Species Distribution Modeling of Non-Native Snappers (*Lutjanus* spp.) in the Hawaiian Archipelago

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BACKGROUND

- Bluestripe Snapper or Taʻape (*Lutjanus kasmira*) and Blacktail Snapper or Toʻau (*L. fulvus*) were introduced to Hawaiʻi in the 1950's from French Polynesia for fisheries enhancement.[1]
- Both species are loosely considered "invasive" despite mixed evidence of competition with and predation on native species.
- *L. kasmira* observed at shallow waters at all islands/atolls of the Main Hawaiian Islands (MHI) and Northwestern Hawaiian Islands (NWHI) except ʻŌnū (Gardner Pinnacles), Kamole (Laysan Island), and Kamokuokamohoaliʻi (Maro Reef)[2]. Not observed at mesophotic depths (45-100 m) beyond Lalo (French Frigate Shoals), where reefs are dominated by endemic fish[3] (**Fig. 1**).
- *L. fulvus* observed in shallow waters (<45 m) only, up to Lalo (**Fig. 1**).

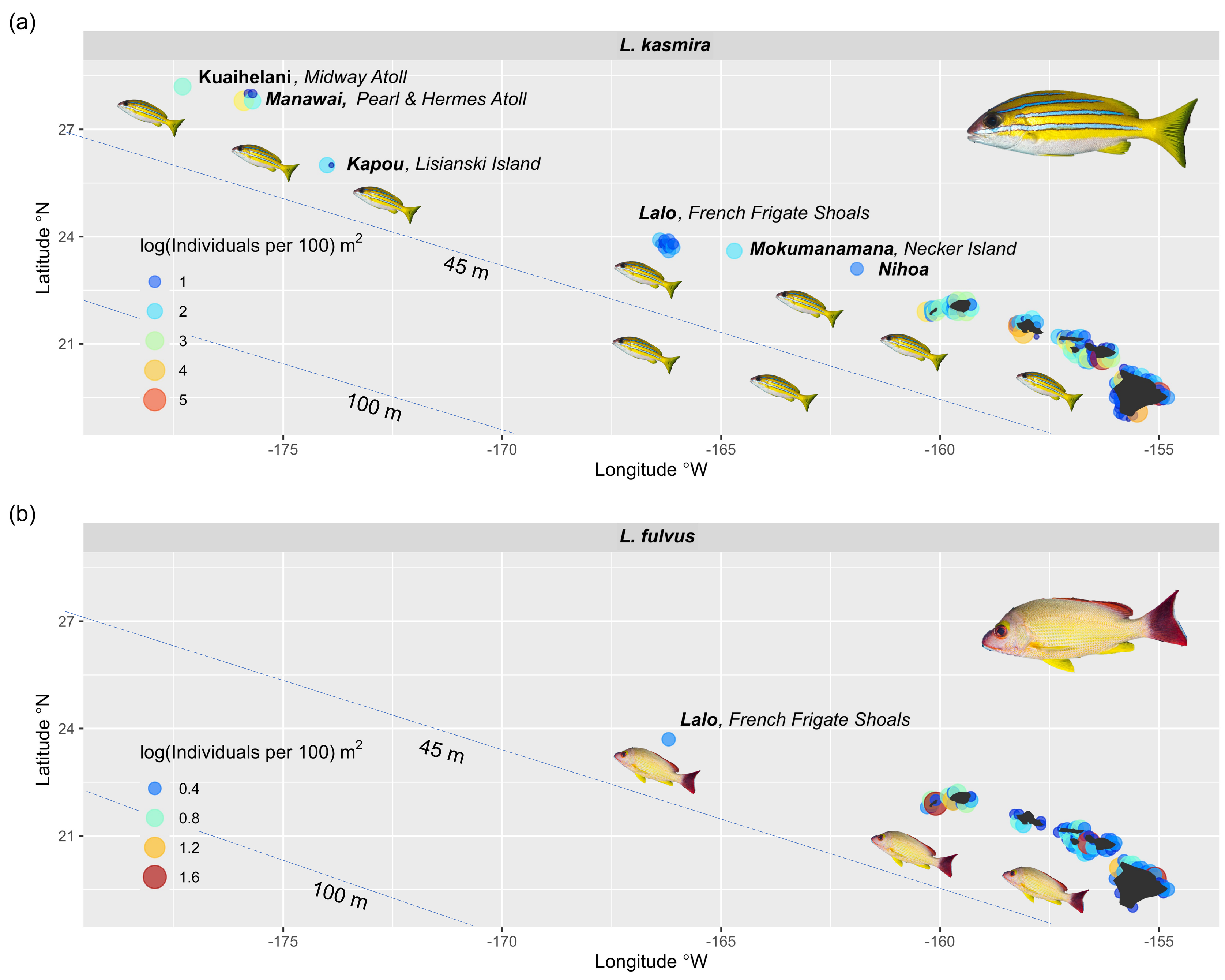


Figure 1. *L. kasmira* and *L. fulvus* distribution and abundance across the Hawaiian Archipelago. **(a)** Distribution of *L. kasmira* in NWHI extends past Lalo up to Kure Atoll (~2250 km NW of Honolulu) **(b)** Distribution of *L. fulvus* in NWHI ends at Lalo (~885 km NW of Honolulu). Figure adapted from Kosaki et al. (2017)[3]. Note that the scales between the two species are different.

OBJECTIVE

Quantify how environmental and anthropogenic variables drive differential distribution patterns between *L. kasmira* and *L. fulvus* and how the patterns differ across spatial and temporal scales.

METHODS

Species Distribution Models using Ensemble Boosted Regression Trees (BRTs):
- Hybrid statistical/machine learning approach to deal with numerous predictors and complex relationships
- Cross validated using a 75/25 split (75 to train the model, 25 to validate)
