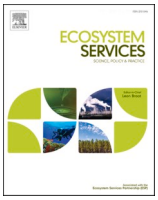
Ecosystem Services 69 (2024) 101661

Contents lists available at ScienceDirect

Ecosystem Services

journal homepage: www.elsevier.com/locate/ecoser



Full Length Article

Impacts of commercial and subsistence fishing on marine and cultural ecosystem services important to the wellbeing of an Indigenous community in Hawai'i

Ron Vave [a,b,*], Nadine Heck [a], Siddharth Narayan [a], Sonya Carrizales [c], Damien Kenison [d], Adina Paytan [e]

[a] Department of Coastal Studies, East Carolina University, NC, USA
[b] Department of Pacific Islands Studies, University of Hawai'i at Mānoa, HI, USA.
[c] Mount Holyoke College, South Hadley, MA, USA
[d] Ho'okena community, South Kona, Hawai'i Island, Hawai'i, USA
[e] Institute of Marine Science, University of California, Santa Cruz, CA, USA

ARTICLE INFO

Keywords:
Indigenous
Fisheries
Commercial
Subsistence
Ecosystem
Culture
Impact

ABSTRACT

Marine ecosystems provide essential services to coastal residents, particularly for indigenous fishing communities that have strong ties to the environment and obtain multiple benefits from their use and management of ocean spaces. However, understanding of how these are impacted by fisheries, external pressures, and ocean management, remains limited due to a focus on economic valuation and aggregated metrics. This study explores the importance of select marine ecosystem services to the wellbeing of an indigenous community in West Hawai'i and the observed impacts on these ecosystem services by commercial and subsistence fishing. We used a mixed-methods approach that combined a workshop with an online survey of community perceptions regarding community important marine resources and cultural values. We find that both fish and non-fish species are important to all four well-being categories, including food security, culture, mental wellbeing, and income, though the least importance was given to the economic value. This study also found that commercial fishing is perceived to have a higher negative impact on marine resources and cultural values than subsistence fishing, but a generally lower impact on non-fish than fish species. The lack of community input into legislation development and a lack of enforcement capacity were perceived to aggravate these further, whereas the integration of place-based knowledge, values and rules of the environment was seen as beneficial to both marine and cultural ecosystem services. Overall, this study shows that non-economic and disaggregated valuation approaches are critical for revealing the variable ecosystem services that marine environments provide to local communities and the importance of more inclusive resource management approaches to manage impacts on these services.

1. Introduction

Oceans and coastal areas provide diverse ecosystem services that are important to a wide variety of stakeholder groups and improve the overall quality of human well-being in coastal communities (Chakraborty et al., 2020). Ecosystem services are defined in the Millenium Ecosystem Assessment (2005) as "benefits that people obtain from ecosystems." These services include supporting (e.g., nutrient cycling) and regulating ecosystem services (e.g., coastal protection, climate regulations), as well as provisioning ecosystem services (e.g, fish, firewood) that are typically more tangible, and cultural services (e.g., tourism, spiritual benefits) (Martinetto et al., 2020; Millenium Ecosystem Assessment, 2005). Coral reefs are a classic example of an ocean ecosystem that provides multiple ecosystem services. For example, reefs providing regulating and supporting ecosystem services including fish nurseries, building materials, sand generation, and nutrient processing (Albert et al., 2015; Archer et al., 2017; Perry et al., 2015). Additionally, coral reef ecosystem services include fish, coral, and non-coral invertebrates that provide food security in the form of vital nutrition to coastal communities as well as diverse livelihood

* Corresponding author at: 1890 East-West Road, Honolulu, HI , USA.
E-mail addresses: ronvave@hawaii.edu (R. Vave), heckn19@ecu.edu (N. Heck), narayans19@ecu.edu (S. Narayan), carri23s@mtholyoke.edu (S. Carrizales), namamo@yahoo.com (D. Kenison), apaytan@ucsc.edu (A. Paytan).

https://doi.org/10.1016/j.ecoser.2024.101661
Received 23 February 2024; Received in revised form 22 August 2024; Accepted 5 September 2024
Available online 11 September 2024

opportunities, including aquarium and curio trade (Woodhead et al., 2019). Coral reefs and the wide variety of fish and non-fish species that inhabit these reefs further provide a range of recreation and tourism services that are of great economic value to local economies. The economic value of tourism and recreation for Hawaii's coral reefs in 2007, for example, was US$356 million annually (Brander and van Beukering, 2013). Finally, coral reefs provide another important but relatively overlooked ecosystem service, namely, cultural benefits (Martin et al., 2016). Collectively, the ecosystem services provided by coral reefs contribute to multiple aspects of human well-being, defined as a state of being of people and the environment, when human needs are met, such that they can act meaningfully to pursue their goals, and they enjoy a satisfactory quality of life (Chakraborty et al., 2020; Leong et al., 2019; Skewes et al., 2016). Human well-being can be described using four broad indicators: income, health, food security, and culture all of which contribute to the overall well-being of coastal communities (Skewes et al., 2016)Despite the intrinsic importance of the concept of human well-being to ecosystem services, the contribution of diverse ecosystem services to distinct well-being aspects of local communities is not well understood to date, particularly in indigenous contexts.

Cultural ecosystem services from ocean and marine ecosystems are important to the well-being of indigenous coastal communities, though local-scale understanding of the impacts to communities due to the degradation of these services is not well understood. In the Pacific, cultural ecosystem services have been shown to play an important role in, for example, adaptation decisions by coastal communities (Narayan et al., 2020). Due to the importance of ecosystem services to local communities' well-being, changes in the availability of these services can affect different components of well-being (Millenium Ecosystem Assessment, 2005) and the degradation of these ecosystem services can cause significant harm to human well-being. Around 60 % of global marine ecosystems have been degraded and are under pressure due to anthropogenic and natural drivers of change (Buonocore et al., 2021; UNEP, 2011). Coral reefs have been reduced by 20 % and of the remaining reefs around 20 % are degraded (Buonocore et al., 2021; IOC/UNESCO et al., 2011). Local stressors to marine ecosystems include tourism, overfishing, illegal fishing, destructive fishing methods, pollution, and sedimentation (Buonocore et al., 2021; Weng et al., 2023). Climate change and specifically the warming of the ocean surface and ocean acidification also reduce the corals' resilience (Bahr et al., 2015). This is important since indigenous coastal communities are highly dependent on coastal fisheries (Sulu et al., 2015). However, little is understood about how impacts on ecosystem services from different ocean uses might affect the wellbeing of local indigenous communities, especially cultural services that are difficult to quantify economically.

Varied, and often intangible, cultural ecosystem services pose a challenge with regard to understanding the impacts of changes to the availability of these services on human well-being, especially at highly local scales. Ecosystem services are often assessed economically via diverse economic tools to measure the monetary values associated with their benefits (Hirons et al., 2016). While cultural ecosystem services are challenging to quantify in monetary values, there have been recent efforts to include cultural services in valuation assessments, though with a bias towards those services for which monetary values or sufficient proxies may be evaluated, such as recreation, tourism, and aesthetic values. However, cultural ecosystem services such as physical health and spirituality are central to human well-being, particularly in indigenous communities, in both tangible and intangible ways. Efforts to assign monetary values to these services do not therefore capture their contribution to human well-being adequately (Hirons et al., 2016). Furthermore, cultural ecosystem services, like other ecosystem services can vary depending on the specific aspect of the ecosystem being assessed, for example, reef fish species that provide food security versus fish species perceived as valuable for tourism. Assessments of these services are often not assessed in detail but pooled into a category such as 'impact on culture' or all fish combined, or focusing on select grouping such as cultural keystone species (Garibaldi and Turner, 2004). There is a knowledge gap on granular, detailed assessments of the myriad benefits and values that constitutes culture, or of the specific value of different reef fish species, which can have varying importance for an indigenous community (Liquete et al., 2013). This gap in knowledge of how changes to specific and varied cultural ecosystem services impact human well-being can hinder our understanding of the impacts of ecosystem service degradation on the well-being of indigenous fishing communities.

This work aims to shed light on the importance of various ecosystem services, including cultural ones, for indigenous fishing communities and identify how existing pressures may impact these ecosystem services at the local scale. We conduct this study in, and with, a coastal community on the West coast of Hawai'i. We use a mixed methods approach to identify what kind of ecosystem services are important to indigenous community members and how these services contribute to four well-being categories: food security, economic income, mental well-being, and cultural practices (Skewes et al., 2016). In addition, we explore community's perception on how these ecosystem services are impacted by marine users, including commercial and subsistence fishing, which is rarely investigated. This information is vital for fostering the integration of indigenous people's values and concerns in coral reef, conservation and ocean management decisions and to improve our understanding of how different ecosystem services contribute to different aspects of well-being in indigenous fishing communities.

