基于高分辨率影像的黄海大型漂浮海藻覆盖面积精确提取

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在过去 10 余年间，黄海连年爆发大规模的大型漂浮海藻藻华灾害。卫星遥感技术以其大范围、实时、长时序的优势，成为大型漂浮海藻监测的主要手段，其中，中/低空间分辨率（30m~1000m）的卫星图像是主要数据源。

本文基于高分辨率（3m）遥感影像的漂浮海藻覆盖面积提取结果，评价了准同步的中低分辨率卫星影像漂浮海藻覆盖面积提取的准确性，结果表明：在忽略混合像元效应情况下，中低分辨率（30m-1000m）影像提取的漂浮海藻面积将显著高估 1.2-6.1 倍。基于统计回归方法，建立了适用于中低分辨率影像的漂浮海藻覆盖面积精细化提取模型，经独立数据检验，模型误差约为 30%。利用该模型提取了 2007-2018 年黄海大型漂浮海藻覆盖面积的年极大值（47.5~732.9km²）。
Automatic Remote Sensing Detection and Accurate Coverage Extraction of Floating Macroalgae

Abstract

In the past 10 years, floating macroalgae blooms have occurred repeatedly in the Yellow Sea and the East China Sea, which adversely affect mariculture, coastal tourism and marine ecological environment. In 2017, the outbreak of *Sargassum* caused a direct loss of millions to the *Porphyra* aquaculture industry in Jiangsu Province. The main technical means of monitoring floating macroalgae is satellite remote sensing, which has the advantages of offering large-scale, real-time, and long-time-series monitoring. Thus, satellite remote sensing plays an important role in monitoring the occurrence and evolution of blooms, with the purposes of disaster prevention and mitigation. The operational monitoring index of floating macroalgae is the spatial coverage of the blooms, which is mainly derived from satellite images with moderate/low resolution (30m~1000m), such as the 250-m-resolution MODIS (Moderate Resolution Imaging Spectroradiometer).

There are two problems in floating algae monitoring: (1) The traditional floating macroalgae remote sensing detection method, which is based on the vegetation index, is very sensitive to the threshold value applied, and is affected by many factors such as complex atmospheric–oceanic environment, observation geometry, etc. The threshold has obvious temporal and spatial variations, and is difficult to determine accurately—expert experience is required to assist identification, and the degree of automation is low. (2) Floating macroalgae mostly distribute in thin strips or scattered patches on the sea surface with the significant difference between the spectrum of floating macroalgae and seawater. Most of the algae pixels in the satellite images are macroalgae-seawater mixed pixels. Therefore, the coverage of seawater may be much larger than floating macroalgae in every pixel identified as algae, the results of floating algae spatial coverage based on medium and low resolution satellite data are obviously overestimated.

Aiming to solve the problems above, this paper has carried out three tasks: (1)
Develop an automatic remote sensing detection method for floating macroalgae based on machine learning; (2) Establish a refined extraction model of floating macroalgae coverage; (3) Estimate the annual maximum of floating macroalgae coverage in the Yellow Sea over the years 2006-2018. based on the above model algorithm. The main conclusions are as follows:

1. An automatic remote sensing detection model of macroalgae based on extreme learning machine (ELM) in the Yellow Sea and East China Sea is constructed. The evaluation based on independent data shows that this method achieves a detection accuracy of up to 86% under clouds, sun glint, high-turbidity water, and other factors. In addition, it achieve fast detection without manual intervention (including thresholds, model parameters, manual mask, etc.), which suggests strong business application potential on the proposed method.

2. The result of 3-m-resolution airborne Synthetic Aperture Radar (SAR) image compared with concurrent low/medium-resolution satellite images shows that: (1) The coverage of floating macroalgae extracted from low/medium-resolution (30m-1000m) images is significantly overestimated 1.2 to 6.1 times When the mixed pixel effect is ignored. (2) A refined extraction model of floating macroalgae coverage for medium/low-resolution images was established based on the assumption of pure pixels (i.e. 100% algae cover), and statistical regression method, with an error of about 30%.

3. Derived the annual maximum coverage of the floating macroalgae blooms in the Yellow Sea from 2007 to 2018 with the statistical regression-based method, which ranges from 46~733km² with an average of 244±182km². The minimum appeared in 2012 and the maximum appeared in 2016.

Key word: floating macroalgae blooms, coverage, automatic detection, extreme learning machine, mixed pixel effect;