
ISLANDS IN SOUTHERN JAPAN

Edited by Shinichi NODA
はじめに

鹿児島大学多島園研究センターでは、平成12年と13年度に学長裁量経費の補助を受け「多島域における小島嶼の自立性」に関する総合研究プロジェクトを行った。

これは、小島嶼の自然環境や社会生活を学際的に研究することによって、過疎に悩む小島嶼が抱える問題点を浮き彫りにするとともに、その自立発展の方策を模索しようとするものである。換言するならば、経済的にもまた産業的にも厳しい環境下にかかっている小島嶼における島民の暮らしや自然の研究から、混迷を極める現代社会のあり方を再考しようとするのが、本研究プロジェクトの上位目標である。

本研究では日本の離島特に南西諸島を対象としたものと、ミクロネシア共和国ヤップ州の研究に分かれる。一見すると関連性のない対象域ではあるが両者は過疎や遠隔性に起因する共通の問題を抱える点で共通している。

今後、当センターにおいて発展的継続が期待される鹿児島県以南の南西諸島の学術総合研究の端緒となることが本報告書に期待されるものであろう。

本研究を行うにあたっては、数々のご支援を賜った鹿児島大学長、田中弘允教授や研究協力課をはじめ関係の皆様に深く御礼申し上げたい。

鹿児島大学多島園研究センター
プロジェクト委員会委員長
野呂 忠秀
Preface

We are pleased to announce the publication of the official report of the research project "Social Homeostasis of Small Islands in an Island-Zone" conducted by the Kagoshima University Research Center for the Pacific Islands (KURCPI) in the years 2000 and 2001.

This multi-disciplinary research project was started in 1999 as a three-year project by the four members of the KURCPI with the collaboration of more than forty researchers from other faculties of Kagoshima University. The term "homeostasis" describes, as its biological origin suggests, the actual and potential ways in which the stability, not necessarily static but also dynamic, and the sustainability of a society are achieved, without forfeiting its interaction and inter-dependency with the outside world. The goal of the project is to obtain an understanding of how social homeostasis may be achieved in a society on a small island. The term "island-zone" indicates that an island, though insulated by the sea, needs to be understood in the context of a group of islands, where networks of people, things, and information are formed and interaction between islands take place.

As the main research fields for the project, we chose the Satsunan Islands in Southern Japan and the island-zone of Yap in Micronesia. Both are island-zones consisting of a group of small islands with biological, social, and cultural relationships among themselves, and they share common difficulties, typical of small islands. The main difference between them is that the Satsunan Islands are a peripheral part of one of the most developed economies in the world, whereas the island-zone of Yap belongs to a modest island nation. This contrast enabled us to make a comparative approach to the studies on small islands.

The present report represents results of the research project in its second and third years. It consists of two parts, each forming an individual volume in the KURCPI Occasional Paper Series. Part One, in volume 38, is a collection of papers which involve the researches carried out in Japan in 2000 and 2001. These researches concern a variety of topics relating to island-zones and small islands in Southern Japan. Part Two, in volume 39, contains papers based on the researches carried out in 2000 and 2001 in Yap, Micronesia, including the research conducted by the Survey Party in Ulithi Atoll in 2001. The drafts of the papers in Part Two were reviewed by the Council of Tamol (traditional chiefs in the Outer Islands of Yap) to ensure accuracy before publication. Reflecting our multi-disciplinary approach, both Part One and Two are subdivided into sections on human activities, physical geography, and people-nature interactions. Each section involves, (1) history, society, culture, education, tourism, and human movement, (2) geology, geography, and ecology, and (3) agriculture, fisheries, public health, and the impact of natural disasters.

We hope this two-volume report will bring benefits to the people of the local communities with which the research was concerned. We also hope this provides us with an insight into the present conditions of the two island zones in the Northwestern Pacific and that it will further encourage studies on the small islands in this part of the world, so that researchers can exchange ideas and information and develop general theories on small islands in the future.

Toru Aoyama
Shinichi Noda
Editor
KURCPI
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Cases of suicide in the islands of Kagoshima Prefecture for the last three years (1999-2001) were investigated. The total number was 165. Average annual suicide rate (per 100,000 population) was estimated to be 29.0. Suicide rate in the male (46.5) was larger than that in the female (13.0; \( p<0.0001 \)). Suicide rate in the male in sixties was larger than that in 1989-1991 (\( p=0.0002 \)). As a background of suicide, pessimistic and economical reasons of male suicides were increased (\( p<0.0001 \)). Recent business depression might have lead to increase male suicidal number. Single or two-person households and past suicide attempt were considered to be risk factors for suicide. Protective activities by government, society and family should be developed for reducing suicidal number.

