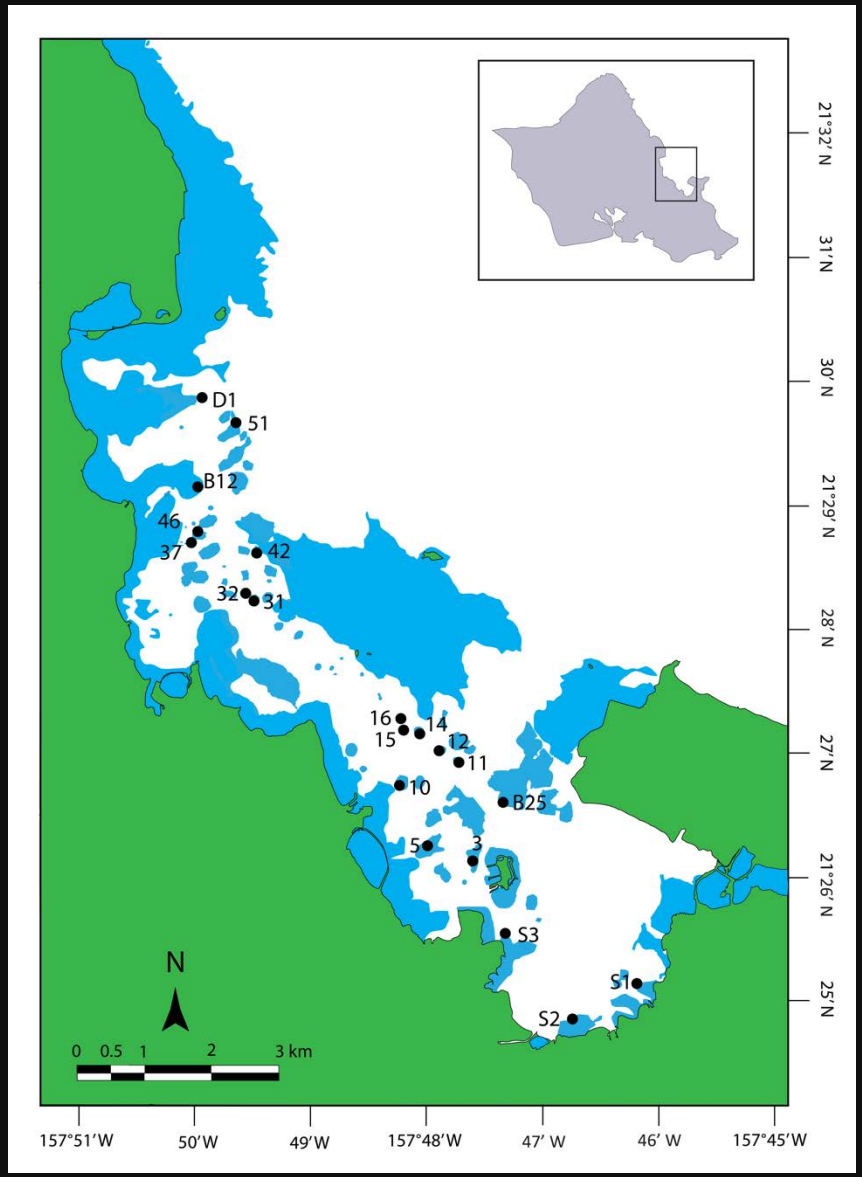
Jerolmon et al, unpublished

Goal

- Identify dispersal pathways
  - Source and sink populations
- Identify areas that may be vulnerable to fishing pressure

