Safeguarding marine species

By examining how species are affected by large predator protection, **Professor Kenneth P Sebens** influences global thinking on the value of marine protected areas. Here, he discusses his progress to date

PROFESSOR KENNETH P SEBENS

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To begin, what is the overall objective of your research into subtidal community marine preserves?

The overall goal is to understand the factors structuring rocky subtidal communities inside and outside of marine preserves in the Salish Sea, Washington. These include the effects of reduced fish populations outside preserves, the impact of invasive species and the changes in physical conditions – such as temperature, water flow, sedimentation and acidification. Factors producing open space and turnover of species (or disturbance) are also targets of our study. I am interested to know whether preserves have higher numbers of certain fish species, and if so, how this affects the abundance of benthic species such as shrimp and snails. I am also looking at the effects of predators and changing ocean conditions on the attached benthos, such as ascidians, sponges, anemones and algae.

Alien invasive species are among the biggest threats to ecosystems worldwide. What introduced species have been found to alter the function of marine communities?

In our area, we found that most invasive species settle in harbours and on wharves or jetties with few invading the deeper subtidal zones. Asian oysters and Sargassum weed have taken over large areas of the intertidal zone and very shallow subtidal areas. In the southern Salish Sea, such as Puget Sound and Hood Canal, there has been more invasion of the subtidal zone by several ascidian species. Ascidians are a problem worldwide, as are invasive snails and crabs. An earlier study by the Sebens laboratory showed that an invasive sea slug (*Tritonia plebeia*) wiped out soft coral populations in Massachusetts and it took decades to recover.

Do you consider abiotic processes and anthropogenic influences, such as nutrient runoff from industrial activities, in your research?

Yes, that is an important consideration for this work. There is major runoff coming from rivers and stormwater discharge throughout the Salish Sea. These runoffs bring with them an excess of nutrients and pollutants which are discharged into our local waters. The San Juan Islands are fairly remote from those sources (primarily Vancouver and Seattle), so we are lucky that our water quality is the best in the US portion of the Salish Sea.

How can marine protected zones be successfully policed, especially in less economically developed countries?

There are a number of ways. For example, in Jamaica local dive operators help police the marine protected areas because they want good fish populations to attract diving tourists. Here, there is only minor policing, but there is a lot of printed and website information about the preserves, so people can be well informed and educated. The mandatory preserves are generally not fished, but the voluntary preserves that our county established are not well respected, and in addition they are too small in areal coverage to make any real difference – fish just come in and go out.

The New Economics Foundation found that northeast Atlantic fish stocks could fully recover if we stopped fishing for a decade. Is this a plausible option? What solution do you propose?

I spent many years working in the northwest Atlantic and I think keeping large areas free from fishing for many decades is the only sensible answer. In our region, the Salish Sea, rockfish harvest has now been completely stopped, but only in the last few years. Even as the stocks declined to almost nothing, fishing was still allowed. These fish are long-lived and slow to mature, and thus take many decades to recover from over harvesting. A larger predatory fish, the lingcod, has done much better in terms of recovering its populations after controls on fishing were put in place.

Do you have any plans to extend this particular project in the future?

Yes, I have kept up a 34-year study in Massachusetts, where I still complete three sampling visits each year. One challenge is marking the sites so anyone can find them, and the other is finding a way to fund such a study. It takes hundreds of hours of diving to monitor even our current modest set of sites. Research grants from the National Science Foundation are certainly helping to ensure its future, but I am not sure the work will continue without that funding, or when I am no longer able to oversee it.