2. Methods

2.1. Study site

Our work was conducted in a small fishing community, Ho'okena, located on the leeward, West side of Hawai'i Island Fig. 1. Ho'okena village is one of the last Hawaiian communities to use outrigger canoes to traditionally fish for mackerel scad (*Decapterus* species) commonly known as ʻōpelu in Hawaiian. Ho'okena community members engage in both subsistence and commercial fishing in the nearshore and offshore waters within the Ho'okena ahupua'a (subdivision of land). Ho'okena waters contain shallow coves (Norris and Dohl, 1979) and are managed by state and federal agencies such as the Department of Land and Natural Resources (DLNR) and the National Oceanic Atmospheric Administration (NOAA), under two types of management structures. The first is the Ho'okena Fish Replenishment Area (FRA), one of nine FRAs on West Hawai'i which, in total, comprise 35 % of the West Hawaiian coastline. These FRAs delineate ocean spaces where all forms of harvest for the aquarium trade are prohibited (Walsh, 2015).

2.2. Data collection

We used a mixed methods approach to assess the importance of ecosystem goods and services (EGS) to indigenous community members and how these services are impacted by multiple local and global pressures and management actions. The population of this indigenous community in 2022 was 52, of which only 17 % identified as Native Hawaiian and Other Pacific Islander. Given the small population, multiple attempts were made to recruit as many participants as possible, through the dissemination of survey forms through community elders, and addressing community elder gatherings.

We first conducted a workshop in June 2022 with nine local community members, including a mix of fishers and non-fishing community members that are part of fishing families. Participants were selected using a purposive sampling approach based on the recommendation of community elders. In this workshop, we asked participants why the marine environment in Ho'okena is important to them. We coded answers into different types of ecosystem services. During this process, we included as participants, members of the native Hawaiian community of Hoʻokena who currently live in nearby native Hawaiian communities

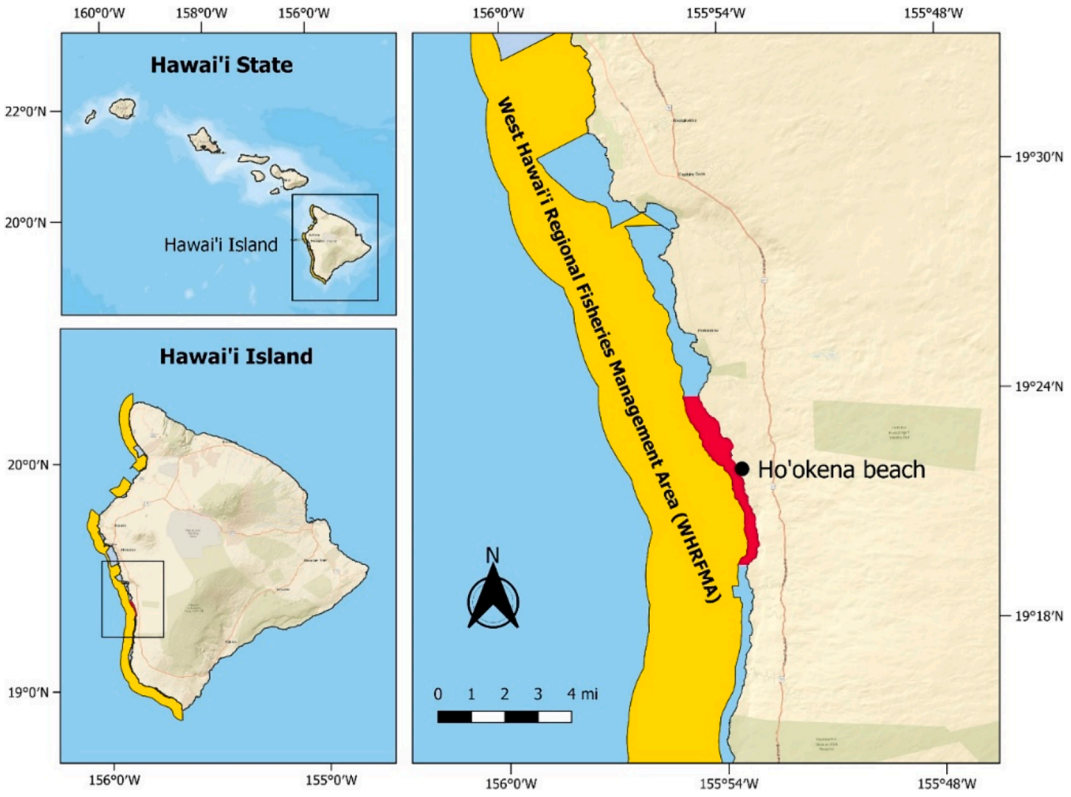


Fig. 1. Two fisheries management strategies in Ho'okena: the Fisheries Replenishment Area (FRA) in red and West Hawai'i Fisheries Management Area in yellow.

but have been users of these waters either presently or in the past.

Results from the workshop were then used to develop an online survey instrument. Survey questions and forms were iteratively revised based on feedback from community elders. We then used purposive sampling approaches to target native Hawaiian community members of Ho'okena through dissemination of links to Qualtrics survey forms via community elder, and also through the West Hawaii Fisheries Council listserv. The survey instrument was also distributed during two community gatherings in June 2022 and June 2023.

A total of 22 respondents completed the survey of which 55 % (n = 12) were male, 32 % (n = 7) were female, and three preferred not to state their gender. Seventeen (77 % of respondents) primarily fished in Ho'okena waters, four (18 %) fished in other waters, while one does not engage in fishing.

Questions included a mix of multiple-choice with Likert-scaled responses, and several open-ended questions (Table 1).

This first section covered questions on the importance of each marine resource to Ho'okena community in terms of (a) food security, (b) income, (c) culture, and (d) mental well-being. Marine resource list and categories were based on local fishermen's knowledge which prioritized community important indicators. Hawaiian marine resource names together with its scientific and English common names can be seen in Appendix 1. Responses on the importance of each marine resource were on a Likert scale from 1 (Not important at all) to 5 (Very important). Food security was loosely defined as access to sufficient, safe, and nutritious food that meets dietary needs and food preferences. Culture was defined as traditional practices and ceremonies whereas mental well-being was in the context of emotional health and well-being. Categorical percentage importance is based on the number of respondents (of the total surveyed) who ranked a particular marine resource as "Important" or "Very important". For example, 100 % importance of pelagic fish for food security means that all respondents rated pelagic fish as important or very important" for food security. Cumulative percentage is not calculated but visualized as the combined 'categorical percentage importance' for all four metrics (food security, culture, mental wellbeing, and income) for each of the marine resource. Higher cumulative percentages (longer bars) in Fig. 3a implies high importance of that marine resource across the metrics being assessed to the Ho'okena community. What followed were questions regarding the personal views of respondents' perceptions regarding the impact of subsistence, and commercial fishing pressure on each marine resource.

This second section looked at the importance of cultural values in terms of (a) traditional practices and ceremonies, plus (b) mental well-

Table 1
The four sections and measures used in the online survey forms.

Section	Question	Measurement
Human well-being	Importance of marine resources for (a) Food security, (b) income, (c) culture, and (d) mental well-being (Skewes et al., 2016)	5-point Likert scale from 1 = Not important at all to 5 = Very important.
Impacts	Impact of Subsistence fishing, and Commercial fishing on marine resources	Binary: 1 = impact, 0 = no impact
Management pressures	Anthropogenic impacts on marine resources and cultural values	Likert scale: −1 (Decrease), 0 (No change), to +1 (Increase), or Don't know.
Concerns	Feeling restricted in ocean use in Ho'okena?	5- point Likert scale from 1 = Not at all to 5 = Very restricted with an open-ended option for explanations.
	Stakeholder issues on ocean use	Yes (please describe) or No.
	Observed stakeholder conflicts on ocean use	Yes (please describe) or No.

being. Responses were on a Likert scale from 1 (Not important at all) to 5 (Very important). Like the previous section, respondents were asked about the impacts of subsistence, and commercial fishing pressure, but this time, on the Hawaiian values which emerged from the intangible benefits identified in the 2022 community workshop (Fig. 2). Similar categorical, and cumulative percentages, were calculated and graphed for cultural values in Fig. 3d.

