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# Research Progress on Ecological Functional Characteristics and Transplantation Techniques of Large Seaweed

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## Abstract

Macroalgae are one of the important drivers in marine ecosystems and ecological processes. The marine basic energy conversion provider and seaweed habitat composed of macroalgae play an extremely important role in purifying the marine water environment and maintaining the growth, reproduction, and feeding of marine organisms. However, in recent years, due to factors such as human activities and the deterioration of the marine environment, large-scale degradation has occurred in seaweed farms. In order to ensure the sustainable utilization of marine biological resources and the sustainable development of marine ecological environment, the restoration of seaweed farms has become a key task in the ecological environment protection of China's nearshore waters. This article collects existing information and summarizes existing work experience, explain the ecological function of large seaweed in marine ecosystems in order to provide suggestions and references for the rational, efficient, and sustainable development of large-scale seaweed transplantation technology and seaweed restoration work.

## Keywords

Large seaweed, Ecological function, Ecological factors, Transplantation Technology

## Introduction

Large algae are mostly benthic algae, mainly composed of brown algae, green algae, and red algae. At present, there are over 4500 recorded species of large seaweed worldwide. Overall, the development and utilization rate of large seaweed is low, and there are only a thousand mature and widely used large seaweed species in various industries. The development prospects of large seaweed are long-term and have great potential. Most of the macroalgae are distributed in warm temperate temperate waters, from the intertidal zone and subtidal zone to the water depth of 200m [1]. In countries such as Japan, South Korea, and the Philippines in Asia, large seaweed is often used as food. In order to increase seaweed production, artificial reefs are built to proliferate seaweed, and artificial aquaculture is also relied on to increase seaweed production. The global distribution of large algae shows a significant latitude gradient. Generally speaking, the richness of large algae species gradually increases from the poles to the equator, with only a few showing opposite trends. The sea area with the largest number of macrobenthic algae genera is concentrated in temperate waters. There are 400 genera of macrobenthic algae distributed in the Indo Pacific waters, southern Australia and Japan waters. The abundance of genera in the Indo Australian archipelago is moderate, with 275 genera present. Large algae, represented by giant algae and large kelp, are often distributed in mid to high latitude waters; In temperate waters, giant algae and kelp often coexist with various brown algae; In subtropical and tropical waters, it is replaced by black horn algae and brown algae.

# 1. Ecological functions of large seaweed

## 1.1 Material absorption and conversion function

Macroalgae, as photosynthetic autotrophic organisms, are one of the fundamental promoters of material input and output in marine ecosystems. There are a lot of inorganic compound and organic substances in seawater, such as nitrogen, phosphorus, sodium, carbon, oxygen, nutrients, etc. Large algae use sunlight for photosynthesis, inhale carbon dioxide from the sea, and release oxygen for their own and other marine life activities. Like most plants, macroalgae are also organisms that need sunlight for growth, development, reproduction and other life activities. At the same time, macroalgae need to absorb a variety of inorganic compound substances in seawater, transform them into organic substances, and discharge them into seawater. Some studies have shown that the ability of macroalgae to absorb inorganic substances is super strong. Experiments by Egan and Yarish show that the ability of giant algae to absorb carbon is 3.4kg yr-1 per square meter [2]. Hatcher et al. found in their experiments that the ability of giant algae to release oxygen is also considerable, with a release of up to 2.2g of oxygen within 24 hours [3]. The above indicates that large algae play an important role in material absorption, transformation, and transport in marine ecosystems.

## 1.2 Food supply function

Relevant research shows that dissolved organic matter produced by the absorption and transformation function of macroalgae is absorbed and utilized by Marine microorganism, providing sufficient food sources for Marine microorganism. Marine animals that consume seaweed stems and leaves selectively nibble on them, as some large seaweed in the ocean have hard stems and leaves that are difficult to nibble on. This large seaweed with hard stems and leaves is less likely to be eaten by marine animals, while herbivorous animals mainly feed on large seaweed with soft stems and leaves. At the end of the life of large seaweed, its main body rapidly withers and becomes benthic detritus organic matter, which is then utilized by marine animals that consume detritus; There is also a situation where debris is generated, which is due to the continuous impact of waves and seawater washing away the stems, leaves, and branches of large seaweed, which are scattered on the seabed with the current and consumed by detrital animals. Due to the ability of large algae to renew their stems, leaves, branches, and other tissues multiple times a year, the consumption of algal debris is usually 3 to 4 times that of phytophagous animals.

## 1.3 Habitat Supply Function

Large algae are not only the drivers and producers of marine ecosystems, but also provide habitats for a large number of marine organisms. Just as various plants in forest ecosystems have diverse branches and leaves for forest animals to inhabit, the stem and leaf forms of seaweed in marine ecosystems have their own unique characteristics. It is this structural system that provides good habitats for many marine organisms. Among marine organisms, some smaller aquatic animal, mainly invertebrates, inhabit and grow on the surface, slits and surrounding areas of large seaweeds. Christie et al. found that the average number of marine organisms on each large seaweed is as high as 8000 [4], while Saarinen et al. conducted field investigations and found that there are 13 to 28 species of marine organisms inhabiting large seaweed [5].

