

The Importance of Fisheries Replenishment Areas in Hawai'i

By Alan M Friedlander, Charles Birkeland, Mark Hixon, Eric Conklin,
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'U'u (menpachi) must be 6.5 inches to reproduce.
They do not reach that size until they are 6 years old.

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The Importance of Fisheries Replenishment Areas in Hawai'i

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UNIVERSITY of HAWAII at MĀNOA
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Maui Nui Marine ResourceCouncil ~ Kahului ~ 2026

SUMMARY

Building a network of fully and highly protected Fisheries Replenishment Areas (FRAs) for Hawai'i



1

BUILT ON TRADITIONAL WISDOM



In the past, Hawai'i's fisheries were sustained through traditional management by konohiki, using kapu systems and natural refuges (pu'uhonua) that protected spawning areas and seasons.

2

FISHERIES HAVE DECLINED



Over the past century, Hawai'i's coastal fisheries have declined by as much as 90% due to urbanization, efficient gear, habitat loss, and the breakdown of traditional practices.



3

FRAs REBUILD FISH AND ECOSYSTEMS



FRAs rebuild fish populations by protecting large, highly productive fish and the entire ecosystem in which they live.

4

MORE FISH, LARGER FISH, MORE REPRODUCTION



In Hawai'i, fully or highly protected areas have more fish, larger fish, and higher reproductive output than areas open to fishing.

5

SPILLOVER BOOSTS NEARBY FISHERIES



Fish move out of protected areas into adjacent fishing grounds. For example, ahi (yellowfin tuna) catch increased by over 50% around Papahānaumokuākea Marine National Monument after its expansion.



6

SEEDING SUPPORTS FISHERIES REGIONALLY



Larvae from protected areas settle on nearby reefs and replenish fish populations. For example, yellow tang larvae dispersed from protected areas to reefs up to 40 miles away in Kona.

7

COMMUNITY-BASED MANAGEMENT WORKS



Community stewardship is re-emerging in Hawai'i and throughout the Pacific. Locally managed areas can be effective, but there are still too few in Hawai'i.

8

INSURANCE FOR OUR FUTURE



A network of fully/highly protected FRAs provides insurance against overfishing, natural disasters, and climate change—supporting food security for future generations.

9

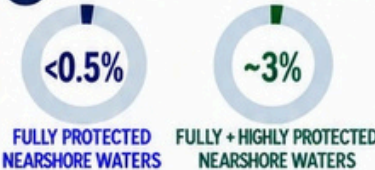
SCIENCE RECOMMENDS 30% PROTECTION



Scientists recommend protecting at least 30% of each habitat type in heavily fished areas, such as the Main Hawaiian Islands, to maintain healthy populations of fisheries species.

10

WE ARE FAR BELOW RECOMMENDED LEVELS



Currently, less than 0.5% of nearshore waters are fully protected FRAs and only about 3% are strongly protected (fully + highly protected).



THE PATH FORWARD:

Expand a network of well-designed and well-managed fully and highly protected FRAs across Hawai'i.

HEALTHY REEFS • HEALTHY FISHERIES
STRONG COMMUNITIES • BRIGHT FUTURE



Protect now. Rebuild today. Sustain Hawai'i for generations to come.

Where Have All the Fish Gone?

Many kūpuna remember a time when Hawai'i's reefs were full of life—large schools of fish, abundant catches, and thriving ecosystems. Today, those conditions are much harder to find.

Over the past 100 years, fish populations across the Main Hawaiian Islands have declined significantly. There is no single cause—rather, it is the result of multiple changes happening at once.

Fishing has become far more efficient. Modern boats, GPS, sonar, and advanced gear allow people to fish deeper, farther, and more effectively than ever before. Refrigeration and access to markets mean that fish are no longer just caught for immediate use—they can be stored, transported, and sold.

Land-based impacts have also taken a toll. Coastal development, sediment runoff, pollution, and the loss of wetlands have damaged reefs and reduced the quality of habitats that fish depend on, especially nursery areas for juveniles.

Perhaps most importantly, **fish no longer have places to escape**. In the past, natural barriers such as depth, distance, rough conditions, and limited technology provided refuge. Today, those protections have largely disappeared.

Traditional Management Practices

Long before modern fisheries science, Native Hawaiians developed a highly effective system for harvesting and managing marine resources (**Fig. 1**). This system was based on careful observation, experience, and a strong cultural connection to the environment^{1,2}.

Resource management was organized by **ahupua'a** and **moku** and overseen by **konohiki** (resource managers)^{3,4}. Fishermen were held in high regard within the community and **po'o lawai'a** (master fishermen) held extensive knowledge that was passed down from generation to generation^{4,5}.

Fishing was regulated through a system of **kapu**, which controlled when, where, and how fishing could occur. These rules often protected fish during critical times, such as spawning seasons. Certain species or life stages were off-limits. Some areas were left unfished to allow populations to recover. The punishment for breaking a kapu was often swift and severe⁶.



This system was not about maximizing short-term catch—it was about sustaining resources over generations^{5,7,8}. Seasonal and monthly harvest restrictions were associated with spawning periods and aligned with annual cycles and moon phases^{4,5}. Importantly, traditional management recognized the connection between land and sea. Activities on land—such as farming and water use—were understood to directly affect the health of reefs.



Figure 1. Hawaiians developed diverse ways to harvest the sea in a sustainable way. Photos: Hawai'i State Archives.



In ancient Hawai'i, important species particularly vulnerable to overharvest were reserved for **ali'i** (chiefs). Prior to the 1800s at least half of the Hawaiian population was not allowed to eat ulua (Giant Trevally), kūmū (Whitesaddle Goatfish), and honu (sea turtles)⁸. Hawaiians long ago recognized that moi (Pacific Threadfin) changed sex from male to female and had specific names for each life phase (**Fig. 2**). Because of the sensitivity of this species to overfishing, moi were reserved for the ali'i. Now, moi are seriously overfished, and individuals are much smaller, with less of the stock reproductively active than 30 years ago⁹. This is a problem because large individuals are generally female, and the reproductive potential of the stock is seriously reduced.

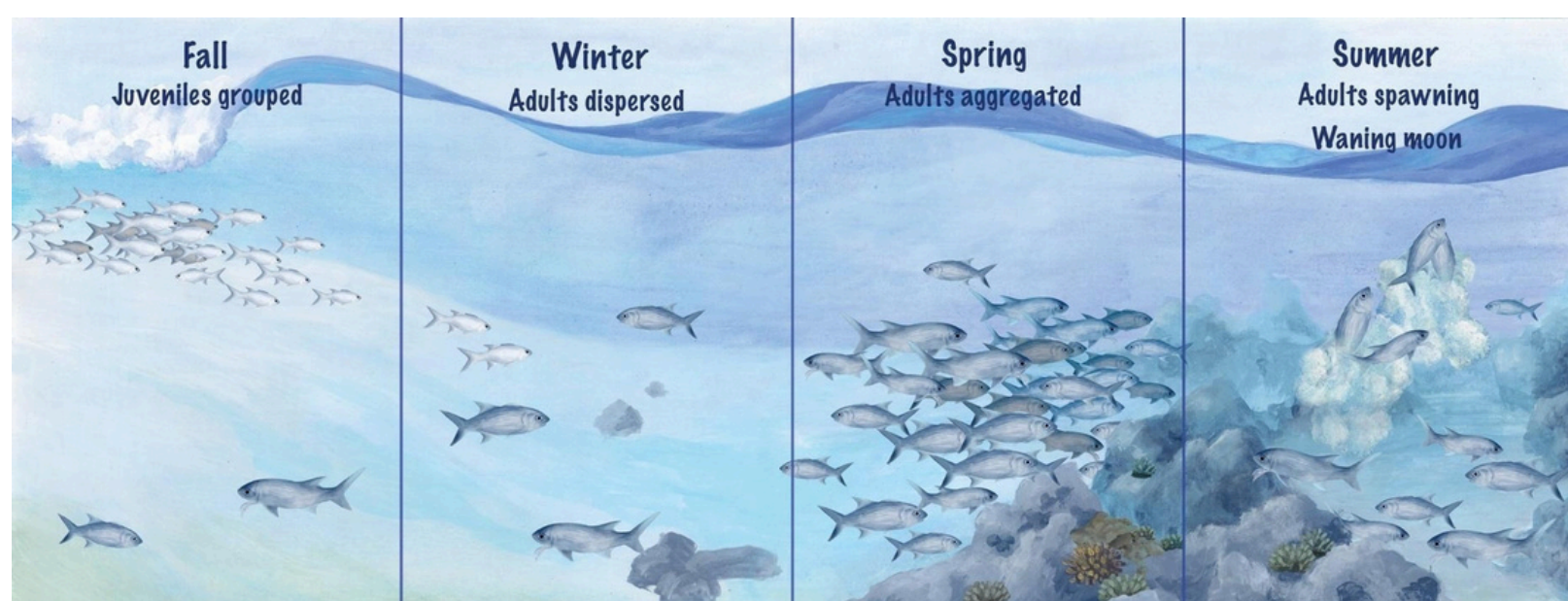


Figure 2. Hawaiians understood the life cycle of species like *moi* and managed them accordingly.

The Breakdown of Traditional Systems

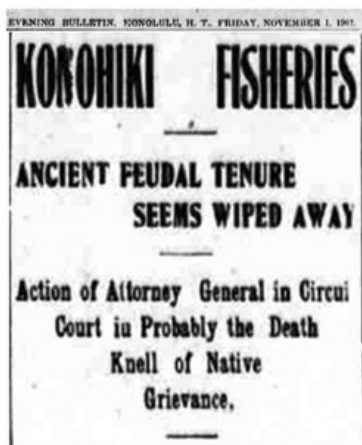


Figure 3A. Loss of konohiki fisheries in the early 1900s.

After Western contact, Hawai'i's economy shifted toward a cash-based system, and fishing increasingly became commercialized¹⁰. Markets expanded, demand increased, and technology improved. At the same time, traditional management systems weakened (**Fig. 3A**). Authority over local resources shifted away from communities, and the **connection between people and place became less direct**.

A striking example of how quickly fish populations can recover comes from World War II. During this period,

offshore fishing was largely restricted (**Fig. 3B**). Fish populations rebounded rapidly. When fishing resumed, however, pressure increased again and populations declined. For a brief period during World War II, there were dense schools of large ulua (jacks) in the Main Hawaiian Islands (MHI), which is still the case today in the Northwestern Hawaiian Islands (NWHI) that is not fished¹¹ (**Fig. 4**).

Today, reefs in the Main Hawaiian Islands look very different from those in remote, less-fished areas. Large predators such as ulua and sharks are far less common, and overall fish biomass is much lower.



Figure 3B. Fishing restrictions lifted after WWII.