The third section is an assessment of the perceived individual impacts of management actions and pressures where respondents choose if it caused a decrease, increase, or no change in (a) marine resources, and (b) cultural values, respectively. The blurred distinctions in ecosystem services definition between benefits and services, tangible and intangible highlighted in La Notte et al. (2017) and Boerema et al. (2017) plus the interchangeable use of these terms can cause confusion. As such, we have opted to only use 'marine resources' and 'cultural values' when presenting the results, and only refer back to ecosystem services in the Discussion section.

Finally, respondents were asked if they felt restricted in their use of Ho'okena waters and explain why. Answers were thematically condensed into a narrative summary (Maxwell, 2013) according to the management actions and pressures identified in the third section.

We accessed, analyzed and visualized Qualtrics data in Microsoft Excel and R version 4.3.1 (R Core Team, 2023) using the qualtRics, likert and tidyverse packages.

3. Results

As the last Hawaiian village that still uses traditional outrigger canoes known as wa'a to fish, the Ho'okena community is highly reliant on the ocean and its resources. In the workshop, community members listed both tangible (Fig. 2) and non-tangible benefits and services that they derive from the ocean. These benefits were categorized into eight broad themes (Fig. 3). Tangible benefits included fishes from pelagic and coastal waters plus other marine resources such as seaweed and corals (Fig. 2). Non-tangible benefits included traditional practices of fishing and traditional canoe use which are passed down from kupuna (elders and ancestors) and are being perpetuated as part of preserving ties and identity to 'āina (land) and ocean as a way of life (Fig. 2). This also included harvesting only what a family needs for direct consumption to ensure future harvests for all so that no one faces food shortage. However, these are affected by increased access (permission and ability to fish) resulting in increased harvest and disrespect for Hawaiian values and ways of fishing by others including external fishers. These in turn affect the community's kuleana (responsibilities) to holistically malama (take care of) the place (environment) and people thereby making the goal of ensuring abundant, healthy resources that meets community's needs difficult to achieve.

3.1. Importance of marine resources and cultural values

Respondents expressed variable individual and cumulative

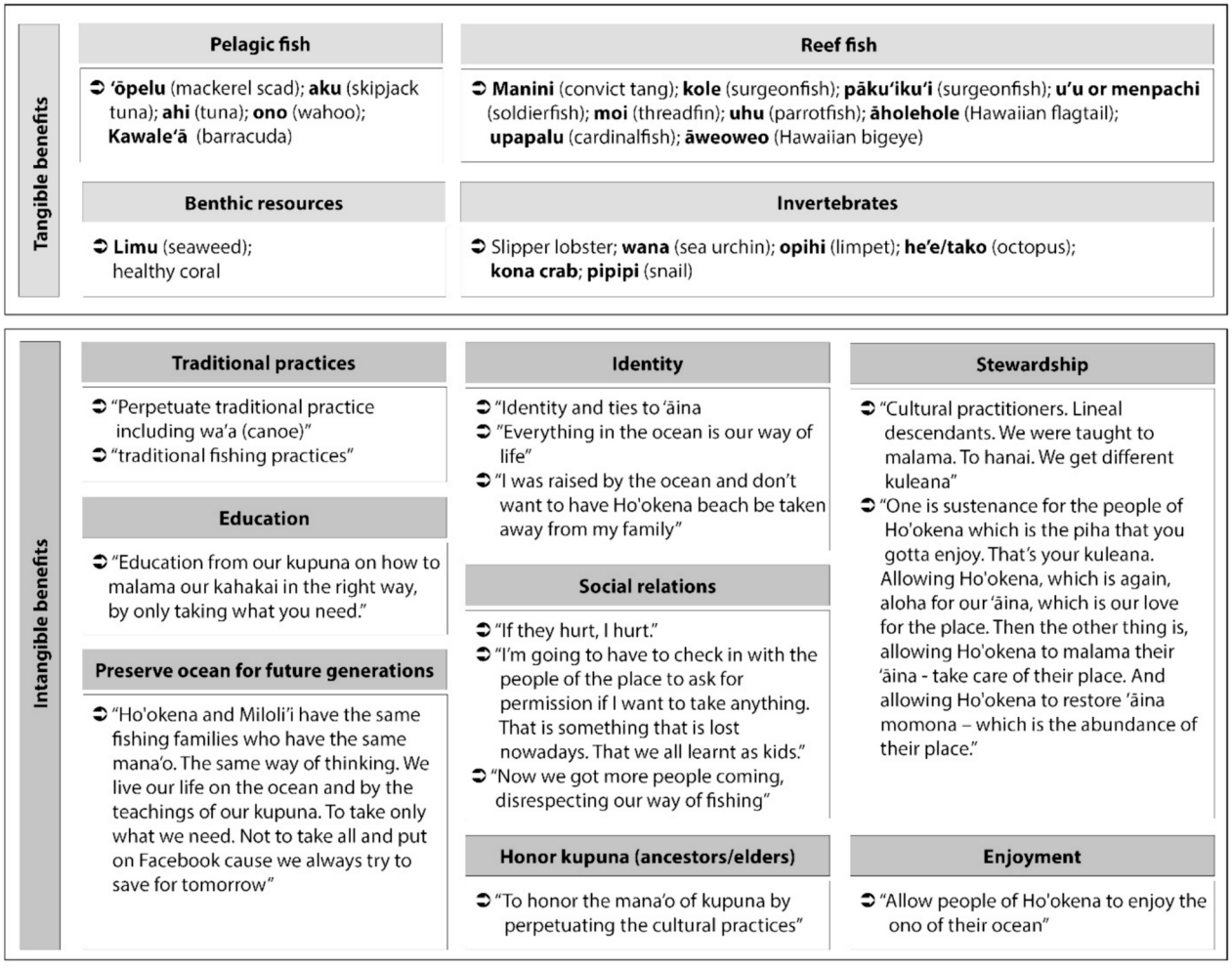


Fig. 2. Tangible benefits identified by community members (English and scientific names are detailed in Appendix 1) plus list of intangible cultural values related to ocean use elicited from Ho'okena community members in the June 2022 workshop.