## 1.4 Enemy Avoidance Function

Some smaller marine organisms inhabit large seaweed year-round to prevent predation by natural enemies and reduce the risk of being washed away by seawater surges. Some large marine organisms use large seaweed as their spawning ground, reducing the risk of predators preying on their offspring and improving their survival rate. A large seaweed research team conducted a diving survey in the waters of the Ma'an Islands in the Zhoushan Islands and found that octopuses lay their eggs at the roots of sargassum, preventing the risk of being washed away by water and eaten by predators. The provision of habitat and avoidance of natural enemies by large seaweed plays a good role in the conservation of marine ecological environment and biological resources.

# 2. Ecological factors affecting the growth of large seaweed

## 2.1 Lighting

### 2.1.1 Light intensity affects seaweed growth

The intensity of sunlight directly affects the growth rate of large seaweed; When the light is suitable, large seaweed grows quickly and has lush branches and leaves; Under low light conditions, growth is slow, and the branches and leaves are narrow and thin and soft; Under strong light, it has an inhibitory effect on the growth of large seaweed, causing serious damage. Different seaweeds have different requirements for light intensity, such as kelp gametophyte suitable for 1000-3000lx, kelp spo-

rophyte suitable for 2000-5000lx; Chlorella is suitable for 3000-4000lx.

#### 2.1.2 Light intensity affects the dispersal and development of spores and gametes

Research has found that the divergence of spores and gametes in large seaweeds not only depends on their maturity level, but also on the brightness and light intensity of their environment. After the spores and gametes mature, after a period of darkness treatment, they can quickly disperse and develop under light conditions. Therefore, the presence and intensity of light have an impact on the growth, development, and propagation of gametes and spores.

#### 2.1.3 Effects of light waves on seaweed growth

Solar light waves are divided into long and short waves, where long waves cannot penetrate deeper waters but can be absorbed and utilized by seawater; Short waves are not easily absorbed by seawater, but can penetrate deeper waters. The energy, light, speed, and other characteristics of long and short light waves affect the rate of photosynthesis in large algae, thereby affecting their growth rhythm and breeding ability. Through research, it has been found that brown algae generally grow in depths of 30-60m and prefer blue and green light; Red algae generally grow in the dark at depths of 30-100m and do not like strong light, preferring to absorb green light; Green algae generally live in seawater at depths of 5-6m and prefer to absorb red, blue, and purple light.

### 2.2 Temperature

Temperature is an important ecological factor affecting the growth of large algae. At the same temperature, different growth stages of large seaweed exhibit different growth rates; Similarly, under different growth temperatures, large algae at the same growth stage also have different temperature adaptation abilities [6]. The temperature of seawater changes much less than that of air, because the volume, density and specific heat capacity of seawater are larger than that of air, and seawater is always in motion. The process of seaweed transplantation requires careful investigation of the daily temperature, seasonal temperature, and annual temperature of the transplanted sea area [7], as changes in seawater temperature and effective accumulated temperature throughout the year can affect the growth and breeding of seaweed and its offspring, resulting in an impact on the effectiveness of seaweed transplantation. The changes in water temperature affect the annual growth and offspring breeding of large algae. For example, the growth cycle of copper algae is from August of this year to June of the following year. Seedlings begin to grow at a water temperature of 23-25 ℃ (July December), and copper algae grow rapidly at a water temperature of 9-22 ℃. March May is the peak period for copper algae growth. Research has found that the effective accumulated temperature required for the growth and development of copper algae on Goji Island is around 3650℃ d, and the effective accumulated temperature exceeds 2600 ℃ d, and the growth of copper algae enters a vigorous period [8].

### 2.3 Waves

Waves are a periodic movement of seawater near equilibrium positions and are one of the important ecological factors affecting the effectiveness of large-scale seaweed transplantation. Some seaweed like wind and waves, often growing in high tide wind and wave zones, such as deer antlers and long seaweed in the phylum Red Algae; Some seaweed cannot withstand wind and waves, and generally grows in the inner bay, such as Enteromorpha in the phylum Chlorophyta, reef membranes, and copper algae in the phylum Brown Algae. About research on the Impact of Waves on Seaweed Currently, there are studies on the impact of typhoons on the distribution of large benthic algae [9], and studies on the impact of wind and waves on the distribution of copper algae [10]. The intensity of storm waves has a significant impact on the transplantation effect of seaweed, such as seaweed with weak wave resistance cannot be transplanted to the upstream sea area; Transplanting seaweed with strong wave resistance into the bay in the back wave zone will limit the absorption of nutrients by seaweed and affect its growth.