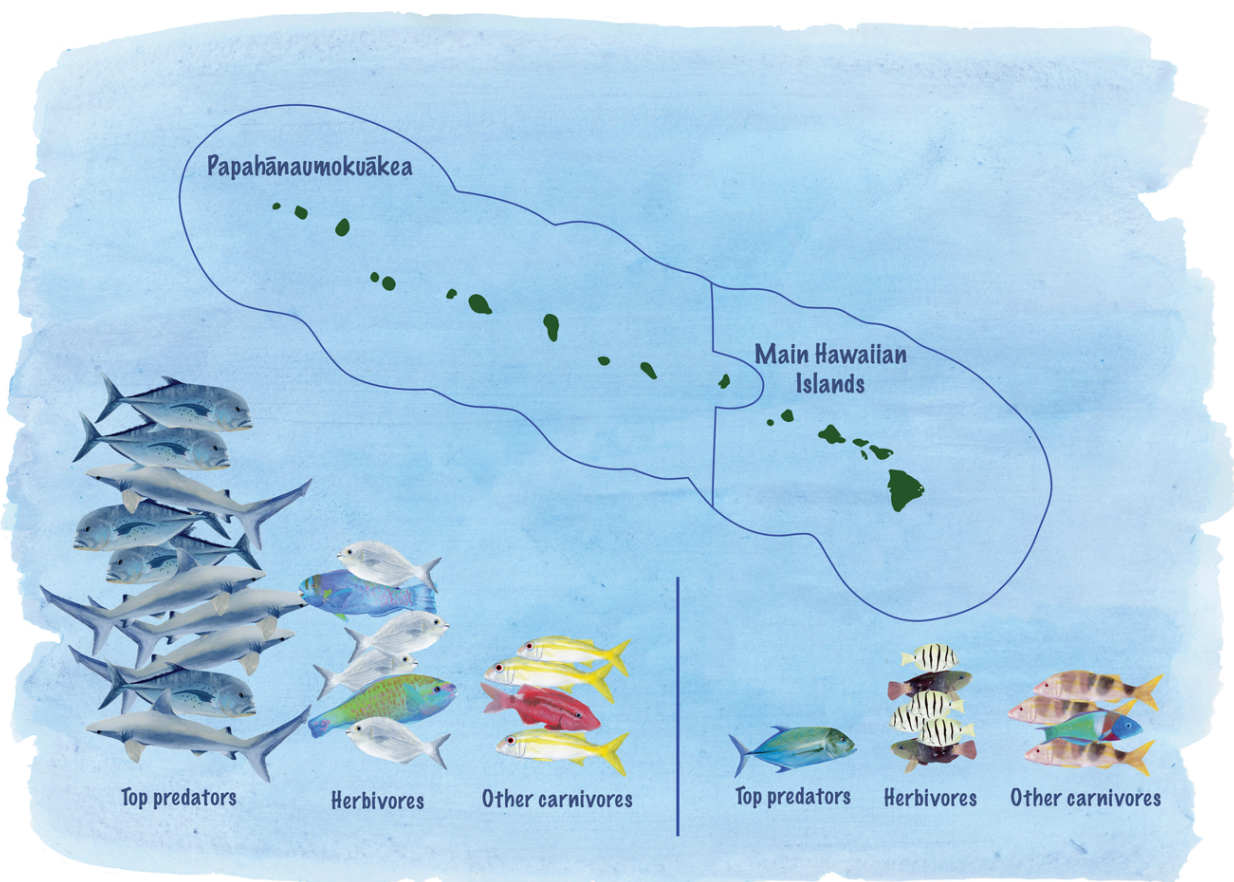


Figure 4. Top predators dominate in the unfished NWHI while herbivorous fishes are the most abundant in the fished MHI. However, the total weight of herbivores is still much higher in the NWHI and the total weight of fishes in the NWHI is 3.6 times that of the MHI.

Fisheries Declines in Hawai'i

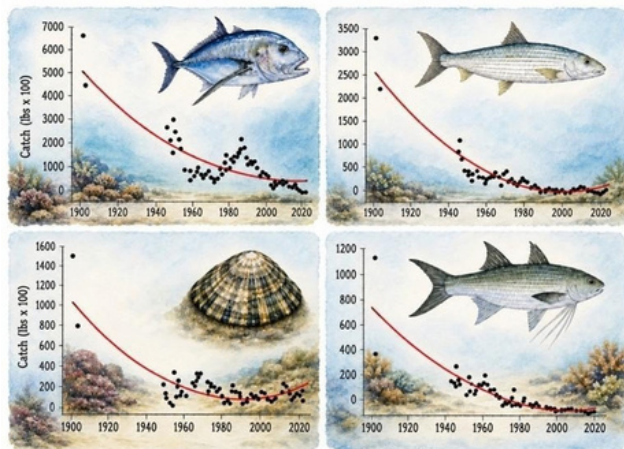


Figure 5. Total landings from Hawai'i commercial fisheries catch since 1900 have consistently and dramatically declined¹².

Although many people acknowledge declines in certain nearshore fishes in Hawai'i, there is little agreement on the causes (**Fig. 6**). To make matters worse, there is poor compliance with existing fishing laws and regulations along with poor enforcement due to lack of resources and political will^{15,16}. Where there are more people, there are fewer food fishes. No such relationship exists for species not targeted by fishing¹⁷. This strongly indicates that fishing pressure is a major driver of declines, even though habitat loss and pollution also contribute.

For 27 reef fish species assessed in Hawai'i, 40% were overfished¹⁸ (**Fig. 7**). These included species with long lifespans like kala (unicornfishes), which can live for more than 50 years and are more easily overfished or those highly targeted like ulua and uhu (**Fig.8**).

Although overfishing is undoubtedly one of the main causes of the decline in fish stocks in the MHI, pollution, sedimentation, coastal development, estuary loss, inappropriate management of freshwater resources, and natural ecosystem changes also contributed to the decline. One issue has been the loss of one habitat affecting others, since neighboring habitats (such as coral reefs and wetlands) are connected through the movement of fisheries species. For example, to protect ulua in Hawai'i we need to protect both their adult habitats on reefs and their juvenile habitats in brackish/freshwater and nearshore¹⁹.

The impacts of these changes are clear. Today, many reef fish populations are significantly depleted compared to historical levels. Some key species have declined by more than 90%¹² (**Fig. 5**). Despite this, nearshore fisheries remain incredibly important. Nearly one-third of households in Hawai'i participate in fishing¹³. These fisheries provide millions of meals each year and play a vital role in culture, recreation, and food security¹⁴.

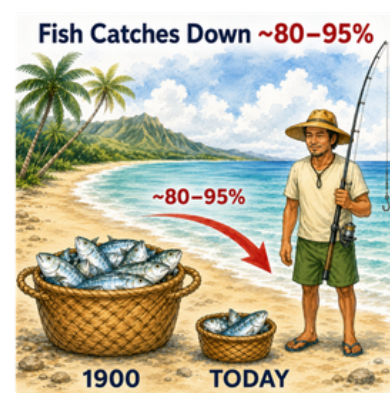


Figure 6. Fish catches have declined by 80 to 95% since 1900¹².



Figure 7. A 2017 feature in the Honolulu Star-Advertiser highlights the threat of overfishing to coral reefs in Hawai'i.



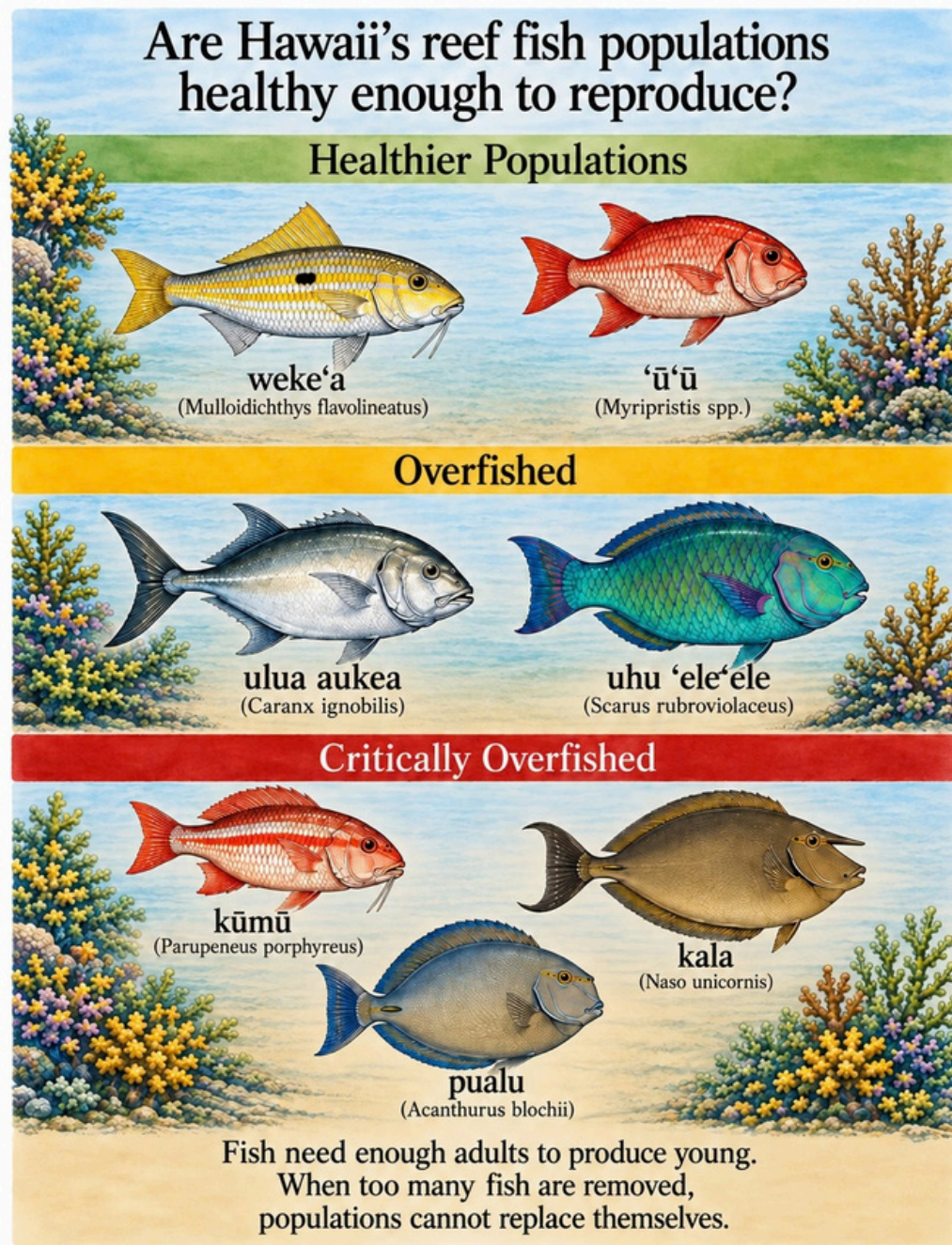


Figure 8. A number of species in Hawai'i are overfished based on size and spawning potential.¹⁸

Fish populations tend to be lowest in places where more people live. Across Hawai'i, areas with high human population—especially around O'ahu—have much less fish biomass than less populated regions (**Fig. 9**)¹⁷. In contrast, some remote areas with fewer people still support large numbers of fish. These places act as important refuges, helping maintain fisheries and reef health, and can supply fish and larvae to other parts of each island. This pattern shows how strongly human activity influences fish

populations across the islands, and it also highlights the value of managing resources at the scale of traditional moku, using knowledge that reflects the natural connections within and across each region.