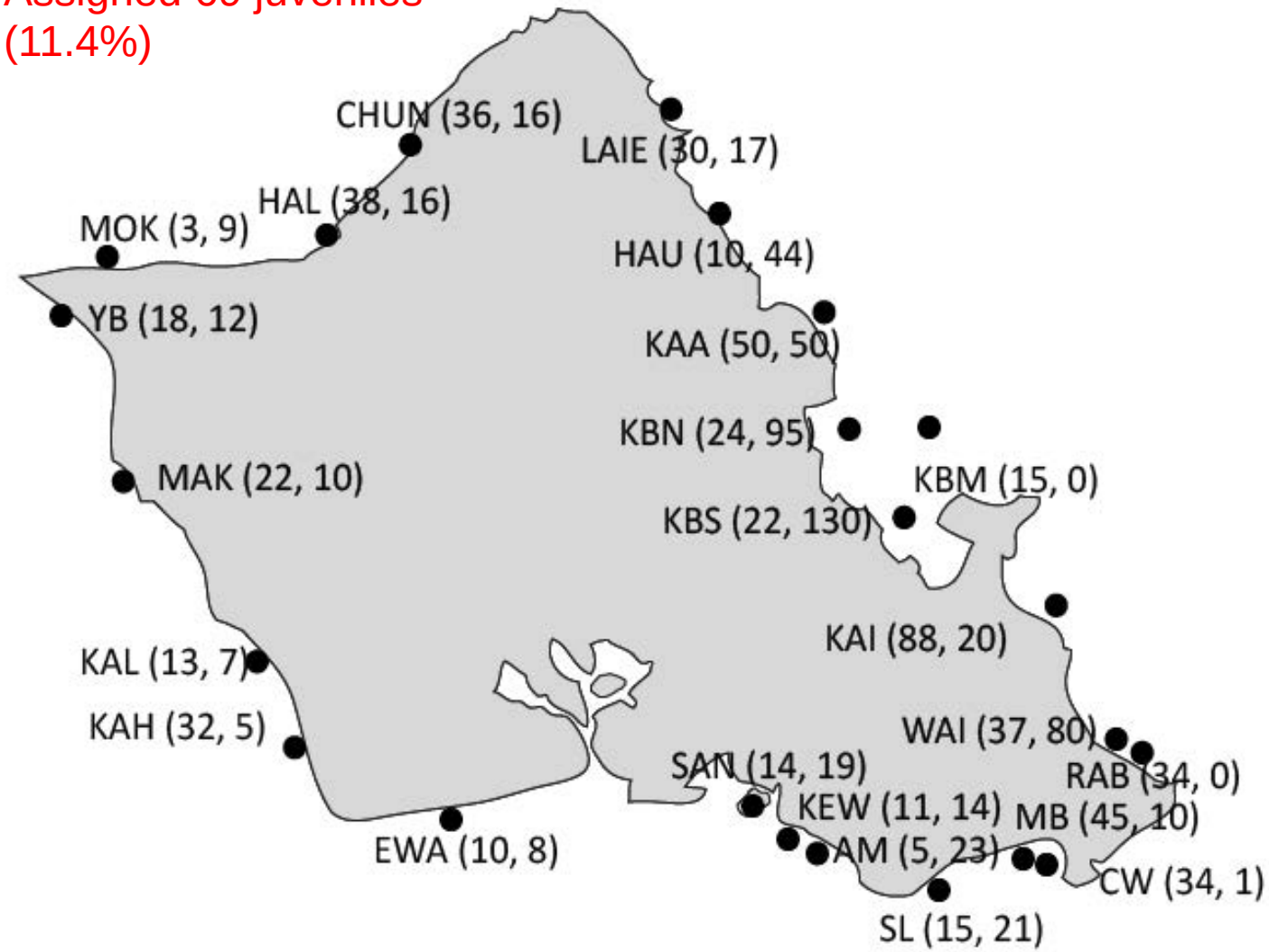
Collection Sites



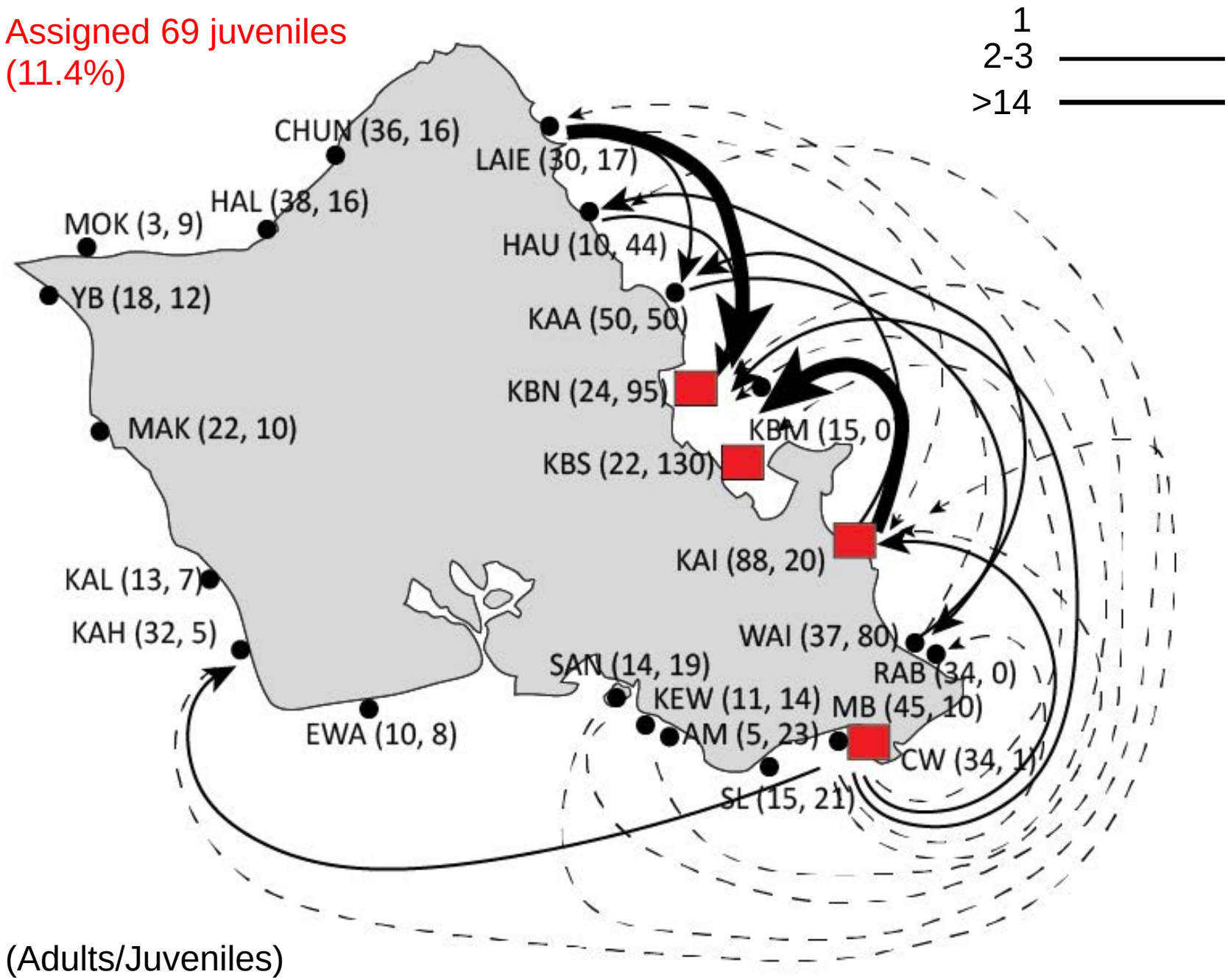