SCULPIN, STRAWBERRY ANEMONES, AND NUDIBRANCHS
© KENNETH P SEBENS

Friday Harbor Laboratories

With a learning experience focused on marine biology and broader oceanographic fields, **Friday Harbor Laboratories** offers undergraduate and graduate students from around the world the chance to study a variety of subjects, working closely with state-of-the-art scientific facilities and environmentally-rich surroundings

THE FERNALD LABORATORY AT FHL (**LEFT**), THE OCEAN ACIDIFICATION EXPERIMENTAL LABORATORY (**MIDDLE**) AND SHIPBOARD SAMPLING (**RIGHT**)

STATIONED ON SAN JUAN ISLAND, Friday Harbor Laboratories (FHL) offers a unique experience to those interested in the marine sciences and oceanography. Part of an archipelago, San Juan boasts an immense flora and fauna, relatively pollution-free waters, swift tideways and a 3 m tidal range to investigate intertidal benthic ecosystems. With the chance to explore the island's many bays, lagoons, swamps and valley lakes scientists and researchers from both national and international locations are enticed each year to this wonderfully diverse field site. Thanks to its natural endowments and exceptional wealth of biodiversity, FHL is well-situated to conduct excellent marine and oceanographic research, education and training.

'The Labs' – as they are colloquially referred– were established in 1904, by Zoology Professor Trevor Kincaid, as a scientific research outpost for the University of Washington. For over a century they have operated as a highly-respected research facility. Although FHL is one of the oldest marine labs in the world, it is today recognised as a thriving hub of research and educational activity.

COURSE CREDIBILITY

FHL delivers specialist academic courses in marine biology, zoology and genetics, among several others, awarding students with accreditation through the University of Washington. Functioning throughout the year, FHL facilitates many high-quality environmental projects and studies and maintains biological reserves at a number of locations (including Shaw Island, False Bay, Argyle Lagoon and Cedar Rock) throughout the archipelago.

Graduate students at FHL are offered the chance to enrol in an award-winning five-week programme hosted annually throughout the summer. Several subjects are taught in the marine sciences, encompassing aspects of algal research, invertebrate zoology, fish ecology and conservation biology, as well as, experimental and field techniques. With numerous contemporary topics also available, students gain practical, hands-on experience to take them forward in their respective careers. In addition, research apprenticeships are available to qualified graduates and post-baccalaureates throughout the spring and autumn and offer great opportunities to develop training skills.

Promoting and encouraging scientific education to all ages is a large part of FHL's repertoire. For example, their K-12 environmental science outreach programme has been designed for students attending schools on the San Juan Islands. Active participation is required from all students, and FHL engages children and young adults in the different scientific processes involved to give them a head start in their academic life.

SCIENCE AT YOUR FINGERTIPS

The scientific resources available at FHL are wide-ranging. The facilities on offer include:

• Laboratories and equipment

Teaching staff and researchers at FHL are equipped with walk-in cold rooms, a microtechnique room, flume and a workshop, an Ocean Acidification research lab, analytical chemistry lab and in-water mesocosms. General analytical equipment – centrifuges, computers, scintillation counter HPLC, LC-Mass spectrometer, electron microscopes, PCR thermocyclers and equipment for molecular biology – is available for use.

• Scuba diving and boating facilities

With permission from the Diving Officer, certified scientific divers are given the opportunity to use five boats and a number of tanks and weights to conduct specific research activities. FHL's extensive library also offers a plethora of information about study sites and check-out dives.

• Marine equipment

Included in FHL's marine facilities is its research vessel Centennial – a 58 ft steel recreational vehicle, equipped for dredging, trawling, net hauling and water sampling. In addition, a recreational submersible vehicle provides opportunities to work to depths of 1,000 ft.

• Synoptic collection and species importation

FHL keeps a collection of preserved marine species, plants, and information on habitats to support with identification and location referencing. Imports of species require a permit from the Washington State Department of Fish and Wildlife and usually depend on strict quarantine of non-native organisms to prevent the risk imposed by alien invasive species.

FRIDAY'S FUTURE

Over the past 100 years the Labs have grown to cover nearly 1,500 acres on two islands, and with the available waters and shoreline, the area has become a remarkable site for biological preservation. Now offering 16 courses – a record in FHL history – the Labs attract more marine and oceanographic enthusiasts year on year. With expansion planned on the adjacent Shaw Island, the future for FHL and the pioneering marine research they pursue looks promising.