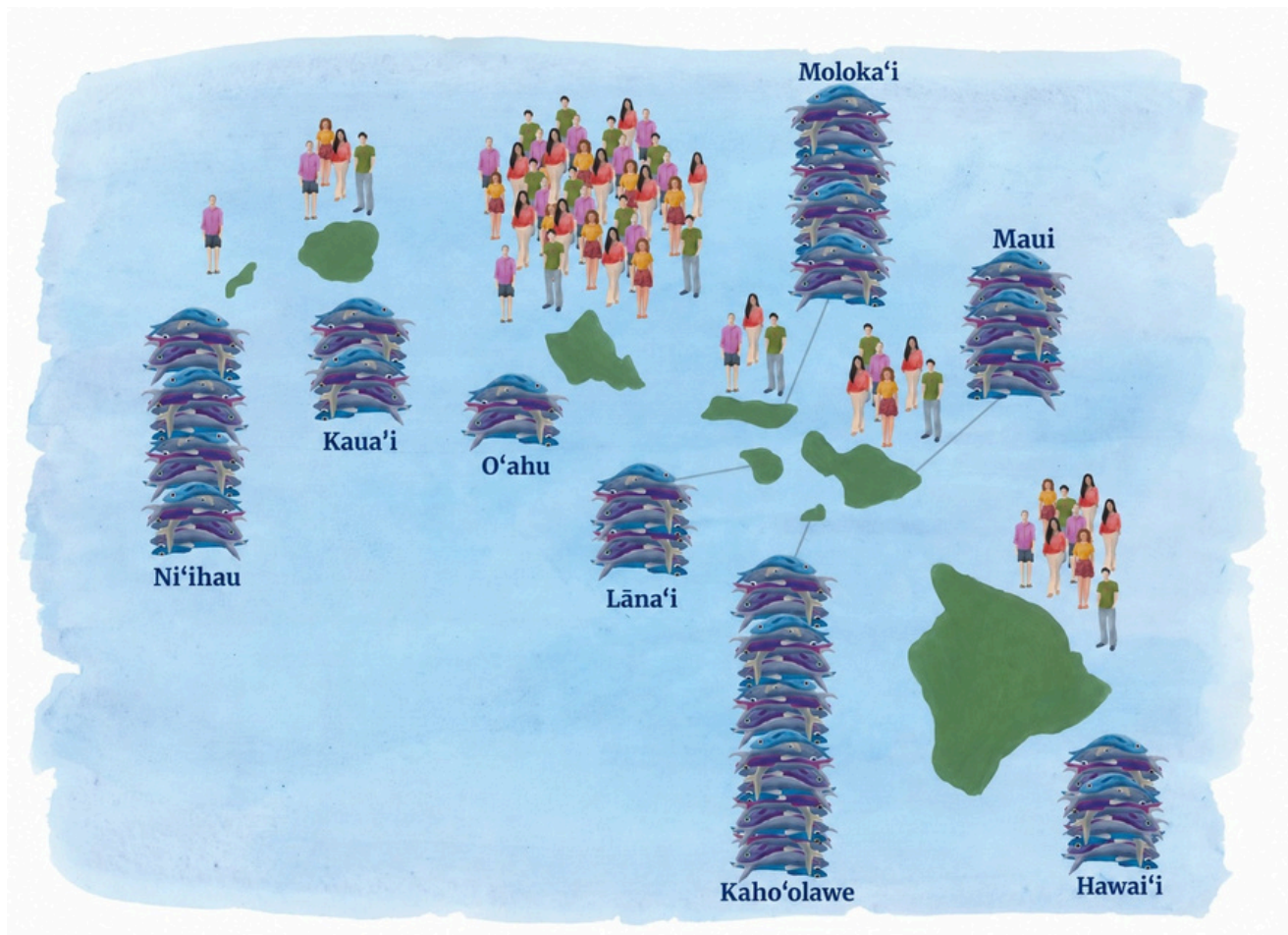


Figure 9. Resource fish biomass by island. The abundance of fishes decreases as human populations increase. This indicates that humans adversely affect fish populations, mostly by overfishing.

Loss of Natural Refuges

Not long ago, fish in Hawai'i had places to hide. Depth, distance, darkness, and limited gear gave them a chance to escape and reproduce. Today, those natural refuges have largely disappeared—and that has changed everything (**Fig. 10**). Over the past 50 years, advances in technology and growing demand for seafood have made nearly every part of the reef accessible. Fish can no longer rely on deep water, nighttime, or distance for protection. As a result, even the largest and most important breeding fish are now routinely removed.

One major problem is the widespread use of monofilament lay gill nets (**Fig. 11**). These inexpensive nets can be set in long lines across reefs, catching nearly everything in their path—including undersized fish and species not meant to be taken. They can also entangle sea turtles and Hawaiian monk seals. Nets often snag on coral, damaging reef habitat, and are sometimes abandoned because they are cheap to replace. This “ghost gear” can continue catching fish for years. In many parts of the Main Hawaiian Islands, lay gill nets have played a significant role in the decline of reef fish populations.

Scuba fishing—especially at night—removes one of the last natural protections fish once had. Many reef fish sleep in predictable places, and with lights and scuba gear, they can be easily located and caught with little chance of escape. This often leads to the rapid loss of the largest breeders and key species like herbivores that help keep reefs healthy. Over time, this weakens the entire ecosystem.

The rise of refrigeration has also changed fishing from primarily subsistence to more commercial use. In the past, catch was limited to what could be eaten or shared. Today, fish can be stored and sold, increasing the incentive to catch more. Fish in the freezer are fish that can no longer reproduce.



Figure 10. The number, size, and variety of fishes are much lower in areas where advanced technologies such as scuba, underwater lights, and power boats are used that allow access to what were previously natural refugees such as in deep water. (After Ellyn Tong.)



Figure 11. Lay gillnets are indiscriminate and kill many juveniles and non-target species.

At the same time, many local communities have lost the ability to manage the resources they depend on. In heavily populated areas, fishing pressure comes from many users, often without strong local oversight.



This creates what is known as the “tragedy of the commons,” where shared resources are overused because everyone has an incentive to take as much as they can.

The result is simple but serious: fish now have fewer places to escape, fewer chances to reproduce, and less time to recover. Without refuges, even healthy reefs can decline quickly. Restoring places where fish are safe is no longer optional—it is essential if we want Hawai‘i’s fisheries to recover and thrive again.



Hawai‘i’s largest uhu are born as brownish red females and turn blue and green only when they become terminal-stage males leading a school. Catching these bright blue males disrupts breeding and population recovery.

The Importance of Fisheries Replenishment Areas

What are Fisheries Replenishment Areas?

Fisheries Replenishment Areas (FRAs) are places where fishing is limited or not allowed so that fish populations can recover. In the most effective FRAs, harvest is fully prohibited or restricted to low-level cultural and traditional practices. The goal is simple: allow fish to grow, reproduce, and rebuild so they can support fisheries.

By protecting fish, habitats, and the relationships that keep ecosystems functioning, FRAs act as safe havens for the entire reef system. Inside these areas, fish live longer, grow larger, and produce far more offspring. Over time, this leads to healthier reefs and stronger fish populations that can “spill over” into surrounding fishing grounds and release larvae that help replenish reefs across a wider region.

In the past, Hawai‘i’s ocean ecosystems were naturally abundant and diverse. But increasing fishing pressure, habitat degradation, and the loss of traditional management have reduced that abundance. At the same time, modern fishing methods have become



so efficient that fish populations have little chance of recovering on their own. FRAs restore what has been lost—places where fish are safe long enough to rebuild the populations that sustain our fisheries.

Not all protected areas are equally effective. Areas with strong, long-term protection consistently produce the greatest benefits, while areas with weak or temporary restrictions often show limited results²⁰ (**Fig. 12**). For FRAs to work, they must be well designed, clearly defined, and supported by community compliance and effective enforcement. When these conditions are met, they become powerful tools for rebuilding fish populations and restoring reef ecosystems.

FRAs are not just about conservation—they are about sustaining livelihoods. Healthy reefs support fishing, tourism, cultural practices, and food security for the people of Hawai'i. In this way, FRAs help maintain the deep connection between island communities and the ocean.