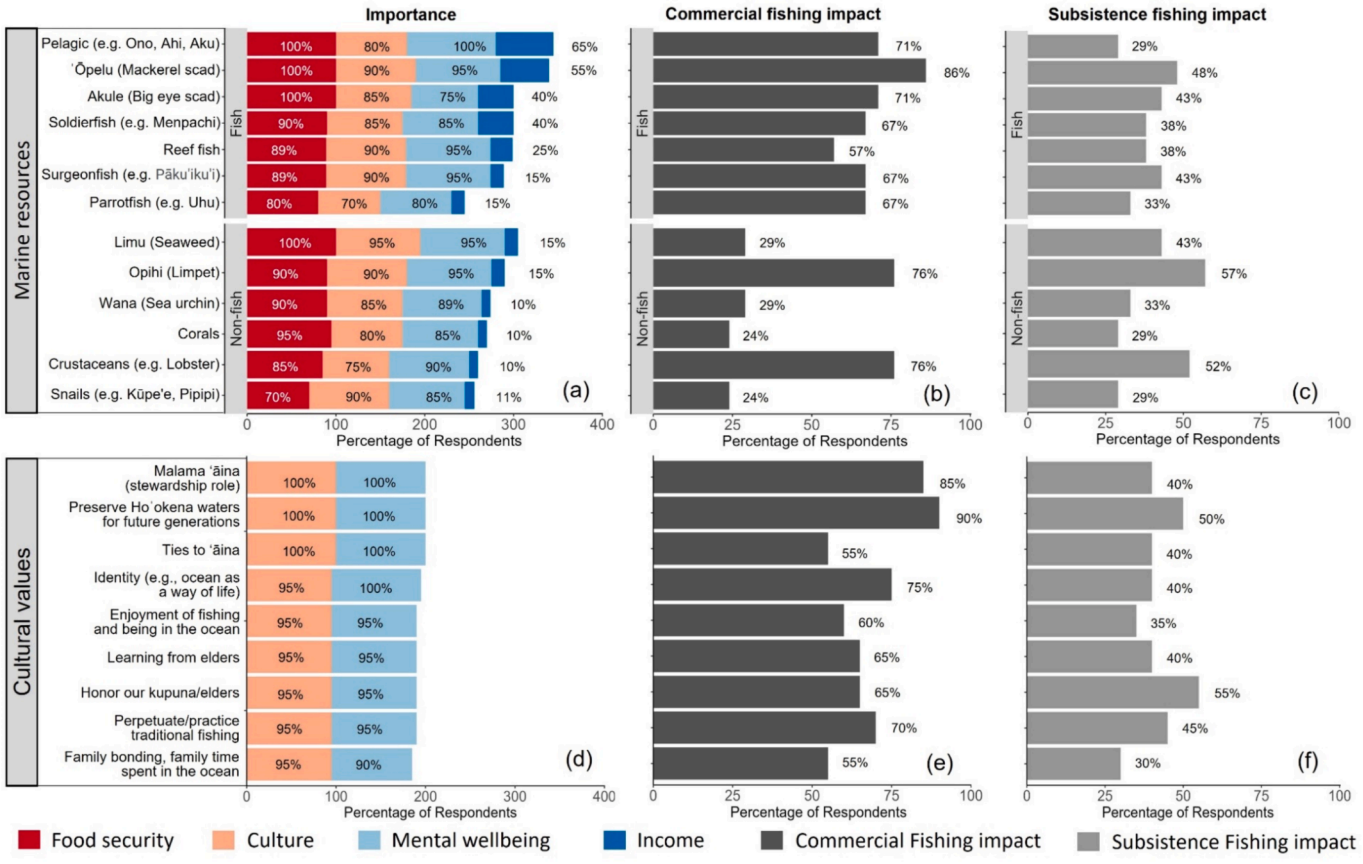


Fig. 3. Categorical and cumulative percentage of respondents ranking (a) marine resources and (d) cultural values as Important and Very important in terms of food security, culture, mental wellbeing, and income. Greyed bar charts (b-c, e-f) are the percentage of respondents' views on perceived impacts of the different fishing types on each marine resource and cultural value, respectively.

importance for the marine resources in the four human wellbeing categories being assessed with all resources being ranked highly for food security, culture and mental wellbeing but less so for income (Fig. 3a). Marine resources with the highest cumulative importance of close to 400 % included pelagic fishes and ʻōpelu (Mackerel scad), plus the limu (seaweed) and opihi (limpet) for non-fishes (Fig. 3a). Conversely, the lowest cumulative importance was for parrotfish and snails which ranked low in most of the categories, especially for income. On the other hand, most respondents ranked all resources (Fig. 3a) as highly important for food security (70–100 % of respondents), culture (70–95 %), and mental well-being (80–100 %). Pelagic fish species and ʻōpelu were ranked more often than other resources for their economic importance, at 65 % and 55 % respectively. Across the four wellbeing categories, the economic importance of marine resources was ranked the lowest.

The importance of cultural values to Hawaiian culture and mental wellbeing in Fig. 3d were relatively similar with all respondents being unanimous in mentioning the high importance for three values: (i) stewardship role, (ii) preserving Ho'okena for future generations, and (iii) ties to ʻāina/land.

3.2. Fishing impacts on marine resources and cultural values

Fig. 3 shows that both commercial and subsistence fishing were perceived by the Ho'okena community to have a negative but varying level of impact on marine resources and the cultural values. Furthermore, a majority (57–86 %) of the respondents perceived commercial fishing to more negatively impact the fish than the non-fishes (Fig. 3b). Ecosystem services with the highest cumulative importance for pelagic fish and ʻōpelu to the community in terms of food, culture, mental wellbeing and income were the ones highly impacted by commercial fishing (Fig. 3a and b). Exceptions to the low commercial fishing impact on non-fishes were the opihi (limpet) and the crustaceans. Conversely, subsistence fishing impacts were generally found to have a lower impact (29–57 %) on marine resources except for opihi and crustaceans. On the other hand, corals and snails were perceived to be the least impacted by commercial fishing. Overall, our findings show that most marine resources were considered most important for the four human wellbeing metrics and that select resources such as ʻōpelu, opihi, crustaceans, pelagic fish and akule were perceived to be highly affected by fishing activities, although the main source of impact was slightly different.

Fig. 3d–f shows that all cultural values were deemed important for culture and mental wellbeing and were perceived to be generally impacted more by commercial (55–90 %) than subsistence fishing (30–55 %). The top three cultural values (25 % for each metric in the normalized Fig. 3d chart) that all community informants agreed on to be highly important were (1) stewardship role, (2) preserving Ho'okena for future generations, and (3) ties to ʻāina/land. Other cultural values were also important but slightly less so than others. Similar to the marine resources, the impacts of fishing on the cultural values was generally higher for commercial (55–90 %) than subsistence fishing (30–55 %).

3.2.1. Impacts of management on marine resources and cultural values

Except for fishery closures and marine conservation efforts, all other management actions faced challenges that were seen as negatively impacting both the marine resources and the cultural values (Fig. 4). Non-compliance with formal regulations was the leading driver of negative impacts on both marine resources (63 % of respondents) and social and cultural benefits (65 %). Over 59 % of all respondents also identified a lack of consideration of traditional indigenous norms in terms of regulations, compliance, and enforcement, as key factors

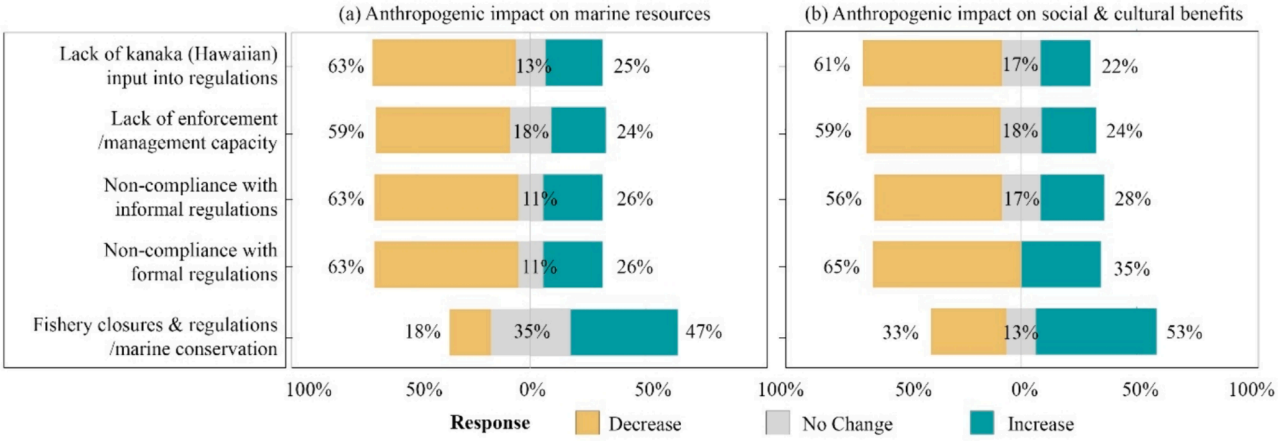


Fig. 4. Divergent chart showing respondents' perceptions of how different management challenges and actions (vertical category axis) influence anthropogenic impacts on a) marine resources, and b) cultural values. Yellow bars indicate negative impacts, green bars indicate an increase, and grey bars indicate no change.

impacting the availability of marine resources and social and cultural benefits. On the other hand, fishery closures and marine conservation were identified by 82 % of respondents as having either no impact (35 %) or a positive impact (47 %) on marine resources. Notably, a higher percent of respondents (33 %) identified fishery closures and conservation as having a negative impact on social and cultural benefits compared to 18 % for tangible marine resources.

3.3. Impacts on indigenous ocean use

Half of the respondents mentioned varying levels of feeling restricted in their use of Ho'okena waters, from somewhat restricted (15 %), restricted (25 %) to very restricted (15 %) – Fig. 5a. And 72 % mentioned that they have concerns with the way other stakeholders (e.g., not from the community) are using the ocean in Ho'okena (Fig. 5b).

The main reasons identified by the community as problematic were non-compliance with existing regulations and not following traditional harvesting practices (Table 2). Specifically, an elder and fisherman stated that the use of non-vegetarian fish bait known as chop-chop is against traditional practices in this area. Also frequently mentioned was harvesting by outsiders who take away resources from local fishermen. Community members mentioned that commercial fishing activities are resulting in depleted stocks due to an influx of commercial fishers from other districts and islands who harvest extensively in local fishing grounds. A respondent noted the additional pressure from influx of users which caused him to sacrifice fishing for months at a time so that others can feed their families and to ensure fish catch when he eventually goes. Respondents also observed less fish and limu (seaweed) now than in the past and noted that the increased influx of non-local people is affecting their traditional canoe use and fishing practice.