A **dynamic approach** to preservation

Delving into a number of related topics, marine scientists at the **University of Washington** are researching the effects of marine protected areas in enhancing marine biodiversity in the San Juan Islands

FACED WITH INCREASING pressure from pollution, overfishing and climate change, the protection of marine biodiversity is a priority for policy makers, scientists and the community. The *Marine Biodiversity Assessment and Outlook: Global Synthesis Report*, prepared by the United Nations Environment Programme in 2010, calculates that by 2050 marine productivity will have decreased in nearly all areas. Worldwide fisheries are expected to become dominated by smaller fishes, while the presence of marine invasive species and the number of native marine species extinctions across all regions is forecast to grow. This demise has a significant impact on the resilience and adaption capabilities of marine environments to climate change. As such, a group of marine specialists at the University of Washington (UW) hope its investigations into the dynamics of marine species will offer valuable knowledge to inform the debate around marine protection zones and preserve establishment.

Performed under the umbrella of UW Friday Harbor Laboratories (FHL), which has built a solid reputation for its groundbreaking studies into marine ecosystems, the research – led by Professor Kenneth P Sebens, FHL Director – is critical to conserve the genetic and species diversity of marine environments. By identifying the best ways to protect intact habitat and biota, this ongoing study provides science-based evidence to policy makers. Seeking marine population sustainability, the marine scientists investigate a number of areas, including the impact of predatory fish abundance on the wider environment and the influence of invasive species and Marine Protected Area (MPA) designation on the subtidal communities of organisms.

PREDATOR-PREY RELATIONSHIPS

This project aims to deliver a comprehensive analysis of the ecological interactions between predators and prey and how any changes impact the wider communities, both inside and outside of MPAs. With a special focus on subtidal dynamics, the marine preserves around the San Juan Islands present the perfect opportunity to study how species communities can recover in the absence of specific types of human damage. "They also provide excellent venues to study the effects of large predators in relatively intact communities, in comparison to nearby non-preserve locations," elucidates Sebens. If certain fish populations increase within MPAs it may impact upon other species in subtidal communities, including other fish, mobile crustaceans and molluscs, and the sessile attached benthic invertebrates and algae. Sebens set out to investigate the connections.

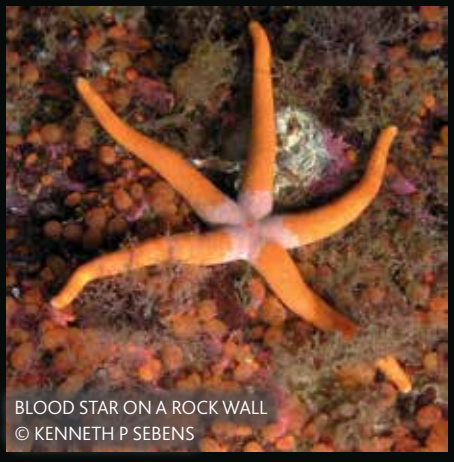
DIVER WITH PUGET SOUND KING CRAB, © KENNETH P SEBENS

Fishing of apex predators can place huge pressure upon food webs and the functionality of all trophic levels within marine environments, but the degree of disturbance has rarely been explored in great detail. Using the San Juan Islands as a case study, FHL PhD candidate Kevin Turner has been investigating what role predatory fishes have in the structure of the ecosystem and how predator recovery in some MPAs change the identity or abundance of other species. He studied the diet of copper rockfish, the most abundant demersal predatory fish encountered in this area, and abundance of a range of other species, including large mobile invertebrates and epibenthic organisms. Turner observed that sites with greater predatory fish biomass had, rather unsurprisingly, fewer prey species – in this case, shrimp.

The findings from this localised study also indicated that areas suffering from heavy fishing contained fewer and smaller predatory fish but more shrimp; zones where fishing was restricted – through protected area status – have more and larger predatory fishes and fewer shrimp. This effect probably extends to other mobile invertebrates as well, which FHL will determine through ongoing caging studies. Setting a benchmark for further research, Turner's work has been encouraging. FHL researchers are keen to explore the complex relationships by conducting surveys on how shrimp abundance affects other species and how predatory fish impact mobile mesofauna.