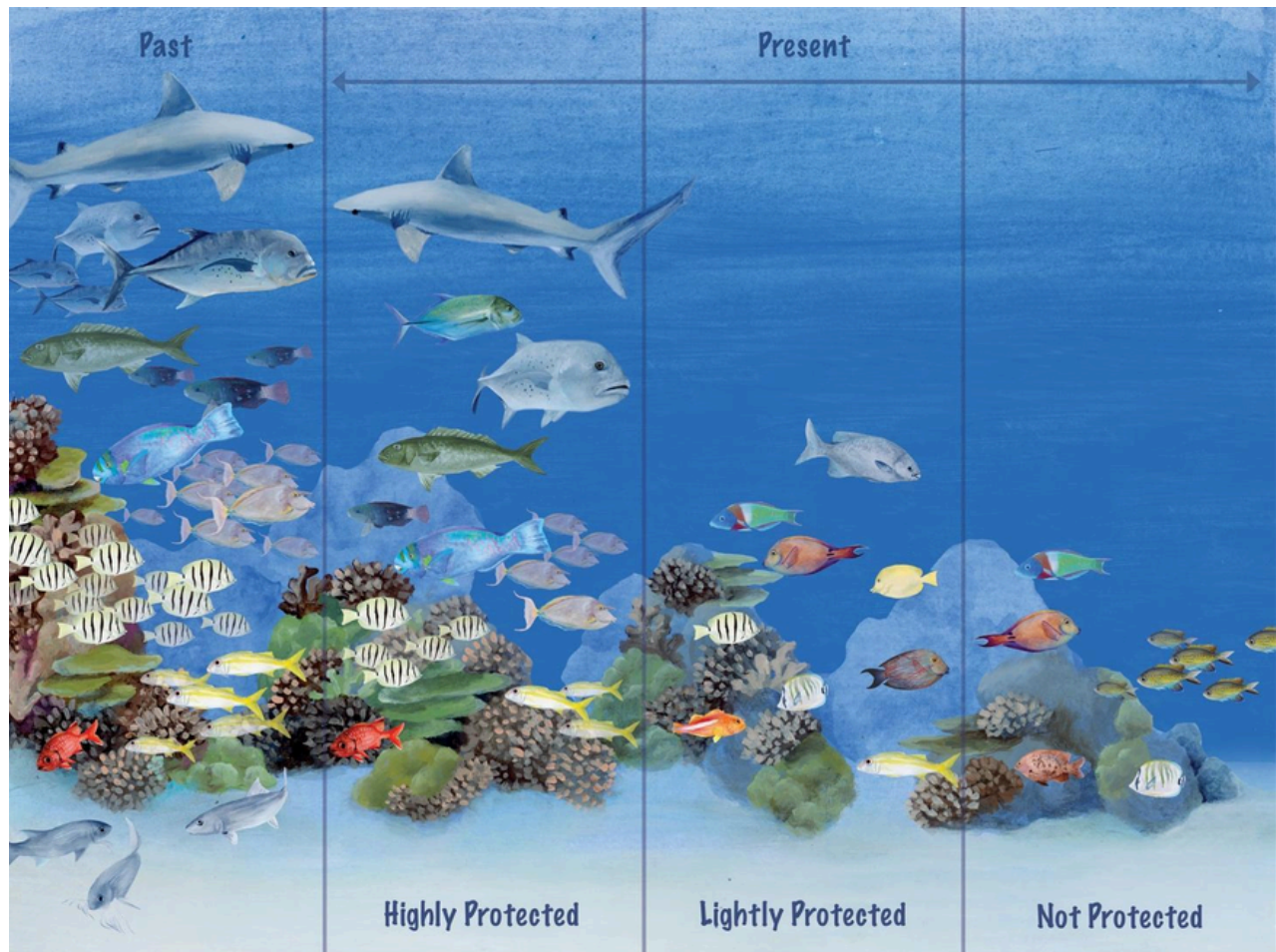


Figure 12. The level of protection, and effectiveness of FRAs. Fully and highly protected FRAs will provide the greatest benefits for people and nature. Lightly or minimally protected areas will provide much fewer benefits.

They also work best as part of a broader approach to managing coastal resources. Fish populations are influenced not only by fishing, but also by water quality, habitat condition, and land-based activities. Managing from mauka to makai—from the mountains to the sea—recognizes these connections. For example, placing FRAs near healthy or restored watersheds can help protect nursery habitats by reducing sediment and pollution entering coastal waters.

At their core, Fisheries Replenishment Areas are a return to a simple idea: if we give the ocean space and time to recover, it will.

Fisheries Replenishment Areas Definitely Work in Hawai‘i

The benefits of Fisheries Replenishment Areas (FRAs) are already clear across Hawai‘i.

The state’s network of 11 Marine Life Conservation Districts (MLCDs) shows that fish biomass is 2.6 times greater inside protected areas than in nearby fished areas, and even higher where protection is strongest²¹ (**Fig. 13**). Large predators such as ulua and ‘ōmilu, along with other food fishes, are more abundant and larger inside these areas—clear evidence that protection works.

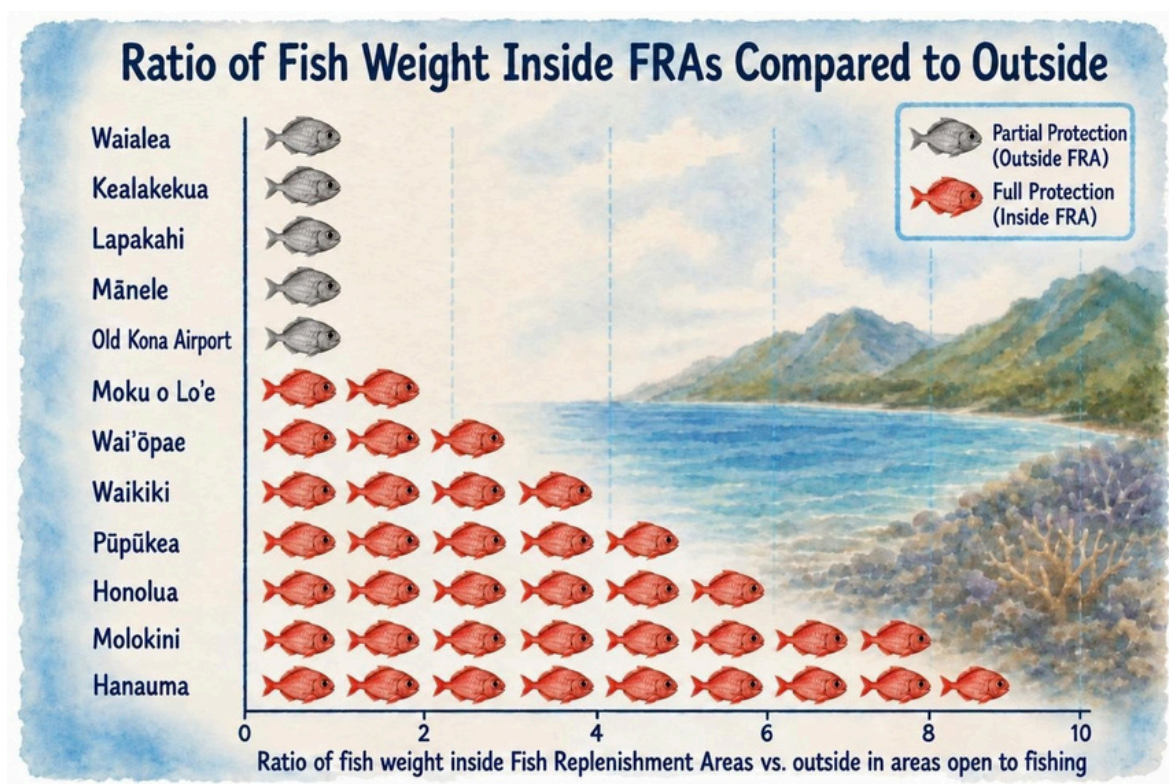


Figure 13. Ratio of fish weight inside Fish Replenishment Areas vs. outside in areas open to fishing. For example, fish biomass is more than eight times higher in Hanauma Bay MLCD than in adjacent areas open to fishing.

Kaho'olawe provides a powerful example at a larger scale. Decades of restricted access created a de facto refuge, and since 1993 the Kaho'olawe Island Reserve Commission has managed the area with limited, culturally based harvest²². Today, it supports the highest fish biomass in the Main Hawaiian Islands and represents the largest highly protected FRA (16.3 sq. miles), showing how strongly reefs can recover when pressure is reduced.



Figure 14. Yellow tang (*Zebrasoma flavescens*) and the endemic kole (*Ctenochaetus strigosus*) are the most valuable fishes in the Hawai'i aquarium trade.

The West Hawai'i Regional Fishery Management Area (WHRFMA) demonstrates how a network of FRAs can rebuild fisheries while still allowing use. Nine protected areas cover 35.2% of the coastline, closing about one-third of the coast to aquarium fishing. Yet fish populations have increased. Yellow tang abundance rose by

64.5% inside FRAs over 15 years, while remaining stable in open areas²³ (**Figs. 14, 15**), likely supported by spillover. Genetic studies confirm that larvae disperse up to **40 miles** from protected areas to fished reefs^{24,25}. During this time, the value of the fishery increased by 79% for yellow tang and 10% for kole.

The Kahekili Herbivore Fisheries Management Area (KHFMA) shows how targeted protection can restore reef balance. Established in 2009 to address coral decline and algal overgrowth, it protects herbivorous fishes and urchins. Within six years, parrotfish biomass increased by 139% and surgeonfish by 28%²⁶ (**Fig. 16**), helping reefs recover.

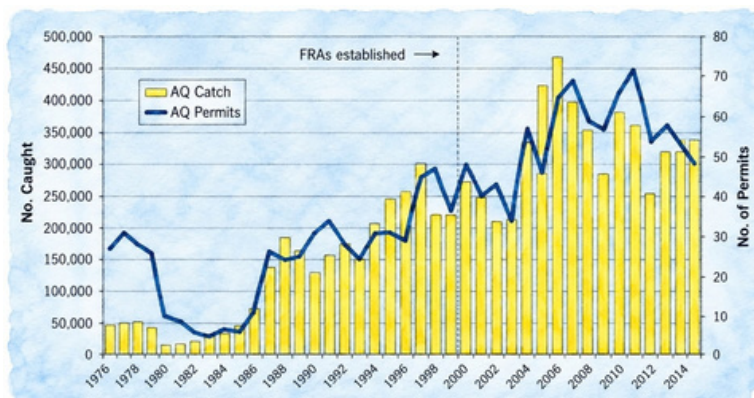


Figure 15. Number of aquarium animals collected, and number of commercial aquaria permits in West Hawai'i for Fiscal years (FY) 1976-2014.

Across Hawai'i, the pattern is consistent: when protection is strong and sustained, fish populations rebound—and the benefits extend beyond the protected areas themselves.



Figure 16. Biomass of parrotfishes increased in the Kahekili Herbivore Fisheries Management Area.

Community-Based Management Improves Marine Resources

Declining ocean health around the world has made it clear that new approaches are needed — approaches that also draw from the past. In Hawai'i and across the Pacific, there is growing recognition that traditional knowledge and stewardship practices once supported sustainable fisheries, and that these ideas still have value today.

A full return to traditional management is not entirely practical given modern governance, population growth, and global economies. However, blending traditional knowledge with contemporary science and management offers a powerful path forward. These hybrid approaches can strengthen local stewardship, improve food security, build social cohesion, and create more adaptable systems that are better able to respond to climate change and other pressures.



Traditional ecological knowledge plays a key role in designing effective Fisheries Replenishment Areas (FRAs). Historically, Hawaiian resource management included place-based protections, seasonal closures, and careful attention to ecosystem connections. Incorporating these principles into modern management can improve the design of FRAs, increase community support, and strengthen compliance.

In Hawai‘i, interest in community-based management has been growing. Communities can work with the State through legislation or through the Department of Land and Natural Resources (DLNR) to establish Community-Based Subsistence Fishing Areas (CBSFAs). These areas are specifically intended to “reaffirm and protect fishing practices customarily and traditionally exercised for Native Hawaiian subsistence, culture, and religion” (Hawai‘i Administrative Rules 2005: Chapter 188-22.6).

Community-based fisheries management (CBFM) brings together local communities, government agencies, scientists, and other partners to manage resources collaboratively. This approach recognizes that the people who depend on these resources are often best positioned to help care for them. By combining traditional knowledge, scientific research, and shared governance, CBFM provides a more holistic and locally grounded approach to marine management (**Table 1**).

Ultimately, successful management in Hawai‘i depends on people as much as it does on policy. When communities are actively involved, management is more effective, more culturally relevant, and more likely to sustain marine resources for future generations.



Ulua aukea, can live up to 25 to 31 years in the wild.
A 100-pound fish is about 17-21 years old.