- 50-model ensemble

Species Dataset:
- NOAA National Coral Reef Monitoring Program (NCRMP) Dataset[4]
  - SCUBA-based Stationary Point Count (SPC) surveys, *n*=8944
    - Randomized hard bottom location at depths of 0-30 m
    - Paired 15-m diameter cylinders (**Fig. 2**)
    - Photographs of benthos taken along transects
    - 2009-2021 (every 3 years) across MHI and NWHI

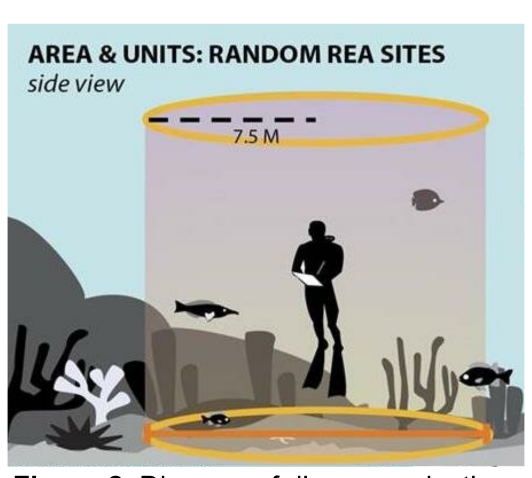


Figure 2. Diagram of divers conducting an SPC survey.

Environmental Datasets and Tools:
- NOAA Environmental Data Summary (EDS)[5-12]
  - Integrates field survey data with gridded environmental data (**Table 1**)
- Ocean Tipping Points (OTP)[13]

Table 1. Descriptions of environmental and anthropogenic variables included in ensemble boosted regression tree models.

Predictor	Metric	Resolution	Justification
Sea Surface Temperature (SST)[6]	Mean	Monthly, 5 km 1985-present	Thermal preference, tolerance
	Q 95	Annual, 5 km	Upper thermal limit, heat event
Chlorophyll a (Chla)[7]	Mean	Monthly, 5 km 1997-present	Food availability/productivity
Depth[8]	Meters	At survey site	Depth constraints, temperature gradients
Rugosity[9, 10, 11]	SD of bathymetry	Climatology 0.1 km (MHI) 0.5 km (MHI & NWHI) 0.5 km (MHI) 0.6 km (NWHI)	Habitat preference
Coral cover[8]	% cover		Habitat preference
Wave energy[12]	Total kinetic energy (TKE)	3 hours, 4 km 2009-2020	Feeding zones, food delivery mechanisms, aggregations at certain flows
Spearfishing effort[13] (Boat- & shore-based)	Hours/ha	--	Human fishing pressure effects on populations
Effluent[8]	g/km²/day	--	Water quality, habitat disturbance
Nearshore sediment[13]	Ton/ha/yr	0.5 km	Reef degradation, changes in temp/salinity
Latitude, Longitude[8]	Degrees	--	Temperature gradients
Year[8]	--	--	Annual variability