GUARDIANS OF MARINE HABITAT

Robin Elahi, another FHL researcher who recently completed his PhD dissertation, examined the role consumers play in controlling prey populations, richness and space utilisation. Eager to understand how important consumers govern the speed at which subtidal sessile communities (such as barnacles, tunicates and coral polyps) develop, Elahi and Sebens correlated space availability with prey and consumer richness. Interestingly, they found that with increased space availability prey richness decreased whilst consumer abundance and richness rose. The scientists also tested a hypothesis as to how sea urchin consumption patterns manage sessile community development. By controlling the number of sea urchins present, Elahi observed that: "Diet analyses and structural equation models together indicate that sea urchins generate available space directly by consuming macroscopic sessile prey and indirectly by facilitating chitons which maintain patches of space free of microscopic algae and recruits of larger sessile taxa".



BLOOD STAR ON A ROCK WALL © KENNETH P SEBENS

Recently published in the journal *Marine Ecology Progress Series*, this discovery indicates that prey abundance buffers the degree to which sea urchin grazing impacts on all sessile organisms; a finding that has significant implications on the health of subtidal communities including coral reefs the world over. Armed with additional knowledge that predators help to regulate the health of these living gardens, it is believed that this research could change fishing policy and marine protection in the near future.

Habitats within marine environments all play different but highly complex roles with respect to marine species. However, certain habitats such as subtidal rock walls remain poorly-known to the scientific community, and therefore deserve further study to determine the extent to which they provide refuge to subtidal species. Elahi has been using univariate and multivariate analysis of long-term datasets to help explain temporal variation in biodiversity within these populations showing that, whilst there has been just under a 1 °C rise in temperature over the past 40 years in the Salish Sea, the rock wall

DIVERS PREPARE FOR PHOTOGRAPHIC SURVEYS
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communities have remained relatively stable. Even with the introduction of a no-take urchin zone in 1984, species numbers did not appear to change significantly compared to data from the same walls collected in the 1960s by then FHL graduate student Charles Birkeland, a now well-known coral reef ecologist. This research has highlighted the key function rock walls play in offering a shelter for marine species, compared to horizontal or sloping surfaces that are more frequently grazed by urchins and other consumers. Elahi explains: "We suggest that subtidal rock walls may serve as potential refugia of biodiversity, and emphasise the need for long-term ecological monitoring with consistent methodology to help understand this function more fully".

SUPPORTING WIDER OUTCOMES

Work continues on these subtidal communities amidst the flurry of positive results achieved so far and mounting pressures from activities that impact on the health of the marine environment.

"Coastal communities are changing due to extraction, invasive species and climate change, yet we know little about these effects in the shallow rocky subtidal zone," points out Sebens. Both within and outside of the regional network of MPAs in San Juan, Sebens and his expanding team of dedicated scientists continue to pose questions and explore the answers for this little-known environment that is so critical to a sustainable resource future. UW currently assists the San Juan Country Marine Resources Committee – a citizen-driven county advisory committee working to protect the local marine environment – through data and information sharing. "Understanding the relative importance of ecological processes at different spatial scales is an issue central to both ecological theory and conservation efforts," emphasises Elahi. Contributing towards a greater understanding of the benefits of MPAs in maintaining and managing biodiversity, Sebens and his team are driven by a passion for the oceans and a desire to preserve the delicate subtidal system.