PRINCIPLES OF COMMUNITY-BASED FISHERIES MANAGEMENT IN HAWAI'I	
PRINCIPLE	WHAT IT MEANS
  Traditional Knowledge	 Seasonal awareness  Sustainable practices  Cultural protocols
  Collaborative Governance	 Communities +  DLNR +  NGOs <i>working together</i>
  Replenishment Areas	 No-take zones  Seasonal closures  Habitat protection
  Community Involvement	 Local decision-making  Monitoring  Stewardship
  Science + Knowledge	 +  +  Research + traditional 'ike to guide management
  Education & Outreach	 Build awareness  Share knowledge  Support conservation

Table 1. Community-based fisheries management principles.

Designing Fisheries Replenishment Areas

Designing Fisheries Replenishment Areas (FRAs) requires more than simply closing areas to fishing—it requires understanding how ecosystems work. Biophysical design guidelines use knowledge of species biology, habitats, and ocean processes to ensure FRAs achieve their goals (**Table 2**). When well designed, FRAs can rebuild fisheries, protect biodiversity, and strengthen reef resilience in the face of climate change—supporting food security, livelihoods, and cultural practices in Hawai‘i.

Different species rely on different habitats throughout their lives. Protecting a range of habitats—such as coral reefs, lagoons, and nursery areas—is essential to maintain healthy ecosystems. Research suggests that protecting at least 30% of each major habitat type is needed to sustain fish populations and allow them to replenish²⁷. These protected areas must also be spaced so that fish and larvae can move between them, maintaining connections across the ecosystem.

Size and shape matter. Individual FRAs must either be large enough to sustain populations on their own (such as Kaho‘olawe) or function as part of a connected network (such as the West Hawai‘i Regional Fishery Management Area). Areas should be large enough to keep adult fish within their boundaries while allowing eggs and larvae to disperse and support nearby fisheries. FRAs that extend from shore to deeper water are especially effective because they include the full range of habitats fish need as they grow and move through their life cycle.

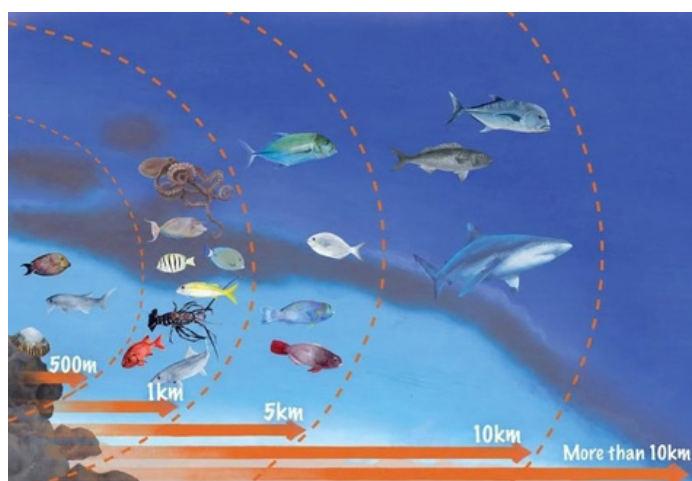


Figure 17. Some species need bigger areas than others to eat, live, and reproduce. To maintain healthy populations of focal species, FRAs should be at least twice the size of the minimum area they need.

A network of FRAs provides the greatest benefit. When multiple protected areas are connected, they can exchange larvae and support one another. This increases the likelihood of protecting species at all life stages and across all habitats. Networks also spread risk—if one area is damaged by events such as coral bleaching or storms, others can help replenish it.

Different species move different distances and require different amounts of space (**Fig. 17**). Smaller

reserves can work well for species that stay close to home, often producing strong spillover benefits. However, larger FRAs are needed for wide-ranging species, especially top predators such as ulua, which are now rare on Main Hawaiian Islands reefs but common in less fished areas. Larger areas are also more resilient to disturbances and can support more complete ecosystems.

BIOPHYSICAL DESIGN GUIDELINES for Fisheries Replenishment Areas (FRAs)		
BIOPHYSICAL DESIGN GUIDELINE	KEY MESSAGES	
 1. Represent & replicate habitats (spread the risk)	- Protect at least 30% of each major habitat. - Include at least three examples of each habitat type.	
 2. Protect critical, special, and unique areas	- Include critical areas for focal species e.g., spawning and nursery grounds. - Focal species include those important for fisheries, ecosystem function (e.g., herbivores), and rare and threatened species.	
 3. Incorporate connectivity: movement of adults, juveniles and larvae	- Populations are linked through the dispersal of individuals as adults, juveniles or larvae. - FRAs must be large enough to sustain focal species within their boundaries during their adult and juvenile life history phases and spaced to allow for larval dispersal within and among them.	
 4. Allow time for recovery	- Populations of focal species recover at different rates depending on their life histories and other factors (e.g., habitat quality and size of the remaining population). - Populations of some species may take decades (>20–40 years) to recover after they are fully protected in FRA, while other species may recover more quickly.	
 5. Protect healthy areas and avoid local threats	- Prioritize protecting places where there are healthy ecosystems and avoid areas with unmanagesable threats. - If this is not possible: ✓ Reduce threats as much as possible ✓ Facilitate natural recovery ✓ Consider costs and benefits of rehabilitating habitats and species	
 6. Adapt to changes in climate and ocean chemistry	Include areas where habitats and species are likely to be more resilient to, or able to adapt to, global environmental change (e.g., warming, ocean acidification, sea level rise).	
 7. Integrate within broader management frameworks	Integrate FRAs within broader marine spatial planning and management regimes (e.g. Ecosystem Based Management and Integrated Coastal Zone Management) to address all threats to marine resources. 	

Table 2. Biophysical design guidelines for FRAs²⁷.

There are tradeoffs. Smaller FRAs may be easier to establish, gain community support, and enforce—but more are needed to achieve the same ecological benefits. Larger FRAs provide broader protection but can be more difficult to implement. A balanced network of both is often the most effective approach.

FRAs must also be protected for long enough to allow fish to grow, reproduce, and rebuild populations. Some species recover quickly, but others—especially large, slow-growing predators—may take decades. Long-term or permanent protection consistently produces the strongest results.

Finally, **clear boundaries and effective enforcement are critical**. Simple, recognizable borders—such as points, bays, or straight lines—make it easier for fishers to follow regulations and for managers to enforce them.

In short, well-designed FRAs are not random closures—they are carefully planned systems that work with nature to rebuild fisheries and restore healthy reefs across Hawai‘i.

Strongly Protected Fisheries Replenishment Areas are Powerful Management Tools – Big Fish Matter

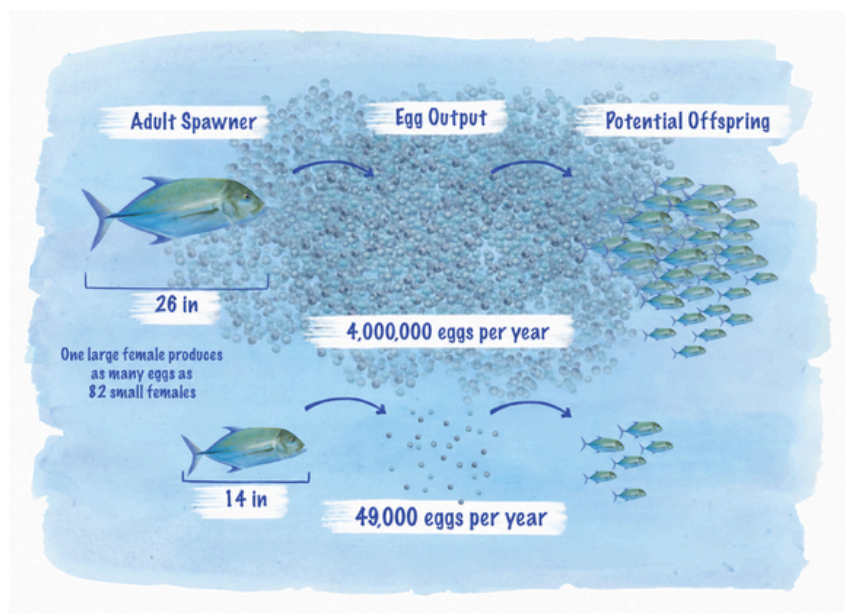


Figure 18. Larger fish and invertebrates produce many more eggs than smaller ones because as a fish doubles in length, its internal volume and body mass increase exponentially.

Fully protected FRAs are powerful because they allow fish to grow large—and big fish are the engine that drives population recovery.

Larger fish produce more offspring than smaller ones, and those offspring are often healthier and more likely to survive²⁸. In fact, egg production increases dramatically with size. For example, a single 26-inch female ‘ōmilu can produce as many eggs as 82 fish that are only 14 inches long (**Fig. 18**).

A 12-inch female weke produces about 45 million eggs per spawning event, spawning multiple times each year—more than 180 million eggs annually. That is equivalent to an output of roughly 2,000 weke half that size. Even small differences matter: a 5.3-inch lobster produces about twice as many eggs as a 4-inch lobster.

Size matters—not just for numbers, but for quality. Larger fish spawn more often, produce more eggs, but also produce stronger, more resilient offspring that are more likely to survive. This makes them much more important for maintaining and rebuilding populations than smaller fish.

One of the greatest benefits of FRAs is that they protect these large individuals. By allowing fish to survive and grow to their full size, replenishment areas restore the natural reproductive capacity of the population and help maintain genetic diversity.

Without protection, however, fishing tends to remove the biggest fish first. Over time, populations become dominated by smaller individuals. These smaller fish produce fewer eggs, reproduce earlier, and invest less energy in growth. As a result, the overall productivity of the population declines.

The long-term consequence is a smaller, less productive fishery. Large fish disappear, reproduction drops, and total biomass is reduced—sometimes permanently.

FRAs reverse this process. By protecting fish long enough to grow large and reproduce, they rebuild the breeding stock that sustains fisheries. In doing so, they restore not just fish populations, but the natural processes that keep Hawai'i's reefs productive and resilient.

Fully Protected Replenishment Areas Support Fisheries Beyond Their Boundaries

Fisheries Replenishment Areas (FRAs) don't just benefit the areas inside them—they also help rebuild fisheries outside their boundaries.

As fish and invertebrate populations grow inside protected areas, some individuals move into nearby fished areas. This process, known as **spillover**, occurs as populations become more crowded and fish spread into surrounding habitats (**Fig. 19**).

These movements can increase fish abundance in adjacent fishing areas—although if FRAs are too small, spillover can reduce their long-term reproductive potential.