4. Discussion

Marine ecosystem services have been extensively assessed using economic methods. Non-economic values of these services are far less understood and are often focused on pooled categories, thereby masking and losing the influence and impacts of granular components particularly for indigenous communities where non-economic services such as cultural services are known to be important. (Chan et al., 2012; Daw et al., 2011), In this study, we explore how indigenous community members value the ocean, how diverse ecosystem services contribute to the well-being of indigenous community members, and how marine uses and management actions are affecting these ecosystem services.

Notably, our results show that economic benefits, which are often the main metric to assess the value of ecosystem services, received the lowest importance compared to other well-being categories. Community members identified diverse ecosystem services as important for food security, cultural heritage, and mental wellbeing including diverse marine resources and cultural values. Similar to (Skewes et al., 2016), our study found that pelagic fish was most important for income and also for food security, culture and health. The benefits of fish species to diverse aspects of community well-being, for example the importance to

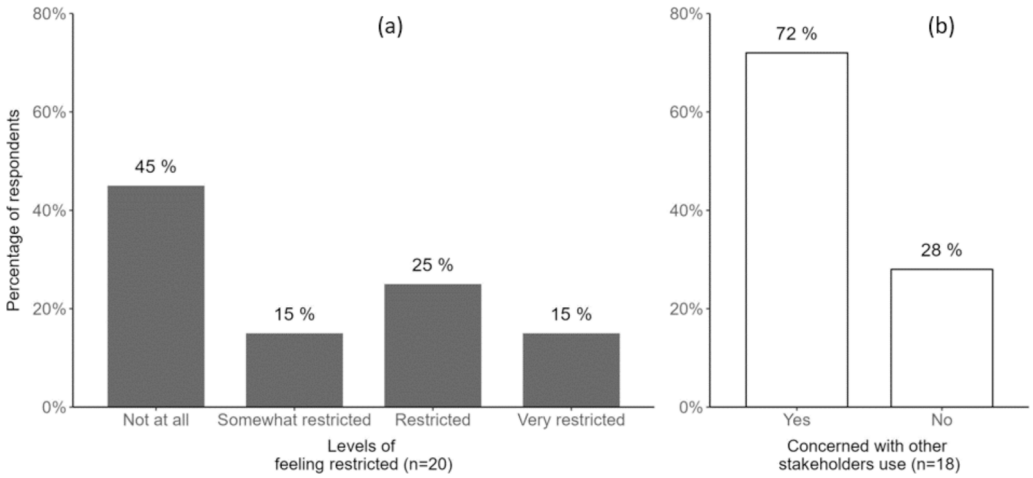


Fig. 5. Communities levels of 'feeling restricted in use of Ho'okena waters' and 'concern with other stakeholders use'.

Table 2
Concerns raised regarding non-community stakeholders use of Ho'okena waters.

Issue	Example quotes
Non-compliance	• Aquarium fishing in closed area • Fishermen using chop-chop (animal-based fish feed) • Fishing all year round for ʻōpelu • People not respecting traditional harvesting practices • I have also heard stories of fishers not from the area insisting on using fishing practices that are not considered pono by the community of Ho'okena
Overharvesting	• Outsiders coming to fish too near or close to shoreline taking the lobsters, opihi and akule • Kona crab commercial fishermen, big corporation seafood harvesting • Outsiders come and take our means of food to make a profit off of. The 'ohana of Ho'okena use the ocean as a way of life. Our main food resource comes from the ocean as well as our mountain, and with the overwhelming amount of outsiders coming and taking our ocean life is decreasing our ocean life in Ho'okena • People from different islands or districts coming here to take fish, spearfish, deplete our stocks to sell in other places. • Commercial fisherman who are not knowledgeable about the area and who just come to take and do not give back to the people of the local community. People who come to harvest with no contribution whatsoever!! • Due to so many families that move in, those who fish I feel responsible to not overfish so others can fish to feed their family. So I don't fish for a months at a time so there is fish when I go.
Lack of awareness	• Fishermen not knowing the right way to fish

culture, can also be explained by the indigenous practice of gifting or sharing of fish catch with relatives and friends (Seto et al., 2024; Vaughan and Vitousek, 2013). Thus, assessing ecosystem services solely based on monetary benefits would fail to account for the diverse well-being benefits that these ecosystem services provide to indigenous communities. Our findings support the assertion by Vaughan and Vitousek (2013) that diverse assessments are needed to uncover the benefits that indigenous people receive from the ocean beyond income. These benefits seem foundational to indigenous peoples and local communities (IPLCs) wellbeing for a variety of reasons, which should be considered in policy discussions (De Valck et al., 2023; Higuchi, 2008). Thus, assessing ecosystem services solely based on monetary benefits would fail to account for the diverse wellbeing benefits that these ecosystem services provide to indigenous communities.

The contribution of marine resources to multiple well-being categories, though, could be in conflict with each other as species that were important for food, culture and wellbeing were also important for income which could result in increased exploitation and conflict. A study by Baker et al. (2020) in Hawai'i, for example, found that higher physical and mental health was associated with higher fish consumption. Yet, higher fish consumption could reduce fish availability for other purposes resulting in conflicts. Thus, sustainable fishing practices that balance the different values attached to fish resources are critical to ensure that one value is not maximized to the detriment of another. This can be challenging as meeting the socioeconomic wellbeing of commercial fishers means higher revenue from higher catch which negatively impacts the socioeconomic wellbeing of indigenous communities who rely on a thriving, intact socioecological system.

Community members further perceive commercial fishing as having a greater impact than subsistence fishing on most fish species, but a similar or lower impact on non-fish species with the exception of lobster and opihi. This could be attributed to commercial fishers targeting fish such as pelagic species which was reported to be Hawaii's largest and most vulnerable fisheries (Hospital and Leong, 2021). In Hawai'i, commercial fishing of pelagic species accounted for over 70 % of catch with crabs (a crustacean) comprising a large portion of non-fish catch (Friedlander and Parrish, 1997). The opihi limpet (*Cellana* species) was found in this study to be one of two non-fish that are highly impacted by commercial fishing for which three species are endemic to Hawai'i (Morishige et al., 2018) and they are highly prized food to have during cultural events (Rogers and Weisler, 2021).

We also found that commercial fishing was generally perceived to have a higher negative impact on both the marine resources and the cultural values, than subsistence fishing. This low subsistence fishing impact on reef fish assemblage in communities using traditional harvest approaches has been ecologically observed in the Marshall Islands by Martin et al. (2017). However, for Hawaii's nearshore reef fisheries, the subsistence fish catch is five times that of commercial catch which highlights its important contribution towards food security and culture plus potential issues with under- and mis-reporting which requires improvements to data reporting and analysis (McCoy et al., 2018). The cultural importance of high subsistence fish catch can also be explained by the indigenous practice of gifting or sharing of fish catch with relatives and friends (Seto et al., 2024; Vaughan and Vitousek, 2013). The high subsistence fishing impact on marine resources has been reported in Fiji (Kuster et al., 2005) and is increasingly being reported as negatively impacting non-fish species in Pacific island countries (Dalzell, 1998). This can be challenging for resource management and policy makers in places like Rapa Nui where subsistence fishing was not captured as part of official landing statistics (Zylich et al., 2014).

Cultural values also seem to be affected by fishing activities, indicating a potential failure to adequately account for cultural resources in decision-making processes and fishery regulations. Exclusion of cultural values such as indigenous worldviews, beliefs and values into management plans and policy development (van Putten et al., 2013) can potentially lead to a loss of cultural knowledge and practices, which in turn might lead to further de-recognition and delegitimization of indigenous peoples values in natural resource management. One option for a better integration of cultural values in fishing management are Community-Based Subsistence Fishing Areas (CBSFA) that emphasize indigenous stewardship roles in fishery management (Hawaii Revised Statutes (HRS), 2005; Higuchi, 2008; Winter et al., 2023).

Our study further highlights the importance of traditional practices as part of cultural ecosystem services. These practices are associated with generational learning and the vulnerability of these practices to ocean use and management conflicts and this knowledge transmission from elders to younger generations is critical for maintaining knowledge about traditional practices (Daliri et al., 2023). However, some younger members of indigenous communities are unaware of or disinterested in sustainable, traditional fishing knowledge and practices which can contribute to lack of compliance and respect (Anon, 2022). The importance of cultural ecosystem services might therefore vary among people based on socio-demographics (Heck et al., 2022) and their pluralistic values, priorities or concerns. This highlights the importance of not treating stakeholder groups as homogenous and to elicit and consider the diverse nature of stakeholders' opinions in natural resource decision-making processes to foster greater equity (Engen et al., 2021; Rasekhi et al., 2023).