- Collected 606 adults, 607 juveniles

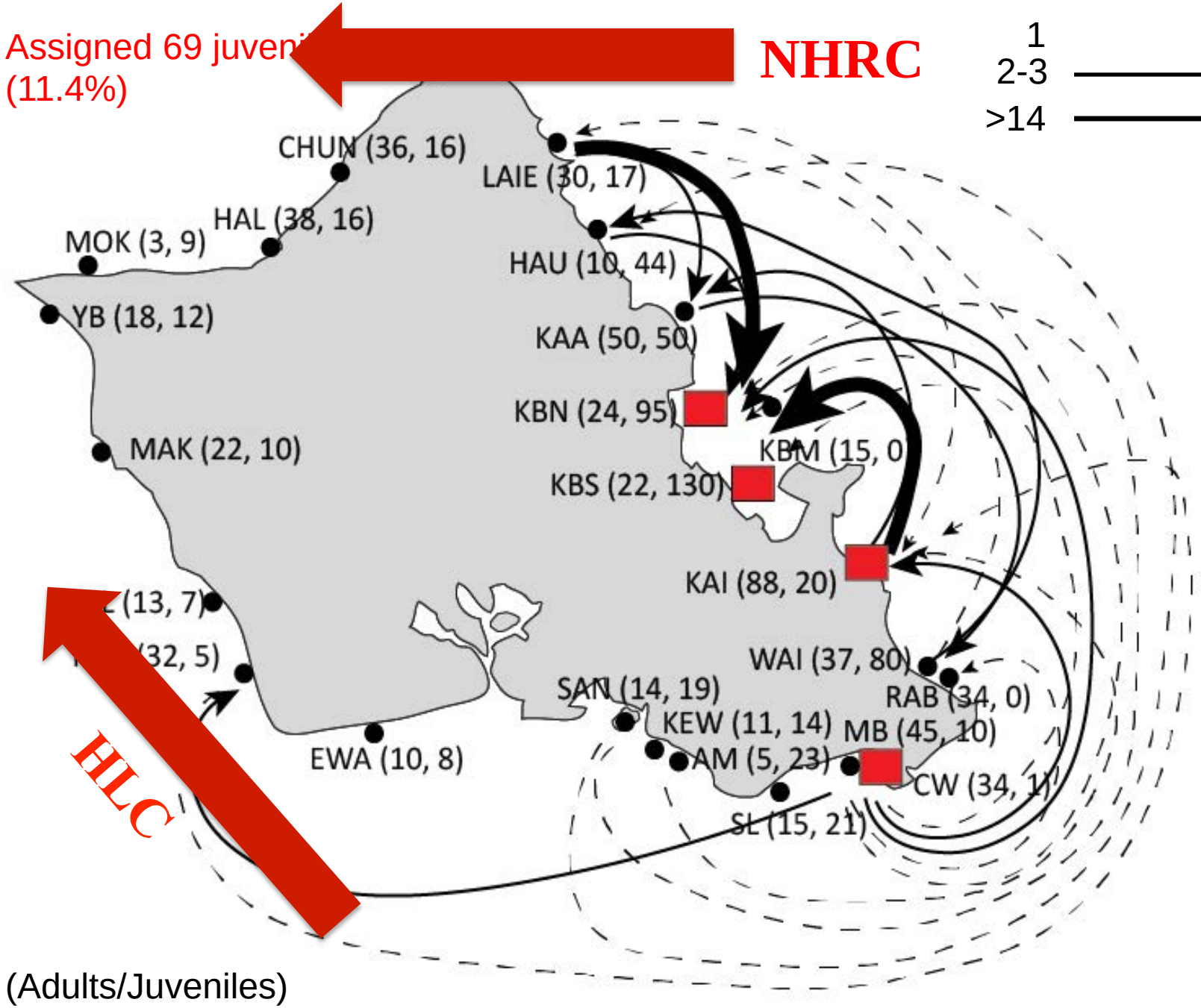
Assigned 69 juveniles
(11.4%)