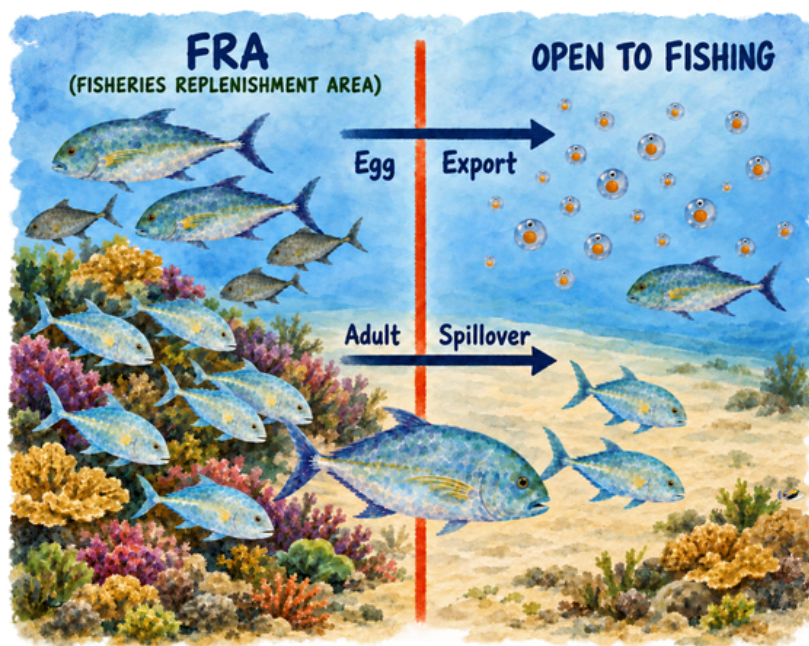


Figure 19. Larger-bodied fishes in higher densities within FRAs produce many more and healthier offspring that can replenish stocks both inside and outside the protected area through the spillover of eggs, young and adults.

In Hawai'i, this effect has been clearly documented. At the **Pūpūkea Marine Life Conservation District** on O'ahu, fish biomass increases extend nearly **0.6 miles into adjacent fished areas**²⁹. Fishers recognize this pattern and often concentrate effort near reserve boundaries (**Fig. 20**). Similarly, in West Hawai'i, adult yellow tang move out of protected areas into surrounding reefs, boosting fish populations in areas open to fishing up to a mile away³⁰ (**Fig.21**).

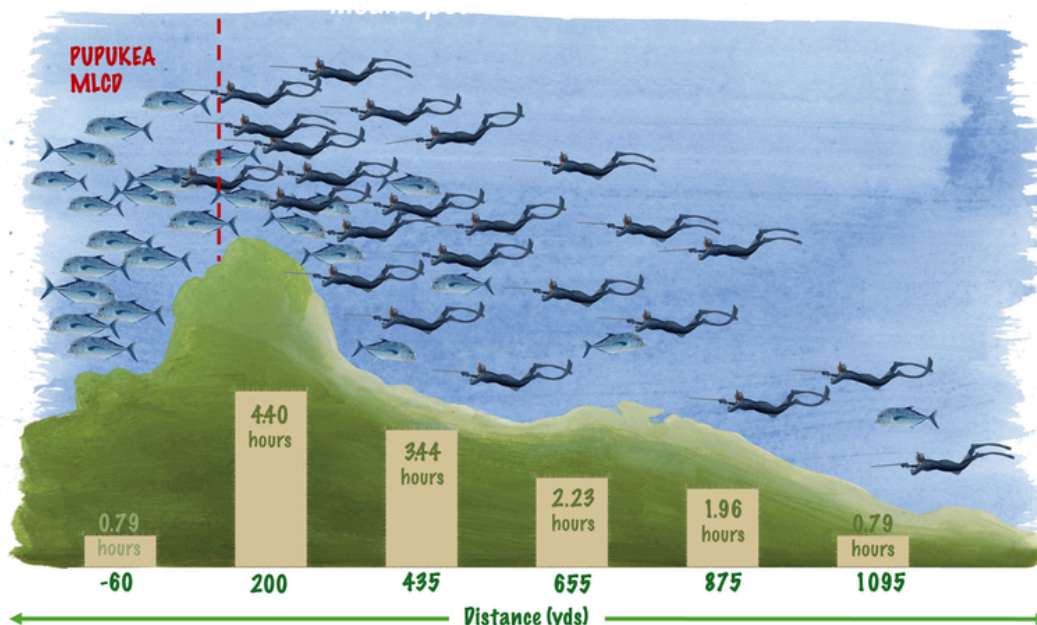


Figure 20. Spearfishing effort adjacent to the Pūpūkea Marine Life Conservation District (MLCD) showing the concentration of fishing effort adjacent to the conservation area's boundary.

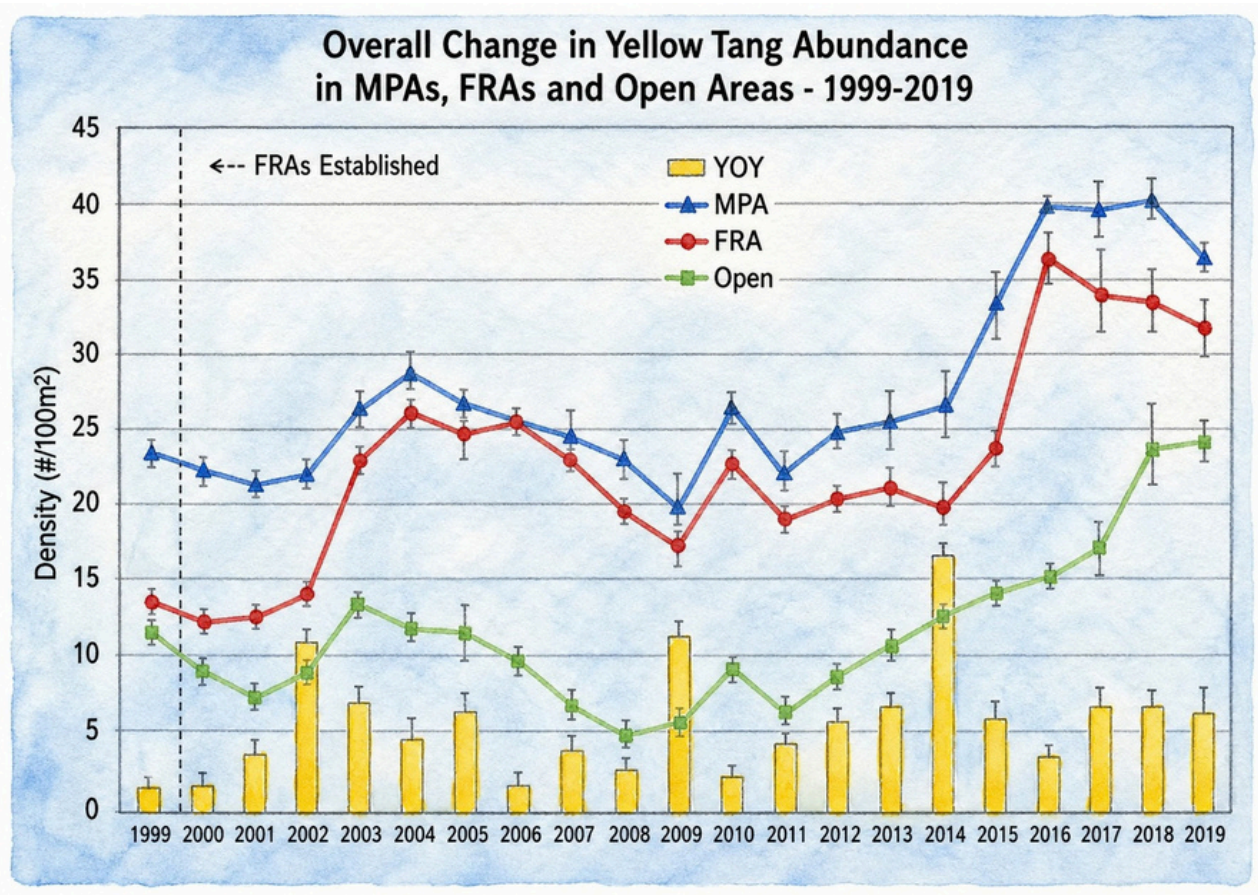


Figure 21. Increases in yellow tang in open areas show the spillover benefits of the replenishment areas.

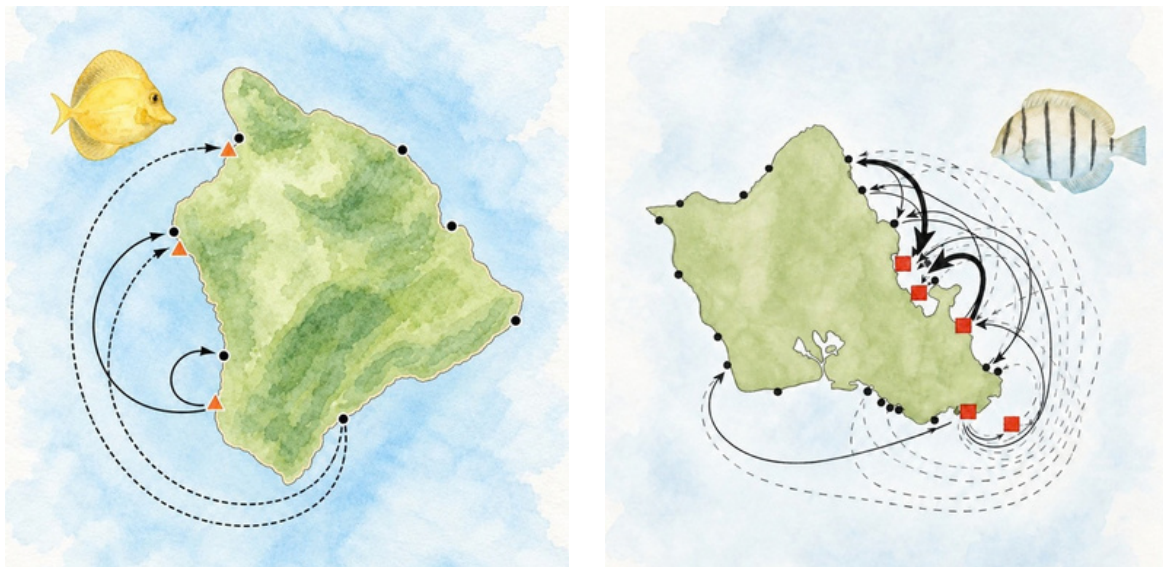


Figure 22A. FRAs support fisheries by exporting larvae. These figures demonstrate patterns of larval movement (connectivity) of yellow tang (Fig. 22A)²⁴ on Hawai'i and manini (Fig. 22B)⁴⁰ on O'ahu. Since there are more adult fishes in FRAs, the larvae they produce support fisheries outside FRAs.

FRAs also support fisheries through the export of larvae. Healthy fish populations inside protected areas produce large numbers of eggs, which develop into larvae that drift with ocean currents and settle on reefs elsewhere. Genetic studies show that some areas supply larvae to reefs as far as **71 miles**, helping replenish important fisheries species³¹ (**Fig. 22A, B**).