Respondents in this study highlighted a perceived lack of Hawaiian community input into fisheries legislation development as contributing to a decrease in marine resources, despite an increase in engagement of communities in natural resource management and governance in Hawai'i (Vaughan et al., 2017; Winter et al., 2021; Winter et al., 2023). It also highlights the fact that not all Hawaiian communities including Ho'okena have gone through the State process of having their place-based concerns, values and knowledge, influence fisheries legislations in their communities' waters. Potential reasons for this delay include slow transition of resource management from 'agency controlled' to 'co-management' (Winter et al., 2021) and the slow bureaucratic process pace which is Honolulu centric (Rossiter and Levine, 2014). This likely led to a devolution of management from State to island level (Rossiter and Levine, 2014) through entities such as the West Hawai'i Fishery

Management Council (WHFMC) meetings on Hawai'i Island in which Ho'okena community elders and other stakeholders participate, thereby ensuring a more collaborative natural resource management process. This increasing inclusion is vital to making sure that resources are accessible and available to local users as regulations without their input seem to be not as effective in preventing a decline in local resources. Community members in this study indicate that cultural values seem to be equally affected by fishing as marine resources suggesting the need to adequately account for cultural dimensions in decision-making processes. Its exclusion prevents integration of locally relevant, indigenous worldviews, beliefs and values into management plans and policy development (van Putten et al., 2013) which can further de-recognize and delegitimize indigenous peoples and their participation and subsequently, the loss of cultural knowledge and practices.

This study revealed the impact of lack of compliance with both formal and informal rules on ocean ecosystem services. This finding indicates that non-compliance might not only occur with formal but also informal rules and regulations, especially in open-access fisheries where indigenous values such as taking only what you need through self-censorship (Frid et al., 2023; Quesnot et al., 2024) and only using fishing practices that are considered pono (right) by the community are not ascribed to by all resource users and are incompatible with national and state regulatory processes.

The participants stated that changes in fishing gear also impacted ecosystem services, an issue that has been identified in other fishing communities around the world. The Ho'okena community in this study opted to maintain traditional fishing canoes with smaller motorized engines which is similar to Alaskan communities who opted to forego developments such as access roads to ensure wildlife habitats and species abundance are maintained (Salcido et al., 2023). However, this could result in traditional methods of fishing being outcompeted by more modern gear and vessels (Calhoun et al., 2020). For example, Turkish community fishers identified several reasons for the decline in quality, quantity and diversity of fish caught which included the change from paddle boats to motorized ones (Rasekhi et al., 2023).

Half of the respondents from our survey felt restricted in their use of Ho'okena waters in addition to 72 % being concerned about other stakeholders' uses. These stemmed from a variety of reasons surrounding lack of awareness and non-compliance with informal rules and practices, which results in overharvesting (Table 2). Participants also highlighted difficulties in sustaining informal norms in taking care of the environment for current and future generations due to overharvesting as a result of egocentric behavior from a lack of concern for others. These behaviors were attributed to outsiders who disregard informal rules by using chop-chop (animal-based fish feed) to attract and catch ʻōpelu instead of the traditional vegetable-based feed (Kimura, 1976). Chop-chop use has been observed to attract not only ʻōpelu but also predators such as sharks which causes a feeding frenzy resulting in low catches (Anon, 2022). Additionally, participant opinions showed that overharvesting occurs in open-access fisheries where indigenous self-censorship values and informal rules such as taking only what you need (Frid et al., 2023; Quesnot et al., 2024) and only using fishing practices that are considered pono (right) by the community, are not ascribed to by all resource users. Our results also indicate a perception of outsiders as not knowing and/or having no respect for the place thereby increasing extractive activities which subsequently affect local communities livelihood (Dove et al., 2019). The opposition to outsiders, if unmanaged, could become a barrier to their involvement in stakeholder engagement and collaborative, holistic management (Cruz, 2021; Daliri et al., 2023; Dove et al., 2019; Heck et al., 2011).

Due to the focus of this study on a local community, the sample size of our study is quite small. Perceptions are thus based on a subset of Ho'okena community members that are grounded in their observations and experiences. Future studies could explore how these perceptions compare to indigenous fishers in other communities that might have different cultural contexts. A larger sample size would also allow to conduct statistical analysis that explores the influence of gender and other socio-demographic variables on the importance of distinct ecosystem services and their contribution to the well-being of indigenous fishing communities.

5. Conclusion

This research focused on select 'marine resources' and 'cultural values' that were deemed important by the indigenous community in West Hawaii and assessed impacts from a suite of 'management actions' and 'pressures.' The results revealed subtle differences in the importance of each marine resource and cultural value, and differences in the impacts of fishing typologies such as commercial and subsistence fishing. This is indicative of differences in views, priorities and even the knowledge of and extent of impacts. Such locally relevant information would be useful in developing rules that are locale and marine resource specific. This could greatly enhance community-State natural resource management partnerships and approaches in Hawai'i potentially resulting in greater support by the diverse stakeholder groups that rely on Hawai'i waters. Furthermore, as this research was on a single indigenous community, it shows that indigenous communities are not necessarily homogenous in their values, outlook, and concerns. Such insights prove the utility of looking at constituent variables rather than larger categories where the constituents show differences which would otherwise be lost when pooled.

CRediT authorship contribution statement

Ron Vave: Writing – original draft, Writing – review & editing, Visualization, Validation, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Nadine Heck:** Writing – review & editing, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization. **Siddharth Narayan:** Writing – review & editing, Supervision, Software, Resources, Project administration, Methodology, Investigation, Conceptualization. **Sonya Carrizales:** Writing – review & editing, Investigation. **Damien Kenison:** Writing – review & editing. **Adina Paytan:** Writing – review & editing, Supervision, Software, Resources, Project administration, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgements

The authors are grateful to the community elders and workshop participants from Ho'okena community in West Hawai'i in addition to the West Hawai'i Fishery Council. This study was funded by the Belmont Forum as part of the NOCRISES project (Negotiating Ocean Conflicts among Rivals for Sustainable and Equitable Solutions); National Science Foundation Belmont award # 217020.

Appendix 1. . Scientific and English common names for marine resources from workshop and survey

Marine resource type	Category	Hawaiian name	English Common name	Scientific name
Fish	Pelagic fish	Ahi	Yellowfin tuna	*Thunnus albacares*
		Aku	Skipjack tuna	*Katsuwonus pelamis*
		Kawalea	Heller's Barracuda	*Sphyraena helleri*
		Ono	Wahoo	*Acanthocybium solandri*
		ʻōpelu	Mackerel Scad	*Decapterus macarellus*
		Akule	Big eye Scad	*Selar crumenopthalmus*
	Reef fish	Āholehole	Hawaiian flagtail	*Kuhlia sandvicensis*
		ʼĀweoweo	Hawaiian bigeye	*Priacanthus meeki*
		Kole	Yellow-eyed surgeonfish	*Ctenochaetus strigosus*
		Manini	Convict surgeonfish	*Acanthurus triostegus sandvicensis*
		Menpachi	Soldierfish	*Myripristis* spp.
		Moi	Pacific threadfin	*Polydactylus sexfilis*
		Pākuʻikuʻi	Achilles Tang (Surgeonfish)	*Acanthurus achilles*
		Uhu	Parrotfish	Scaridae family
		Uʻu	Soldierfish	*Myripristis berndti*
Non-fish	Crabs	Aʼama	Hawaiian black crab	*Grapsus tenuicrustatus*
		Kona crab	Spanner crab	*Ranina ranina*
	Snails	Kūpeʻe	Polished nerite	*Nerita polita*
		Pipipi	Anchialine pool snail	*Neritilia hawaiiensis*
		Opihi	Limpet	*Cellana* spp.
	Sea urchin	Wana	Long spined sea urchin	*Echinothrix diadema*
	Corals	Corals	Corals	
	Seaweed	Limu	Seaweed	

References

Albert, J.A., Olds, A.D., Albert, S., Cruz-Trinidad, A., Schwarz, A.-M., 2015. Reaping the reef: provisioning services from coral reefs in Solomon Islands. Mar. Policy 62, 244–251. https://doi.org/10.1016/j.marpol.2015.09.023.

Anon, 2022. Understanding coastal fisheries and resource governance issues between traditional and non-traditional fishers in Kauhako Bay, Hoʻokena: Workshop report. NOCRISES.