COPPER ROCKFISH
© KENNETH P SEBENS

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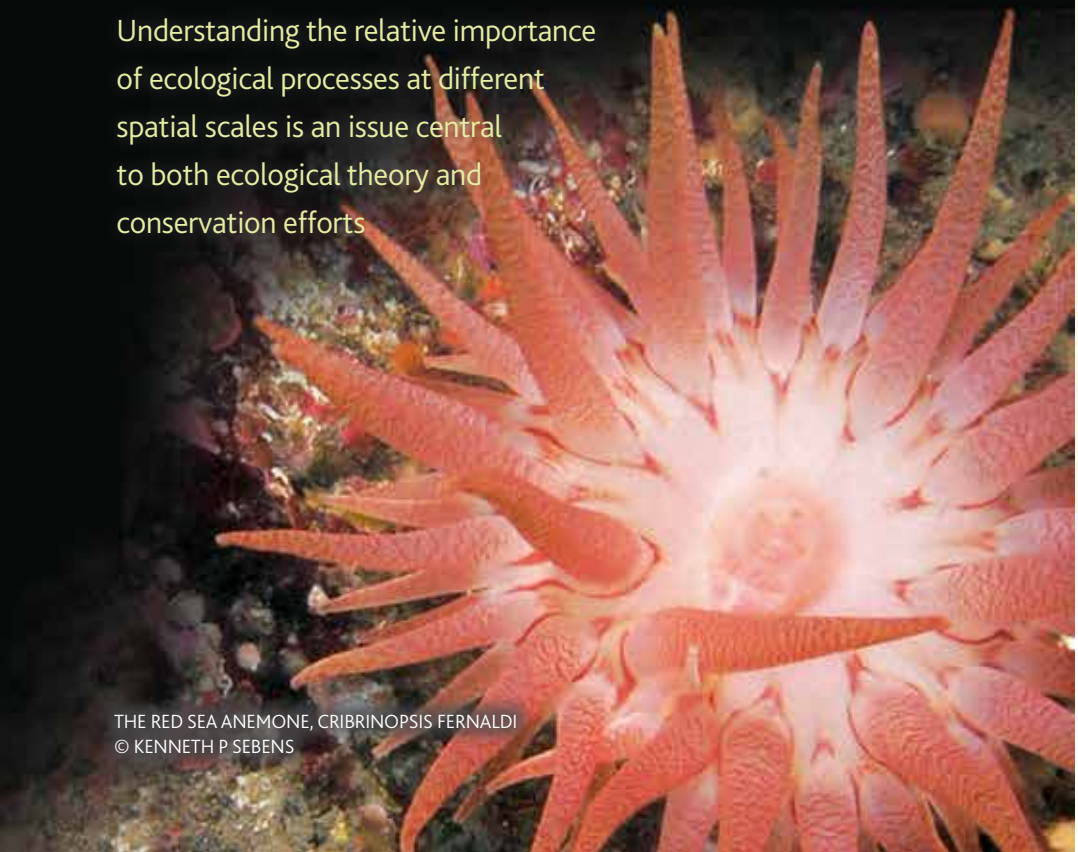

THE RED SEA ANEMONE, CRIBRINOPSIS FERNALDI
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INTELLIGENCE

EFFECTS OF MARINE PRESERVES AND NONINDIGENOUS SPECIES ON ROCKY SUBTIDAL COMMUNITIES: INDIRECT INTERACTIONS, DISTURBANCE AND COMMUNITY DYNAMICS

OBJECTIVES

- To explore the interaction of predators and prey in marine subtidal communities, including fish populations in marine preserves, and to examine the effects of nonindigenous species on native flora and fauna
- To motivate students pursuing graduate and professional training and to equip them with field experiences in marine ecology

KEY COLLABORATORS

Kevin Turner

Robin Elahi

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KENNETH P SEBENS conducts research on marine subtidal benthic populations and communities in both temperate and tropical locations including an ongoing investigation into community and population dynamics and long-term changes in rocky subtidal habitats in Massachusetts, one of the most extensive long-term studies of coastal marine communities in the world. Sebens has had over 38 years experience as a diving scientist, including missions living and working in the underwater laboratories 'Hydrolab' and 'Aquarius', located on Caribbean coral reefs. He has published over 80 papers and book chapters on a wide variety of topics and has mentored 31 graduate students at four universities since 1978.