### 2.4 Tide

Tide is a phenomenon of periodic vertical movement of seawater, caused by the gravitational pull of the sun and moon. In recent years, seaweed researchers have increasingly attached importance to seawater movement, including tides because seawater movement has a significant impact on the attachment, growth, development, and reproduction of seaweed. Tide is also one of the main factors affecting the vertical distribution of seaweeds in the tidal zone (supratidal zone, intertidal zone, subtidal zone). Among them, the environmental impact factors in the high tide zone in the intertidal zone change the most, and the temperature, salinity, nutrients, acidity and alkalinity change greatly in the environment where the sea water recedes into the open air. Only the seaweeds with strong vitality, good adaptability and strong ability to dry out are suitable for living here.

## 3. Large scale seaweed transplantation technology

### 3.1 Reproductive mode of large seaweed

#### 3.1.1 Nutritional reproduction

The vegetative reproduction of large seaweed can be divided into two types: algal rupture and reproduction of small branches. The reproductive mode of algal rupture is through the decay and rupture of the branch and leaf bodies to produce small branches or segments of the algal body. In an environment with suitable growth conditions, the broken branches or segments of the algal body continue to grow into new algal bodies, such as copper algae, Sargassum wallichii, and Sargassum. The reproductive form of reproductive branchlets is the growth of many small branches on certain parent algae, which have various shapes. When the small branches detach from the parent algae, they can attach to the reef substrate and grow into new algae. Such small branches are called reproductive branchlets, such as those in the Blacktop algae family.

#### 3.1.2 Sexual reproduction

The sexual reproduction of macroalgae is a kind of reproduction mode in which germ cell is produced by algae body, and germ cell fuse and mate to reproduce offspring. Sexual reproduction can be basically divided into two types: gamete reproduction and egg reproduction. Gamete reproduction, gametes are transformed from algal (diploid) somatic cell into gametangium mother cells, and gametangium mother cells produce gametes after meiosis; Or the algal (haploid) somatic cell directly converts into the gametangium mother cell to produce gametes [11]. Egg like reproduction in seaweed is actually heterogamy.

### 3.2 Large scale seaweed transplantation technology

#### 3.2.1 Stone throwing transplantation method

It is used in sea areas that are suitable for seaweed growth but lack a growth substrate, to increase the attachment of seaweed to the growth substrate. There are two specific methods of stone throwing and proliferation. One is the direct stone throwing method, which involves directly throwing stones of appropriate size and shape into seawater to allow seaweed to naturally adhere, grow, and develop, or manually throwing a portion of the spores, allowing them to disperse and adhere to the stones. The second step is to apply spores to the rocks before they are thrown into the seabed, ensuring that they adhere firmly. Then, the rocks are thrown into the designated sea area. The marine environment chosen by the stone throwing method should first be an environment suitable for the growth of seaweed. For example, choose a sea area with low wind and waves, good seawater transparency, and a mixed sediment substrate. The size and quantity of stones to be placed should also be suitable for the marine environment. Generally, the weight of stones should be maintained at around 20kg, and the amount of stones to be placed in a 1-acre marine area should be maintained at around 2000.

#### 3.2.2 Reef cleaning and transplantation method

Manually remove miscellaneous algae, sediment, and other debris from natural reefs in the seaweed field, and add new spores to achieve proliferation. Most seaweeds grow in intertidal zone and subtidal zones, so reef cleaning should be carried out in combination with the tide. In the low tide period of the intertidal zone, various cleaning tools such as brooms can be used to manually clean debris on the rocks; Underwater cleaning can be carried out by divers or professional underwater cleaning machines in the tidal zone. The selection of the cleaning time period is also important. The cleaning should be carried out before a large number of seaweed spores are released, so that the spores can be directly attached to the reef after the cleaning is completed.

## 4. Outlook

The deterioration of the marine ecological environment is the main obstacle to the efficient proliferation and transplantation of large algae. In situations where the marine ecological environment cannot be restored to its natural level, we should seek large seaweed with strong adhesion and vitality as the main species for marine transplantation and proliferation. Alternatively, new transplantation techniques can be used to prepare artificial spore adhesives, seeking artificial materials with high viscosity, fast adhesion, anti dilution, anti erosion, and pollution-free functions. When transplanting and proliferating large seaweed, it is necessary to match the species of seaweed with the growing sea area, and to choose the dominant species that are suitable for the growth and development of the local sea area. For example, when transplanting and proliferating large seaweed along the coast of Zhejiang, it is necessary to choose the local dominant species - Sargassum watsonii. At present, the restoration of seaweed farms is very difficult, mainly reflected in the weak and insignificant sustainability of ecological restoration. The transplanted seaweed will die and have difficulty reproducing in the coming year. If artificial transplantation is not continued in the coming year, the transplantation effect will not be significant or the area of the seaweed farm will be further reduced. In

the future, we will continue to study the issue of seaweed firmly adhering and improving reproductive stability.

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