Archer, S.K., Stevens, J.L., Rossi, R.E., Matterson, K.O., Layman, C.A., 2017. Abiotic conditions drive significant variability in nutrient processing by a common Caribbean sponge, Ircinia felix. Limnol. Oceanogr. 62 (4), 1783–1793. https://doi.org/10.1002/lno.10533.

Bahr, K.D., Jokiel, P.L., Toonen, R.J., 2015. The unnatural history of Kāneʻohe Bay: coral reef resilience in the face of centuries of anthropogenic impacts. PeerJ 3, e950.

Baker, K.K., Watters, C.A., Dannemiller, J.E., Iwamura, S.T., Brooks, B.A., 2020. Fish consumption for the adult population of hawaiʻi, collected with a self-reported household survey. Hawaii J. Health Soc. Welf. 79 (2), 51–59.

Boerema, A., Rebelo, A.J., Bodi, M.B., Esler, K.J., Meire, P., 2017. Are ecosystem services adequately quantified? J. Appl. Ecol. 54 (2), 358–370. https://doi.org/10.1111/1365-2664.12696.

Brander, L., van Beukering, P., 2013. The total economic value of U.S. coral reefs: a review of the literature. National Oceanic and Atmospheric Administration (NOAA), Coral Reef Conservation Program (U.S.), & National Marine Protected Areas Center (U.S.). https://repository.library.noaa.gov/view/noaa/8951.

Buonocore, E., Grande, U., Franzese, P.P., Russo, G.F., 2021. Trends and evolution in the concept of marine ecosystem services: an overview. Water 13 (15), 2060. https://www.mdpi.com/2073-4441/13/15/2060.

Calhoun, S., Leong, K., Hospital, J., 2020. Hawaiʻi Bottomfish Heritage Project: Traditions and Fishery Development. U.S. Dept of Commerce NOAA Technical Memorandum NOAA-TM-NMFS-PIFSC-97. doi: 10.25923/1s8m-z563.

Chakraborty, S., Gasparatos, A., Blasiak, R., 2020. Multiple values for the management and sustainable use of coastal and marine ecosystem services. Ecosyst. Serv. 41, 101047 https://doi.org/10.1016/j.ecoser.2019.101047.

Chan, K.M.A., Satterfield, T., Goldstein, J., 2012. Rethinking ecosystem services to better address and navigate cultural values. Ecol. Econ. 74, 8–18. https://doi.org/10.1016/j.ecolecon.2011.11.011.

Cruz, P.M.C.D.L., 2021. The knowledge status of coastal and marine ecosystem services - challenges, limitations and lessons learned from the application of the ecosystem services approach in management [review]. Front. Mar. Sci. 8 https://doi.org/10.3389/fmars.2021.684770.

Daliri, M., Salarpouri, A., Kamrani, E., Zahirinia, M., Momeni, M., Salahi, M., Jentoft, S., 2023. Fishers' traditional knowledge: a primary requirement for adaptive fisheries management in the Northern Persian Gulf. Thalassas. Int. J. Mar. Sci. 39 (2), 915–922. https://doi.org/10.1007/s41208-023-00542-9.

Dalzell, P., 1998. The role of archaeological and cultural-historical records in long-range coastal fisheries resources management strategies and policies in the Pacific Islands. Ocean Coast. Manag. 40 (2), 237–252. https://doi.org/10.1016/S0964-5691(98)00043-X.

Daw, T.I.M., Brown, K., Pomeroy, R., Rosendo, S., 2011. Applying the ecosystem services concept to poverty alleviation: the need to disaggregate human well-being. Environ. Conserv. 38 (4), 370–379. https://doi.org/10.1017/S0376892911000506.

De Valck, J., Jarvis, D., Coggan, A., Schirru, E., Pert, P., Graham, V., Newlands, M., 2023. Valuing ecosystem services in complex coastal settings: an extended ecosystem accounting framework for improved decision-making. Mar. Policy 155, 105761. https://doi.org/10.1016/j.marpol.2023.105761.

Dove, M., Johnson, A., Lefebvre, M., Burow, P., Zhou, W., Kanoi, L., 2019. Who is in the Commons: Defining Community, Commons, and Time in Long-Term Natural Resource Management. In (pp. 23-40). doi: 10.1007/978-3-030-15800-2_3.

Engen, S., Hausner, V.H., Gurney, G.G., Broderstad, E.G., Keller, R., Lundberg, A.K., Murguzur, F.J.A., Salminen, E., Raymond, C.M., Falk-Andersson, J., Fauchald, P., 2021. Blue justice: a survey for eliciting perceptions of environmental justice among coastal planners' and small-scale fishers in Northern-Norway. PLoS One 16 (5), e0251467.

Frid, A., Wilson, K.L., Walkus, J., Forrest, R.E., Reid, M., 2023. Re-imagining the precautionary approach to make collaborative fisheries management inclusive of Indigenous Knowledge Systems. Fish Fish. 24 (6), 940–958. https://doi.org/10.1111/faf.12778.

Friedlander, A.M., Parrish, J.D., 1997. Fisheries harvest and standing stock in a Hawaiian Bay. Fish. Res. 32 (1), 33–50. https://doi.org/10.1016/S0165-7836(97)00038-6.

Garibaldi, A., Turner, N., 2004. Cultural keystone species: implications for ecological conservation and restoration. Ecol. Soc. 9 (3). http://www.ecologyandsociety.org/vol9/iss3/art1/.

Chapter 188-22.6. Hawaiʻi State Legistlature, Honolulu, Hawaiʻi, USA., 2005. http://www.capitol.hawaii.gov/hrscurrent/Vol03_Ch0121-0200D/HRS0188/HRS_0188-0022_0006.htm.

Heck, N., Dearden, P., McDonald, A., 2011. Stakeholders' expectations towards a proposed marine protected area: a multi-criteria analysis of MPA performance criteria. Ocean Coast. Manag. 54 (9), 687–695. https://doi.org/10.1016/j.ocecoaman.2011.07.003.

Heck, N., Paytan, A., Potts, D., Haddad, B., 2022. Variations in stakeholders' ecosystem service priorities for managing a marine protected area. Mar. Policy 146, 105330. https://doi.org/10.1016/j.marpol.2022.105330.

Higuchi, J., 2008. Propagating cultural kipuka: the obstacles and opportunities of establishing a community-based subsistence fishing area. Univ. Hawaii Law Rev. 31 (1), 193.

Hirons, M., Comberti, C., Dunford, R., 2016. Valuing cultural ecosystem services. Annu. Rev. Env. Resour. 41 (1), 545–574. https://doi.org/10.1146/annurev-environ-110615-085831.

Hospital, J., Leong, K., 2021. Community participation in Hawaiʻi Commercial fisheries. doi: 10.25923/p4aj-k323.

IOC/UNESCO, IMO, FAO, & UNDP., 2011. A Blueprint for Ocean and Coastal Sustainability. IOC/UNESCO. https://www.undp.org/sites/g/files/zskgke326/files/publications/interagency_blue_paper_ocean_rioPlus20.pdf.