PRELIMINARY RESULTS

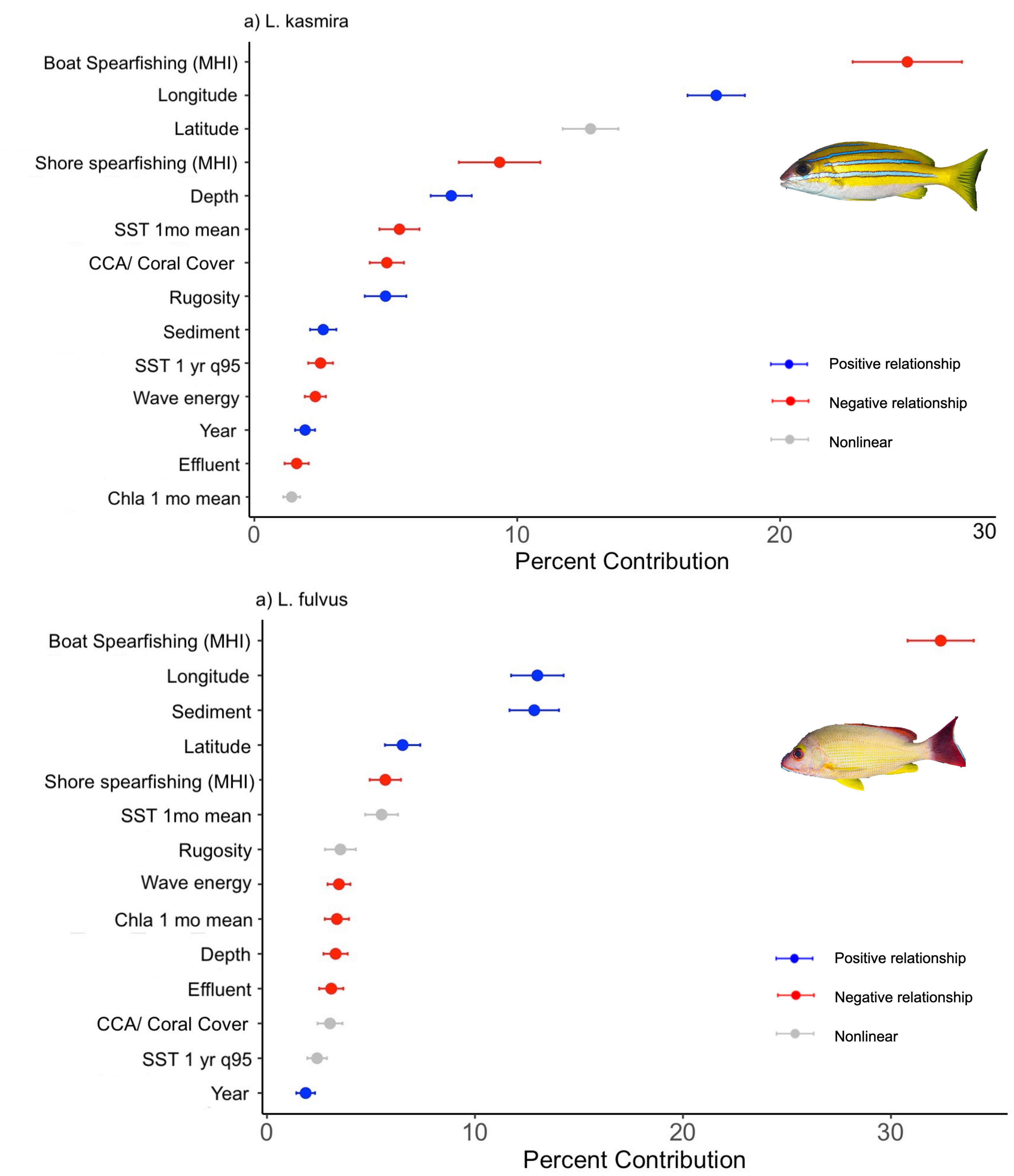


Figure 3. Mean percent contribution (± s.d.) of environmental and anthropogenic variables to the presence or absence (P/A) of **(a)** *L. kasmira* and **(b)** *L. fulvus* determined by ensemble boosted regression tree models. Colors represent the relationship between the predictor variables and the P/A responses, where blue indicates a positive relationship, red indicates a negative relationship and gray indicates a relationship that is not clearly linear. The percent contribution is a measure of each predictor variables importance to the overall model fit.

DISCUSSION

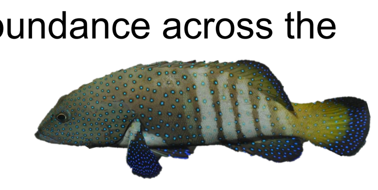
Human influences
- The most significant predictor of *L. kasmira and L. fulvus* presence is boat-based spearfishing, indicating a strong negative association between encounter probability and fishing effort.
- Shore-based spearfishing is also an important negative predictor for both species.

Habitat influences
- *L. kasmira* presence is positively associated with depth and rugosity but negatively with coral cover, which indicates they may prefer deeper, cooler edge habitats with structural complexity.
- *L. fulvus* is more likely to be in higher sediment habitats, potentially indicating association with freshwater outflows.
- The presence of both *L. kasmira* and *L. fulvus* is heavily influenced by latitude and longitude, which may indicate the influence of underlying spatial processes from variables that are not currently represented in the model (i.e., upwelling, trade winds, and biological processes like dispersal).
- There are no standardized species datasets at mesophotic depths, so our ability to understand what is going on beyond 30 m is limited.
- Lack of freshwater input due to less complex topography in the NWHI may be contributing to lower *L. fulvus* presence.

Management and ecological implications