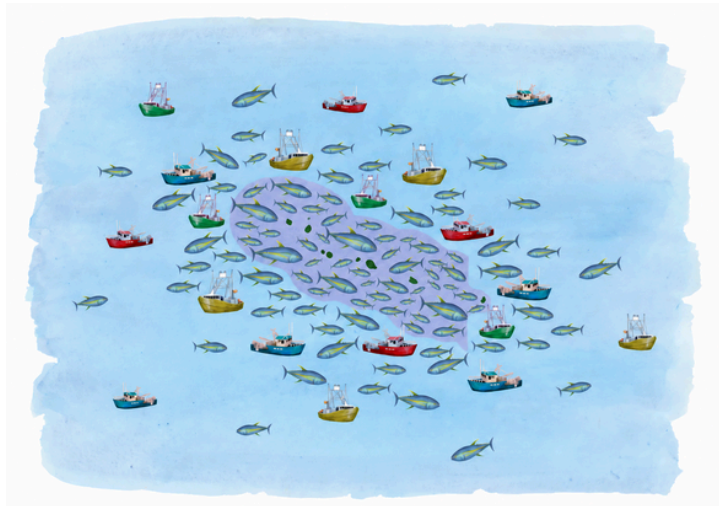


Figure 23. Following the expansion of the Papahānaumokuākea Marine National Monument (in purple), longline catch rates of ahi (yellowfin tuna) increased.

This benefit can extend even further. Following the expansion of **Papahānaumokuākea Marine National Monument**, longline catch rates for ahi (Yellowfin and Bigeye Tuna) increased both near and far from the monument, providing strong evidence of large-scale spillover and larval export³² (**Fig. 23**).

The takeaway is clear: well-designed, fully protected areas not only rebuild fish populations within their boundaries—they help sustain fisheries across much larger regions.

Minimally Protected Areas Do Not Work

Not all protected areas are equally effective. In Hawai'i, fully or highly protected areas consistently rebuild fish populations, while areas with only limited restrictions perform little better than places open to fishing (**Fig. 24**).

Short-term or rotational closures have a long history in Hawai'i and across the Pacific. Traditionally, they were used to ensure large catches for special occasions or to provide a temporary reserve when fishing

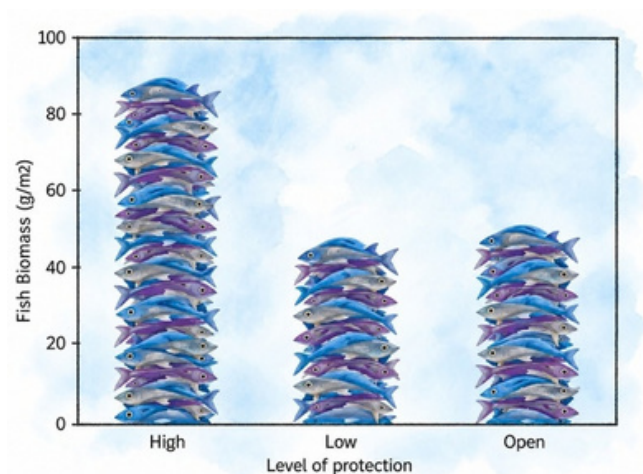


Figure 24. Fish biomass by level of protection across the Main Hawaiian Islands.

grounds were depleted. These approaches can benefit fast-growing species in the short term—but those gains are often quickly lost once fishing resumes.

In modern Hawai‘i, rotational closures have generally not been effective at rebuilding fisheries. When areas reopen, there are often few limits on fishing effort. This can create a “derby” effect, where fishers rush to harvest as much as possible before the next closure. The result is intense, short-term pressure that quickly erodes any gains made during the closed period.

The Waikīkī–Diamond Head Fisheries Management Area is a clear example. During closure periods of one to two years, fish biomass increased slightly but declined rapidly when the area reopened³³. Over time, the overall trend was negative—total biomass dropped by about two-thirds, and larger fish (>16 inches) nearly disappeared. This pattern highlights how short closures without strong controls can fail to rebuild stocks.

It is clear that rotational closures alone are not sufficient to achieve long-term goals such as rebuilding fisheries, conserving biodiversity, or strengthening reef resilience. They can play a role, but only when combined with longer-term or permanent protected areas, and when fishing effort during open periods is carefully managed.

Enforcement is also critical. Even small amounts of poaching can undermine the success of a replenishment area²⁷. Where enforcement is weak, compliance tends to decline, especially if penalties are not strong enough to deter violations. In contrast, stewardship by local communities has often proven more effective than top-down regulation alone.

Ultimately, protection only works if it is strong, consistent, and respected.

Without that, even well-designed areas will struggle to deliver lasting benefits for Hawai‘i’s fisheries.

Hawai‘i Needs a Network of Fisheries Replenishment Areas Throughout the Archipelago

Well-designed FRAs—especially those that are fully or strongly protected—are among the most effective tools for rebuilding fish populations and protecting biodiversity in a changing ocean.

In places like the Main Hawaiian Islands, where fishing pressure is high and fish stocks have significantly declined, scientists recommend protecting at least 30% of each major marine habitat in no-take areas to rebuild fish populations and sustain fisheries²⁷.



Currently, Hawai'i falls far short of that goal. Only 12% of nearshore waters (within 50m depth) and 5% of state waters (≤ 3 nautical miles) have some form of management²². However, fully protected areas make up less than 0.5% of nearshore waters. Even when combined with highly protected areas that allow limited fishing, only about 3.4% of these habitats are strongly protected (Fig. 25).

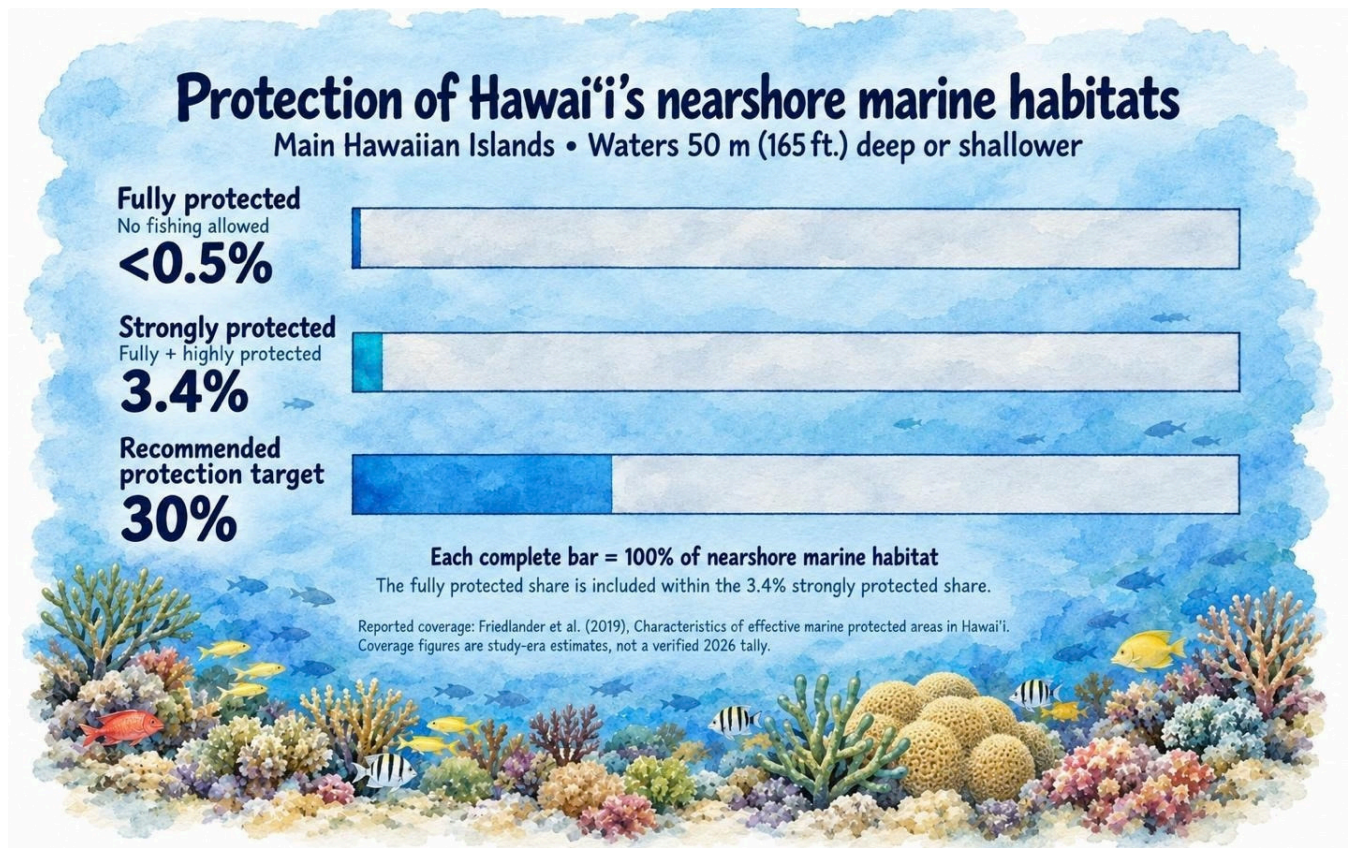


Figure 25. All nearshore protected areas in the Main Hawaiian Islands total less than 4%, far short of the recommended 30% protected area target.

In addition, most existing replenishment areas are small—with a median size of just 0.7 square miles—too small to effectively protect many important fisheries species. As a result, the current system does not provide the scale of protection needed to rebuild fish populations across the islands.

Expanding a network of fully protected FRAs is urgently needed. A well-designed network can rebuild fisheries, grow food security, strengthen local economies through fishing and tourism, and sustain the cultural practices that connect communities to the ocean.

There is already a clear path forward. At the 2016 IUCN World Conservation Congress in Hawai‘i, Governor Ige committed to effectively manage 30% of Hawai‘i’s nearshore waters by 2030. While the State of Hawai‘i has since abandoned the explicit 30x30 goal this target remains a goal for many fisheries conservation organizations. Achieving this goal will require scaling up protection, improving management, and working in partnership with communities across the state.

The science is clear—and the opportunity is now: by expanding a connected network of replenishment areas, Hawai‘i can restore its reefs and ensure that they continue to support people and nature for generations to come.

Fisheries Benefits

Fisheries Replenishment Areas (FRAs) provide multiple benefits that help sustain Hawai‘i’s fisheries over the long term (**Table 3**). By protecting fish populations, habitats, and ecosystem processes, they allow stocks to rebuild, support higher catches over time, and reduce impacts on vulnerable species. FRAs also serve as important reference areas and provide a buffer against uncertainty, helping ensure that Hawai‘i’s fisheries remain productive for future generations³⁴.