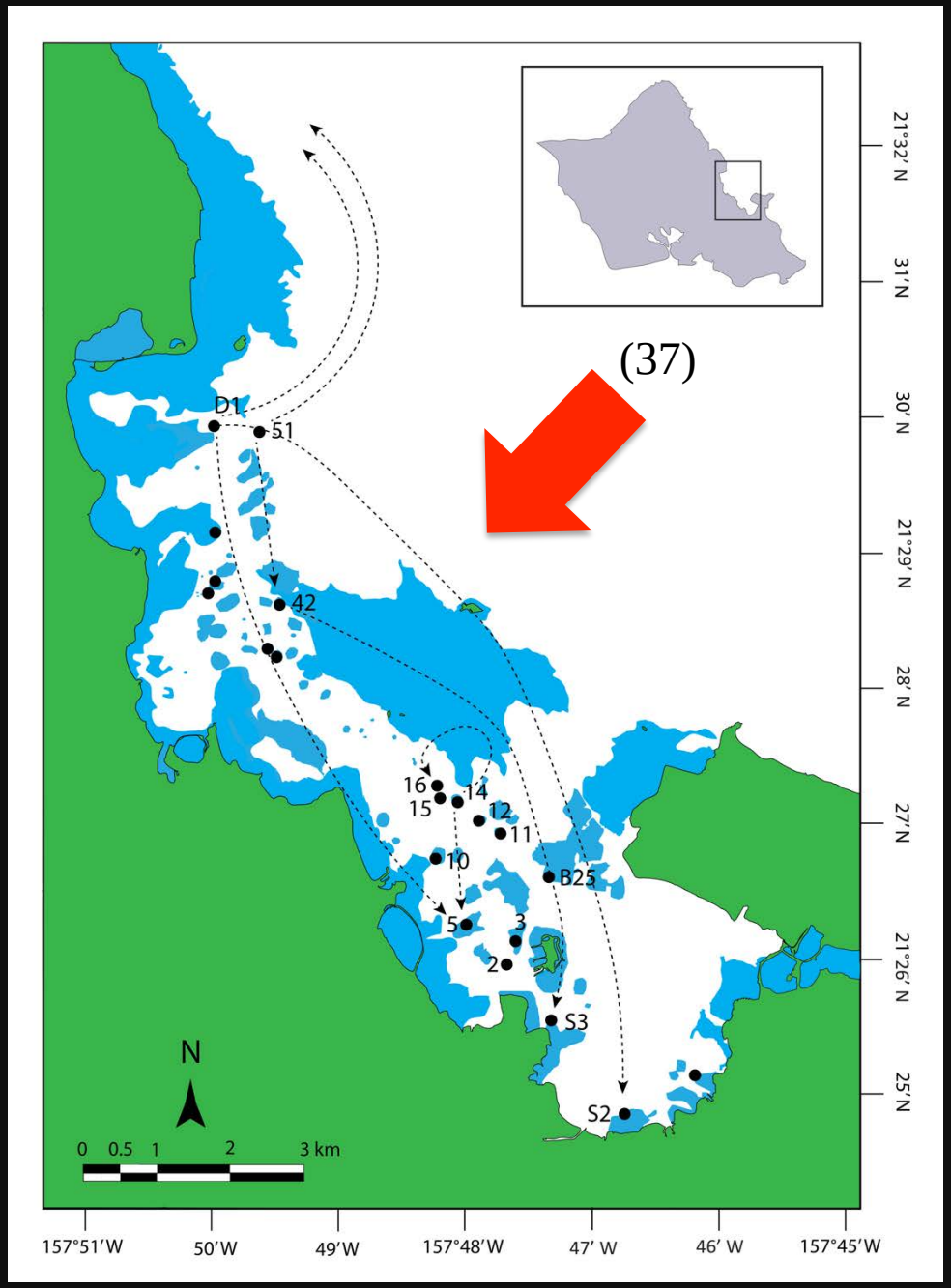
(Adults/Juveniles)



(Adults/Juveniles)