- Spearfishing could be a potential control strategy, given the strong influence it seems to have on presence of these invasive species.
- Changing climate conditions such as warming temperatures may have a relatively small impact on *L. kasmira* but seems unlikely to outweigh other drivers.

NEXT STEPS & FUTURE DIRECTIONS

- Run models with abundance as response variable (separate from presence/absence, P/A, models) to better understand drivers of differential distribution.
- Combine P/A and abundance results in hurdle models to predict fish abundance across the entire spatial domain and in changing climate scenarios.
- Include Peacock Grouper or Roi (*Cephalopholis argus*, shown right) as a third major invasive species in the Hawaiian archipelago.



- Share results with local fishing community to encourage development of a sustainable fishery.

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[1]Parrish et al. (2000) Interactions of Nonindigenous Blueline Snapper (Taape) with Native Fishery Species: Final Report. [2]Fukunaga et al. (2017) Distribution and abundance of the introduced snapper *Lutjanus kasmira* (Forsskål, 1775) on shallow and mesophotic reefs on the Northwestern Hawaiian Islands. Bioinvasion Records 6(3), 259-268. [3]Kosaki et al. (2017) Scientists Discover Large Taʻape-Free Zone on Deep Coral Reefs of the Northwestern Islands, Hawaii Fishing News. [4]Ayotte et al. (2015) Standard Operating Procedures: Data Collection for Rapid Ecological Assessment Fish Surveys. [5]Couch et al. (2023) Ecological and environmental predictors of juvenile coral density across the central and western Pacific. [6]Coral Reef Watch (CRW). [7]European Space Agency Ocean Color Climate Change Initiative (ESA OCCI). [8]National Coral Reef Monitoring Program (NCRMP). [9]National Geophysical Data Center Coastal Relief Model. [10]National Centers for Environmental Information (ETOPO). [11]Pacific Islands Ocean Observing System (PacIOOS). [12]Regional Ocean Modeling System (ROMS). [13]Ocean Tipping Points (OTP PacIOOS).