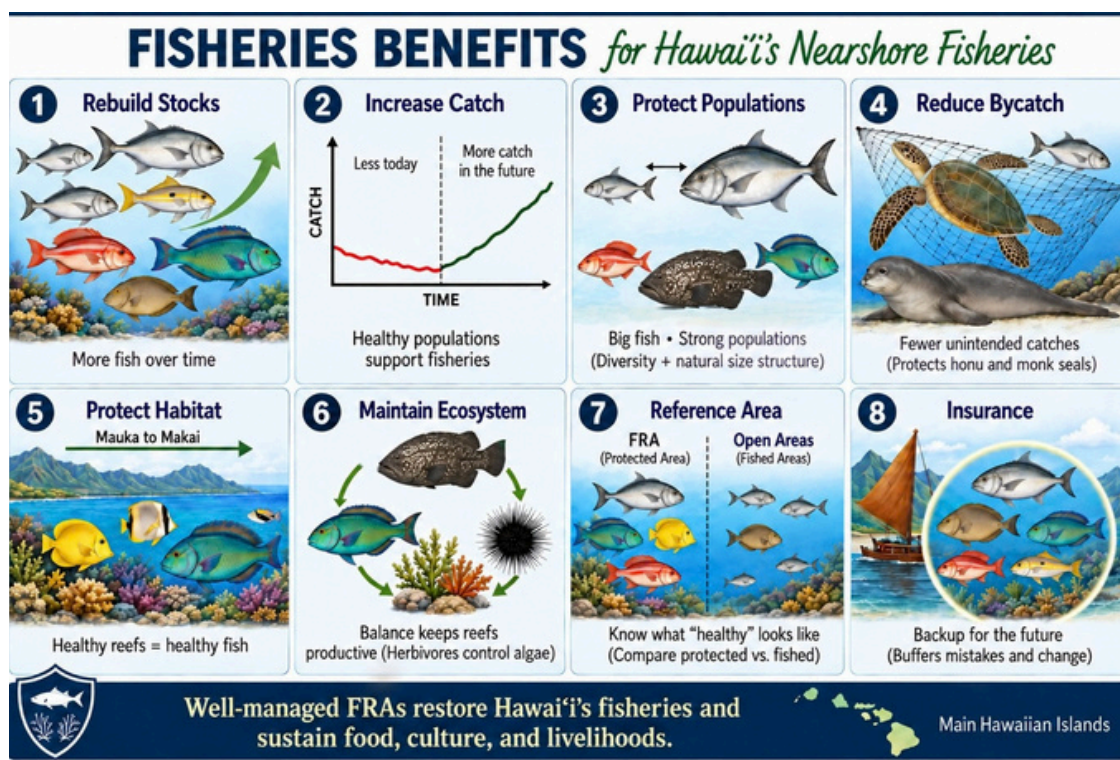


Table 3. Fisheries Replenishment Areas provide multiple benefits to communities.

Ecological Benefits

Fisheries Replenishment Areas (FRAs) provide important ecological benefits beyond fisheries. By protecting marine life and habitats, they help conserve biodiversity, maintain ecosystem structure, and support essential processes such as nutrient cycling, shoreline protection, and climate regulation. These healthy ecosystems also provide opportunities for tourism and recreation.

As marine species continue to decline, protecting intact ecosystems becomes increasingly important. FRAs safeguard species and the habitats they depend on, helping preserve ecosystems that may otherwise be lost.

They also serve as valuable reference areas. In many places, long-term human impacts have altered marine ecosystems so much that it is difficult to know what “healthy” conditions look like—a problem known as the shifting baseline syndrome³⁵. FRAs provide rare opportunities to study reefs with reduced human pressure, improving our understanding of how marine ecosystems function and how best to manage them.

Socioeconomic Benefits

Fisheries Replenishment Areas (FRAs) provide important benefits for the people of Hawai‘i by supporting food security, livelihoods, and cultural practices. Healthy nearshore ecosystems are central to local communities, and FRAs can help maintain and revive cultural connections to the ocean, especially when they incorporate traditional management approaches and community stewardship.

Coral reefs are also a major economic asset. In Hawai‘i, reefs contribute an estimated **\$1.2 billion per year** through tourism, fisheries, coastal protection, and other services, with a total asset value of about \$33.6 billion³⁶. Well-managed FRAs and other protected areas can help sustain these benefits. An economic analysis of several intensively used marine managed areas estimated annual recreational benefits of approximately **\$35 million at Hanauma Bay, \$20 million at Molokini, \$9.4 million at Kahalu‘u, and \$2.6 million at Honolulu** (2003 dollars)³⁷. These benefits included the value visitors placed on their reef experience as well as reef-related expenditures and their broader effects on Hawai‘i’s economy.

At the same time, maximizing economic benefits does not require maximizing visitor numbers. Hanauma Bay once experienced as many as **13,000 visitors per day**, with heavy use contributing to sediment disturbance, coral trampling, fish feeding, trash, and other impacts. Subsequent management progressively reduced these pressures, and



measures introduced following the 2020 closure—including a reservation system, limits on daily visitation, and two closure days each week—have reduced visitation substantially. Despite lower visitation, Hanauma Bay currently generates approximately **\$8–9 million annually in direct admission, parking, concession, and related revenues**. The experience at Hanauma Bay demonstrates that managing visitor use within ecological limits can both protect the reef resource and maintain substantial economic benefits.

Despite the clear economic importance of healthy reefs, **less than 1% of Hawai‘i’s state budget is allocated to natural resource management, which is one of the lowest among all U.S. states**. This highlights a major opportunity: investing in FRAs and ecosystem protection can provide long-term returns for both the environment and the economy.

In Hawai‘i, healthy reefs are not just an environmental priority—they are a foundation for culture, community, and economic well-being.

Climate Resilience

Fisheries Replenishment Areas (FRAs) can help Hawai‘i’s reefs better withstand the impacts of climate change. By protecting marine life and habitats, FRAs support healthy, diverse ecosystems that are more resilient to warming waters, ocean acidification, coral bleaching, and extreme weather events. These ecosystems are better able to recover from disturbances and provide important benefits to people.

By reducing local stressors—such as overfishing, coastal impacts, and destructive practices—FRAs give reefs a greater chance to cope with large-scale environmental change. This is



Table 4. Abundant herbivores maintain healthy coral reef ecosystems.

especially important in Hawai'i, where declining water quality and increasing coral bleaching are placing reefs under pressure.

A key factor in reef resilience is **abundant herbivorous fishes**, such as uhu and kala, which help control algae and allow corals to recover and grow. Studies in Hawai'i show that reefs with high herbivore biomass are more resistant to climate impacts^{38,39}. Protecting these species within FRAs can play a critical role in maintaining reef health into the future (**Table 4**).

FRAs can also act as **refugia**, providing safer habitats where species can survive as conditions change elsewhere. By protecting spawning and nursery areas, they help sustain the fish populations that support food security and livelihoods for coastal communities.

In a changing climate, protecting healthy reefs is one of the most effective ways to ensure they continue to support Hawai'i's people and ecosystems for generations to come.

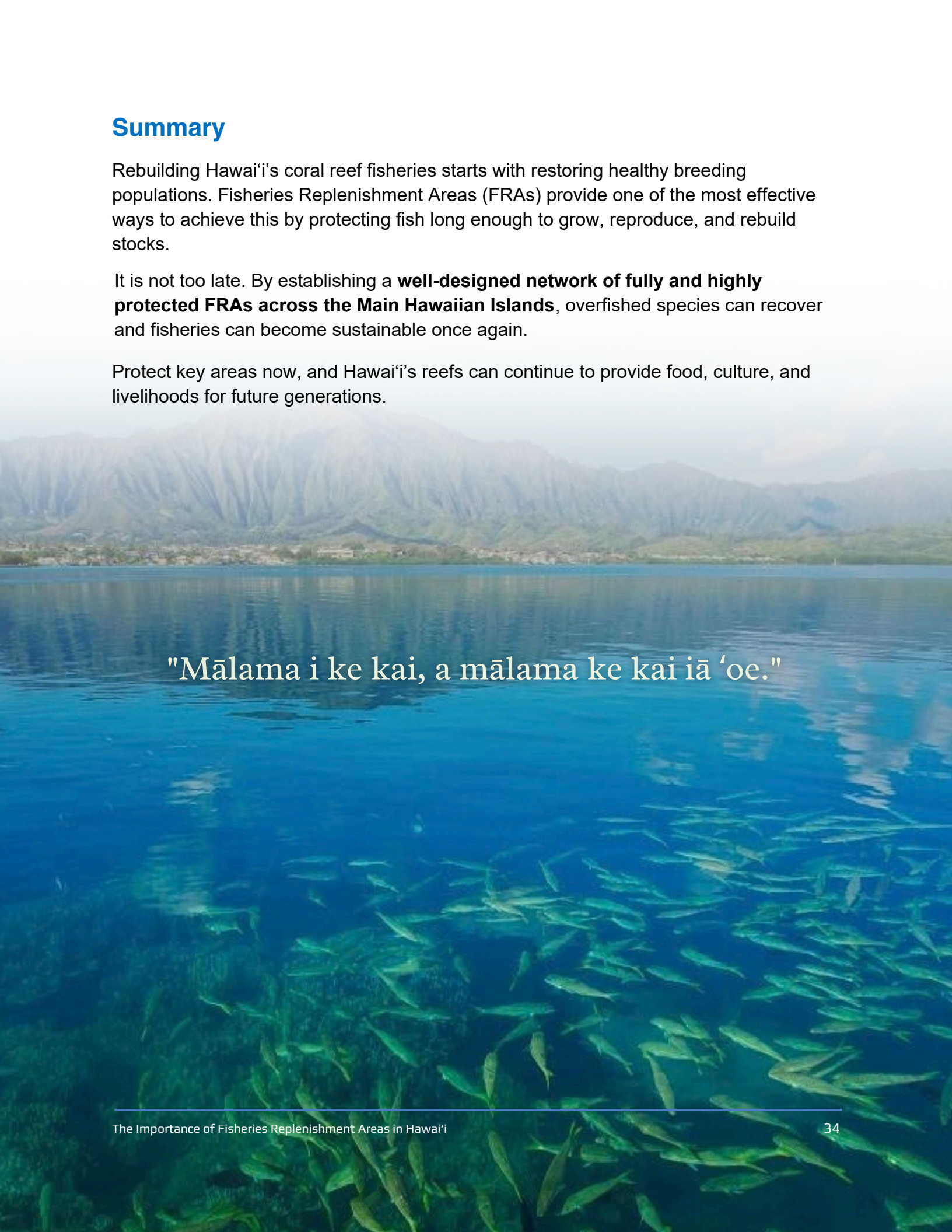


Summary

Rebuilding Hawai'i's coral reef fisheries starts with restoring healthy breeding populations. Fisheries Replenishment Areas (FRAs) provide one of the most effective ways to achieve this by protecting fish long enough to grow, reproduce, and rebuild stocks.

It is not too late. By establishing a **well-designed network of fully and highly protected FRAs across the Main Hawaiian Islands**, overfished species can recover and fisheries can become sustainable once again.

Protect key areas now, and Hawai'i's reefs can continue to provide food, culture, and livelihoods for future generations.



"Mālama i ke kai, a mālama ke kai iā 'oe."

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