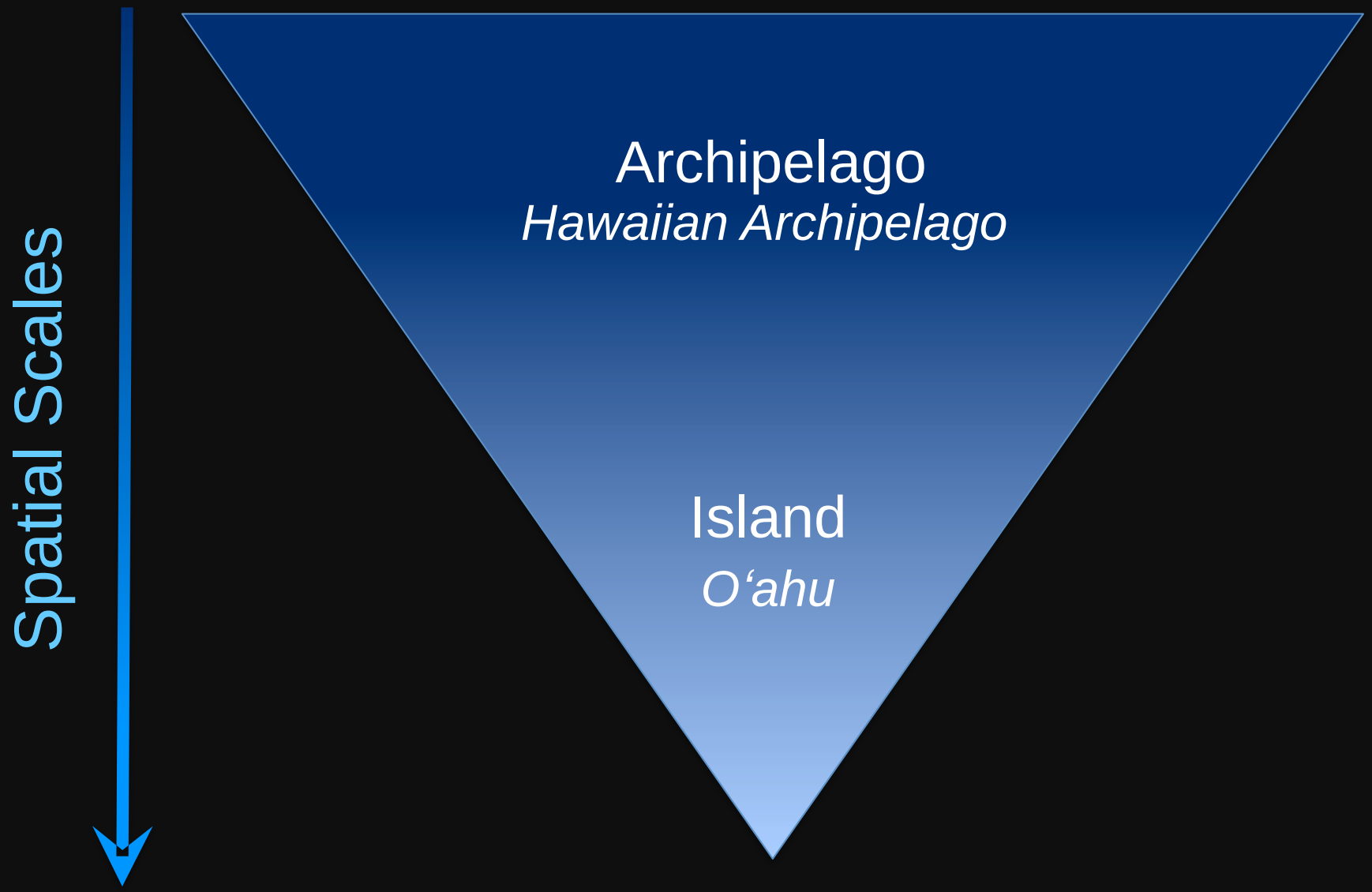
(Adults/Juveniles)