Kimura, L., 1976. Interview with Smith Hawila Kaleohano of Ka'ohe, South Kona. Born July 25th, 1911. (44 pages). The Multi-cultural center, Honolulu, Hawaii.
Kuster, C., Vuki, V.C., Zann, L.P., 2005. Long-term trends in subsistence fishing patterns and coral reef fisheries yield from a remote Fijian island. Fish. Res. 76 (2), 221–228. https://doi.org/10.1016/j.fishres.2005.06.011.
La Notte, A., D'Amato, D., Mäkinen, H., Paracchini, M.L., Liquete, C., Egoh, B., Geneletti, D., Crossman, N.D., 2017. Ecosystem services classification: a systems ecology perspective of the cascade framework. Ecol. Ind. 74, 392–402. https://doi.org/10.1016/j.ecolind.2016.11.030.
Leong, K.M., Wongbusarakum, S., Ingram, R.J., Mawyer, A., Poe, M.R., 2019. Improving representation of human well-being and cultural importance in conceptualizing the West Hawai'i Ecosystem [Original Research]. Front. Mar. Sci. 6 https://doi.org/10.3389/fmars.2019.00231.
Liquete, C., Piroddi, C., Drakou, E.G., Gurney, L., Katsanevakis, S., Charef, A., Egoh, B., 2013. Current status and future prospects for the assessment of marine and coastal ecosystem services: a systematic review. PLoS One 8 (7), e67737.
Martin, T.S.H., Connolly, R.M., Olds, A.D., Ceccarelli, D.M., Fenner, D.E., Schlacher, T.A., Beger, M., 2017. Subsistence harvesting by a small community does not substantially compromise coral reef fish assemblages. ICES J. Mar. Sci. 74 (8), 2191–2200. https://doi.org/10.1093/icesjms/fsx043.
Martin, C.L., Momtaz, S., Gaston, T., Moltschaniwskyj, N.A., 2016. A systematic quantitative review of coastal and marine cultural ecosystem services: current status and future research. Mar. Policy 74, 25–32. https://doi.org/10.1016/j.marpol.2016.09.004.
Martinetto, P., Alemany, D., Botto, F., Mastrángelo, M., Falabella, V., Acha, E.M., Antón, G., Bianchi, A., Campagna, C., Cañete, G., Filippo, P., Iribarne, O., Laterra, P., Martínez, P., Negri, R., Piola, A.R., Romero, S.I., Santos, D., Saraceno, M., 2020. Linking the scientific knowledge on marine frontal systems with ecosystem services. Ambio 49 (2), 541–556. https://doi.org/10.1007/s13280-019-01222-w.
Maxwell, J.A., 2013. Qualitative Research Design: An Interactive Approach, third ed. SAGE Publications, Inc., Thousand Oaks, California.
McCoy, K.S., Williams, I.D., Friedlander, A.M., Ma, H., Teneva, L., Kittinger, J.N., 2018. Estimating nearshore coral reef-associated fisheries production from the main Hawaiian Islands. PLoS One 13 (4), e0195840.
Millenium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: synthesis (A report of the Millenium Ecosystem Assessment). (J. Sarukhán & A. Whyte, Eds.). Island Press. https://www.millenniumassessment.org/documents/document.356.aspx.pdf.
Morishige, K., Andrade, P., Pascua, P., Steward, K., Cadiz, E., Kapono, L., Chong, U., 2018. Nā Kilo 'Āina: visions of biocultural restoration through indigenous relationships between people and place. Sustainability 10 (10), 3368. https://www.mdpi.com/2071-1050/10/10/3368.
Narayan, S., Esteban, M., Albert, S., Jamero, M.L., Crichton, R., Heck, N., Goby, G., Jupiter, S., 2020. Local adaptation responses to coastal hazards in small island communities: insights from 4 Pacific nations. Environ. Sci. Policy 104, 199–207. https://doi.org/10.1016/j.envsci.2019.11.006.
Norris, K.S., Dohl, T.P., 1979. Behavior of the Hawaiian Spinner dolphin, Stenella longirostris. Fish. Bull. 177 (4). https://spo.nmfs.noaa.gov/sites/default/files/pdf-content/1979/774/norris.pdf.
Perry, C.T., Kench, P.S., O'Leary, M.J., Morgan, K.M., Januchowski-Hartley, F., 2015. Linking reef ecology to island building: parrotfish identified as major producers of island-building sediment in the Maldives. Geology 43 (6), 503–506. https://doi.org/10.1130/g36623.1.
Quesnot, T., Schmitter, É., Wencélius, J., Bambridge, T., 2024. Moorea lagoon fishers' mental maps: an exploratory analysis of Polynesian spatial knowledge. Ethos, n/a(n/a). doi: 10.1111/etho.12416.
R Core Team, 2023. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. In www.R-project.org.
Rasekhi, S., Sharifian, A., Shahraki, M., Silvano, R.A.M., 2023. Indigenous fishers' knowledge on fish behavior, fishing practices and climatic conditions in a conservation priority coastal ecosystem in the Caspian Sea. Rev. Fish Biol. Fish. 33 (3), 629–648. https://doi.org/10.1007/s11160-022-09746-3.
Rogers, A.J., Weisler, M.I., 2021. He i'a make ka 'opihi: optimal foraging theory, food choice, and the fish of death. J. Archaeol. Method Theory 28 (4), 1314–1347. https://doi.org/10.1007/s10816-021-09506-w.
Rossiter, J.S., Levine, A., 2014. What makes a "successful" marine protected area? The unique context of Hawaii's fish replenishment areas. Mar. Policy 44, 196–203. https://doi.org/10.1016/j.marpol.2013.08.022.
Salcido, E.L., van Riper, C.J., Stewart, W.P., Leitschuh, B.A., 2023. Roles for wildlife in the development of place meanings ascribed to a protected area. Environ. Manag. 72 (5), 1072–1085. https://doi.org/10.1007/s00267-023-01869-y.
Seto, K.L., Friedman, W.R., Eurich, J.G., Gephart, J.A., Zamborain-Mason, J., Sharp, M., Aram, E., Tekaieti, A., Tekiau, A., Golden, C.D., 2024. Characterizing pathways of seafood access in small island developing states. Proc. Natl. Acad. Sci. 121 (7), e2305424121 https://doi.org/10.1073/pnas.2305424121.
Skewes, T.D., Hunter, C.M., Butler, J.R.A., Lyne, V.D., Suadnya, W., Wise, R.M., 2016. The Asset Drivers, Well-being Interaction Matrix (ADWIM): a participatory tool for estimating future impacts on ecosystem services and livelihoods. Clim. Risk Manag. 12, 69–82. https://doi.org/10.1016/j.crm.2015.08.001.
Sulu, R.J., Eriksson, H., Schwarz, A.-M., Andrew, N.L., Orirana, G., Sukulu, M., Oeta, J., Harohau, D., Sibiti, S., Toritela, A., Beare, D., 2015. Livelihoods and fisheries governance in a contemporary pacific island setting. PLoS One 10 (11), e0143516.
UNEP, 2011. Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication - A Synthesis for Policy Makers. United Nations Environment Programme (UNEP). https://sustainabledevelopment.un.org/content/documents/126GER_synthesis_en.pdf.
van Putten, I., Lalancette, A., Bayliss, P., Dennis, D., Hutton, T., Norman-López, A., Pascoe, S., Plagányi, E., Skewes, T., 2013. A Bayesian model of factors influencing indigenous participation in the Torres Strait tropical rocklobster fishery. Mar. Policy 37, 96–105. https://doi.org/10.1016/j.marpol.2012.04.001.
Vaughan, M.B., Thompson, B., Ayers, A.L., 2017. Pāwehe Ke Kai a'o Hā'ena: creating state law based on customary indigenous norms of coastal management. Soc. Nat. Resour. 30 (1), 31–46. https://doi.org/10.1080/08941920.2016.1196406.
Vaughan, M.B., Vitousek, P.M., 2013. Mahele: sustaining communities through small-scale inshore fishery catch and sharing networks. Pac. Sci. 67 (3), 329–344. https://doi.org/10.2984/67.3.3.
Walsh, W.J., 2015. Report on the Findings and Recommendations of Effectiveness of the West Hawai'i Regional Fishery Management Area. Prepared by Department of Land and Natural Resources (DLNR), State of Hawai'i. https://dlnr.hawaii.gov/dar/files/2015/01/ar_hrs188_2015.pdf.
Weng, K.C., Friedlander, A.M., Gajdzik, L., Goodell, W., Sparks, R.T., 2023. Decreased tourism during the COVID-19 pandemic positively affects reef fish in a high use marine protected area. PLoS One 18 (4), e0283683.
Winter, K.B., Vaughan, M.B., Kurashima, N., Giardina, C., Quiocho, K., Chang, K., Akutagawa, M., Beamer, K., Berkes, F., 2021. Empowering Indigenous agency through community-driven collaborative management to achieve effective conservation: Hawai'i as an example. Pac. Conserv. Biol. 27 (4), 337–344. https://doi.org/10.1071/PC20009.
Winter, K.B., Vaughan, M.B., Kurashima, N., Wann, L., Cadiz, E., Kawelo, A.H., Cypher, M., Kaluhiwa, L., Springer, H.K., 2023. Indigenous stewardship through novel approaches to collaborative management in Hawai'i. Ecol. Soc. 28 (1), 26 https://doi.org/10.5751/ES-13662-280126.
Woodhead, A.J., Hicks, C.C., Norström, A.V., Williams, G.J., Graham, N.A.J., 2019. Coral reef ecosystem services in the Anthropocene. Funct. Ecol. 33 (6), 1023–1034. https://doi.org/10.1111/1365-2435.13331.
Zylich, K., Harper, S., Licandeo, R., Vega, R., Zeller, D., Pauly, D., 2014. Fishing in Easter Island, a recent history (1950–2010). Lat. Am. J. Aquat. Res. 42 (4) https://doi.org/10.3856/vol42-issue4-fulltext-11.