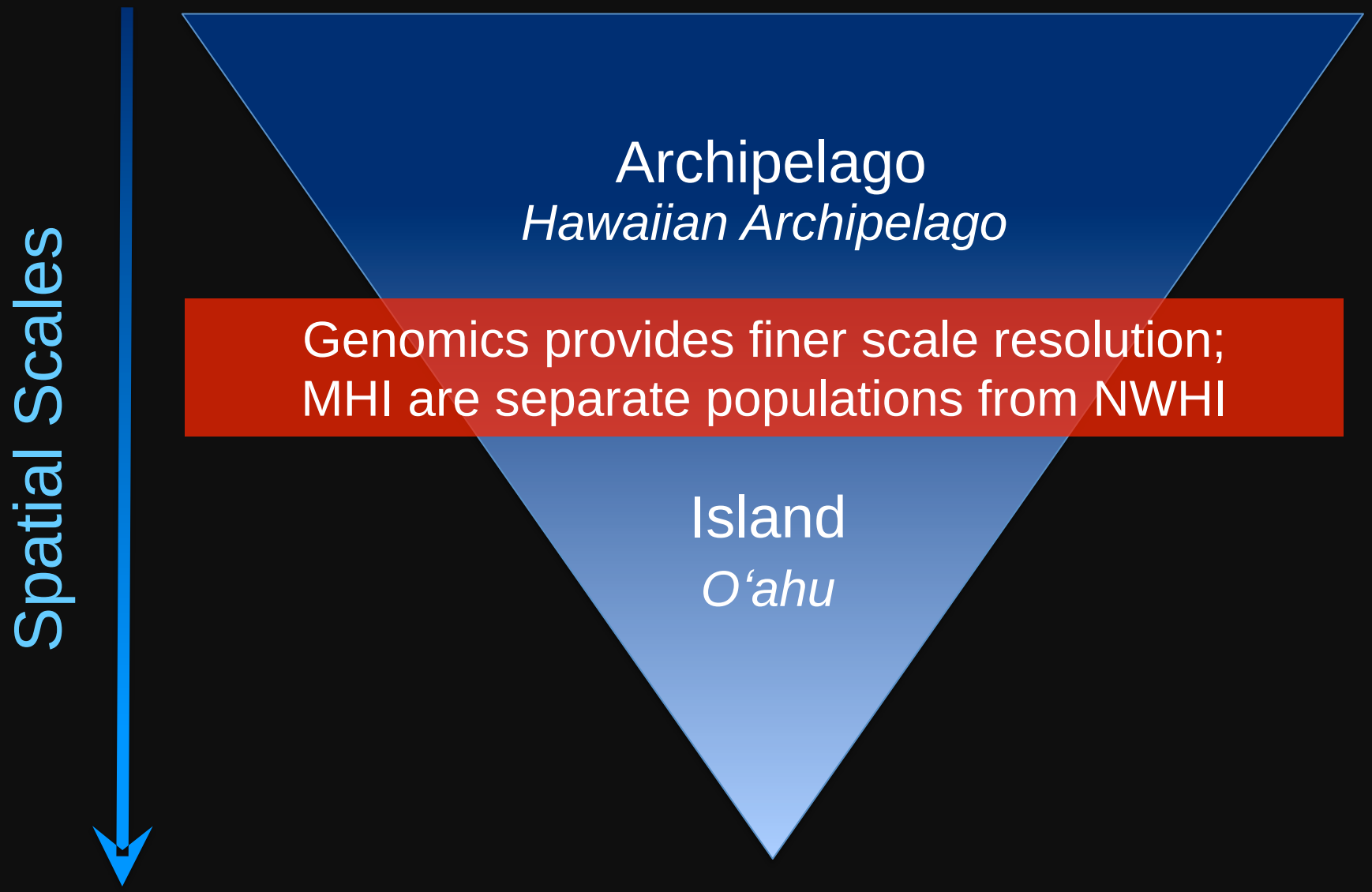


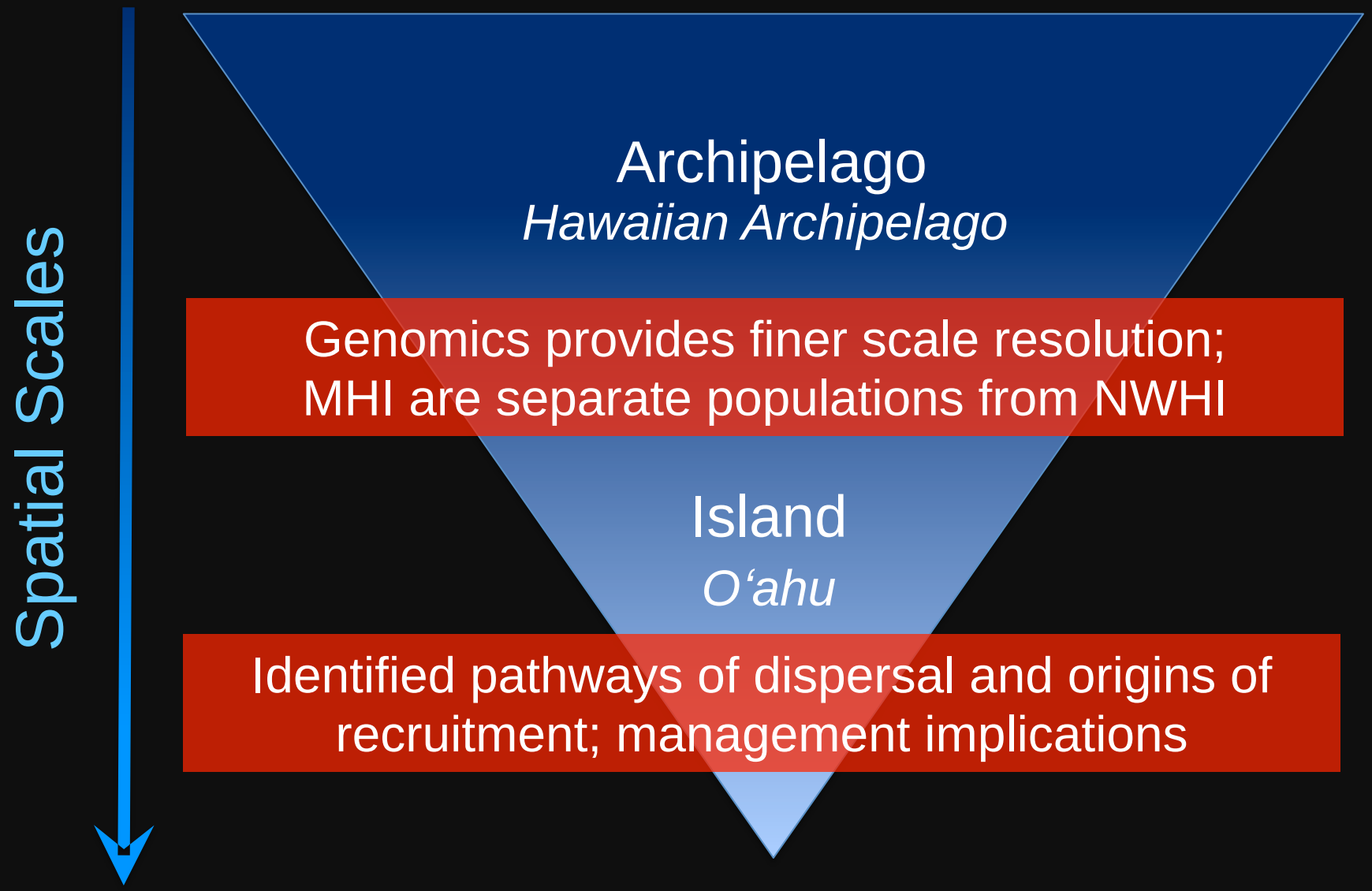
- Six occurrences of retention inside Kāne‘ohe Bay
- Two instances of dispersal out of the bay (Hau‘ula, Lā‘ie)

Conclusions: Island

- Majority of larvae do not disperse far
  - Most dispersal is limited to the <30 km
  - Some indication of local retention
- East O‘ahu is a source for recruitment
  - Kāne‘ohe Bay is dependent on recruitment from outside of the bay
    - Management Implications
  - Not many adults within the bay

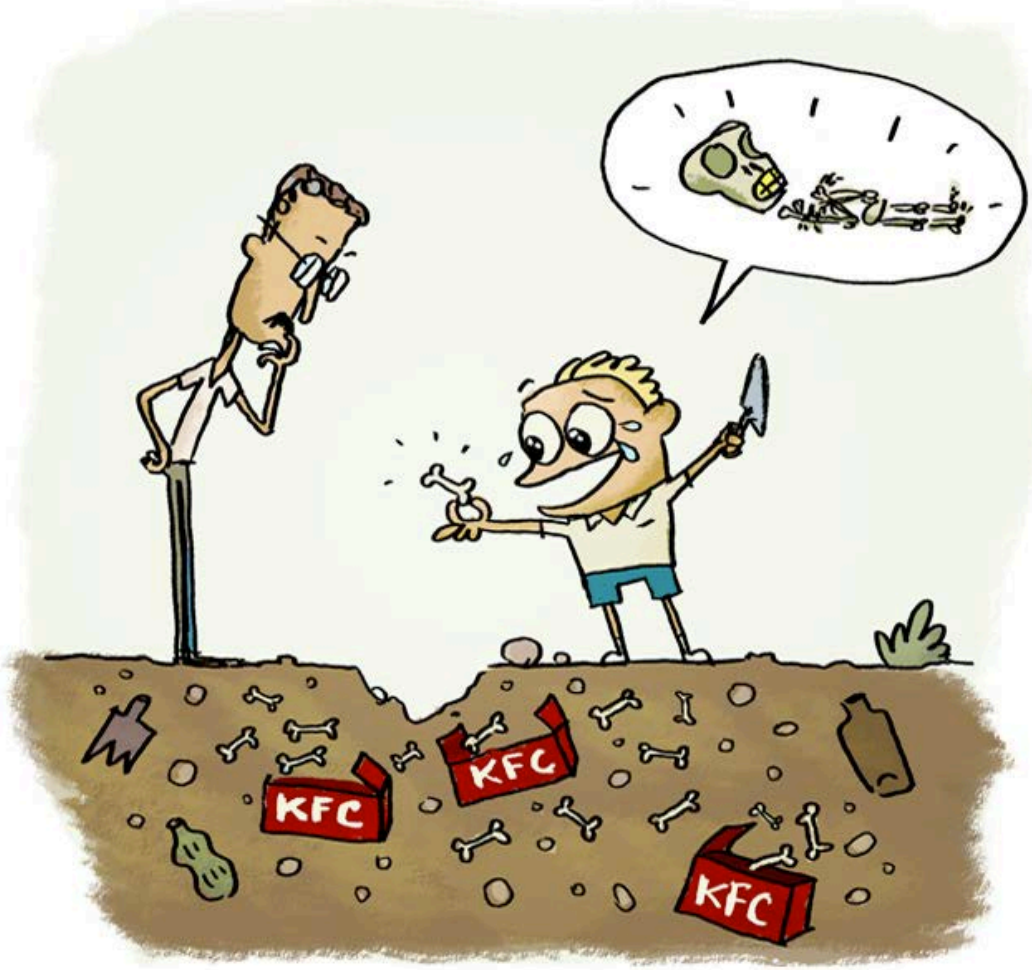

Spatial Scales
Archipelago
Hawaiian Archipelago
Island
O‘ahu


Spatial Scales
Archipelago
Hawaiian Archipelago
Genomics provides finer scale resolution;
MHI are separate populations from NWHI
Island
O‘ahu


Spatial Scales
Archipelago
Hawaiian Archipelago
Genomics provides finer scale resolution;
MHI are separate populations from NWHI
Island
O‘ahu
Identified pathways of dispersal and origins of
recruitment; management implications


CANADIAN No 1

Problems in the field



@PostAntiquarian

Once I got very excited to find some bones in a trench, thinking it may have been a midden, then the KFC wrapper emerged. #fieldworkfail

Problems in the field

- Misidentifications in the field

How many species do you see?








How many species do you see?

Problems in the field

- Misidentifications in the field
- Incorrect labeling


TANE SINCLAIR-TAYLOR

Problems in the field

- Misidentifications in the field
- Incorrect labeling
- Inadequate sample size
- Making sure DNA remains stable
  - Proper preservation solution
  - Avoid extreme heat
- Contamination

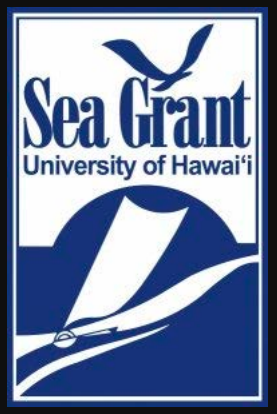
Genetics as a tool

- Genetics be can useful in addressing a variety of questions
- Provides insight into evolutionary mechanisms
- Informs management and conservation
- As molecular technology advances, our ability to answer questions increases

Acknowledgements

Funding Sources

- Office of National Marine Sanctuaries (NOAA), Dr. Nancy Foster Scholarship
- NSF Graduate Research Fellowship Program
- Castle Foundation
- University of Hawaii Sea Grant Program



Acknowledgements

ToBo Lab members (past and present), Fish Flow team

Field Help: Anela Akiona, Keisha Bahr, Evan Barba, Lindsay Bull, Gregory Burgess, Katia Capel, Bailey Carlson, Howard Choat, Daniel Coffey, Delany Coleman, Joshua Copus, Chelsie Counsell, Matthew Craig, Joseph DiBattista, ʻAleʻalani Dudoit, Jeff Eble, Iria Fernandez Silva, Kelle Freel, Michelle Gaither, Campbell Gunnell, Mykle Hoban, J.P. Hobbs, Griffin Holms, Kaleonani Hurley, Conor Jerolmon, Garrett Johnson, Steve Karl, Derek Kraft, Randall Kosaki, Sarah Leitner, Cory Lescher, Claire Lewis, Dan Levy, Joshua Levy, Kaimana Lundquist, Cassie Kaʻapu-Lyons, Sean Mahaffey, Carl Meyers, Eileen Nalley, Edna Diaz Negron, Yannis Papstamatiou, Julien Paillusseau, Mark Sparky Priest, Joshua Reece, D. Ross Robertson, Mark Royer, Tane Sinclair-Taylor, Kim Tenggardjaja, Kai Steuer, Zoltan Szabo, Kaliko Thomas, Jackie Troller, Sarah Tucker, Leon Weaver, Robert Whitton, Van Wishingrad, Jill Zamzow, Julie Zill, and many more.

Logistical Support: David Pence, Jason Jones, and UH Dive Office, Crew of the R/V Hiʻialkai, Dream Divers, Dolphin Divers, M/V Deli, the Administration of the British Indian Ocean Territory and Chagos Conservation Trust, University of Milano-Bicocca Marine Research and High Education Centre in Magoodhoo, the Ministry of Fisheries and Agriculture, Republic of Maldives, and the community of Maghoodhoo, Faafu Atoll


Questions?