Key words: Islands of Kagoshima Prefecture, Protective activities by society, Suicide

緒言

近年，全国的に自殺者数の増加が指摘されている。交通事故による死亡者数と比較する
と、以前から自殺者数の方が多いのに加え、ここ数年は交通事故死者数が横ばいであるため、その差は開く一方で、現在では交通事故死者の 3 ～ 4 倍の人数が自殺によって死亡しているといわれている。交通事故に対しては県警や行政による防止対策が奏功していると思われるが、自殺に対して社会的防止策は殆ど行われていない。

ところで、鹿児島県は自殺率が比較的高く、都道府県別の集計（2000年）では男性7位、女性18位に位置している。

今回われわれは、総合研究「多島域における小島嶼の自律性」に参加させていただいたのを機に、自殺を予防する方策を探るための第一歩として、鹿児島県の島嶼地区における自殺の現状について10年前の状況と比較しつつ検討したので報告する。

方 法

1999～2001年の自殺例を対象として、吉岡（1997）の調査項目に準じて、年齢、性別、島嶼地区か否か、自殺企図推定日時、手段、背景、過去の企図歴、既往歴、家族構成について、匿名化に充分留意して調査を行い、各々の結果を10年前（1989～1991年）と比較した。自殺率、地区全体の世帯人数の比率は国勢調査（1990, 2000年）の値に基づいて算出した。統計学的解析はカイ二乗分布検定によった。

結 果

1. 自殺者数、自殺率

最近3年間の島嶼地区における自殺者数は165人であった。年間平均自殺率（人口10万対）は29.0で、10年前の値（24.3）に比して統計学的に有意な差を認めなかった。なお、この自殺率は県全体の率（26.5）とも有意な差を認めなかった。

2. 性別、年齢別の検討

男性自殺率は46.5で、女性の値13.0に比して有意に高値を示した（p < 0.0001）。男女とも10年前の自殺率と有意差を認めなかった。年齢層別に検討すると、男性では50歳代、女性では60歳代が最多であった（Fig.1）。10年前と比較すると、男性60歳代に有意の増加を認めた（p = 0.0002）。

Fig.1. Suicide rate in the islands of Kagoshima Prefecture.
3. 月別、曜日別、時間帯別の検討
月別では12〜2月と7〜9月、曜日別では水〜金曜、時間帯別では午前8時〜午後2時の時間帯に多いという結果を得た。

4. 自殺手段
男女とも縊死（首吊り）が最多であった（男性63％、女性48％）。男性では縊死の割合が女性よりも高率である一方、入水、服毒の割合は低率であった（Table 1）。10年前の割合と比較すると、男女とも縊死の割合が減り、服毒の比率が増えている。

Table 1. Methods of committing suicide in the islands

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>縊死 Hanging</td>
<td>69%</td>
<td>63%</td>
<td>56%</td>
<td>48%</td>
</tr>
<tr>
<td>入水 Submersion</td>
<td>2</td>
<td>6</td>
<td>24</td>
<td>18</td>
</tr>
<tr>
<td>服毒 Poisoning</td>
<td>11</td>
<td>13</td>
<td>6</td>
<td>21</td>
</tr>
<tr>
<td>排ガス Vehicle exhaust gas</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>飛び降り Jumping from height</td>
<td>7</td>
<td>6</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>焼身 Burning</td>
<td>4</td>
<td>6</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>その他 Others</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>3</td>
</tr>
</tbody>
</table>

5. 自殺の背景
男性では、病苦（精神科的疾患を含む）50％、労世21％、借金苦などの経済的責任20％、家庭や職場等での対人関係8％の順で、女性では、病苦58％、労世22％、対人関係18％、経済的責任2％の順であった（Table 2）。10年前と比較すると、男性では労世、経済的責任の割合が有意に増加していた（p < 0.0001）一方、女性では差を認めなかった。なお、年齢層別検討において10年前より増加していた60歳代男性の背景をみると、病苦、労世、経済的責任のいずれもが10年前に比べ有意に増加していた。

Table 2. Background or motive of suicide in the islands

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>病苦 Pain of sickness</td>
<td>63%</td>
<td>50%</td>
<td>70%</td>
<td>58%</td>
</tr>
<tr>
<td>労世 Pessimistic</td>
<td>5</td>
<td>21*</td>
<td>6</td>
<td>22</td>
</tr>
<tr>
<td>経済的責任 Economical</td>
<td>5</td>
<td>20*</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>対人関係 Personal relationship</td>
<td>14</td>
<td>8</td>
<td>15</td>
<td>18</td>
</tr>
<tr>
<td>その他 Others</td>
<td>13</td>
<td>1</td>
<td>6</td>
<td>0</td>
</tr>
</tbody>
</table>

*: p<0.0001

6. 自殺企図経験者の割合
過去における自殺未遂の有無が判明している例について企図経験者の割合をみると、男性は12％、女性は21％を占めていた。なお、10年前は男性9％、女性4％であった。

7. 家族構成の検討
家族構成がわかるている例の世帯人数は独居29％、2人38％、3人以上33％であり、国勢調査から算出した島嶼地区全体の割合（独居13％、2人14％、3人以上73％）と比較すると、自殺者では独居、2人暮らしの比率がともに有意に高値を示し、逆に3人以上同居の比率が有意に低値を示していた。
考 察

近年、全国的に自殺者数が増加しているといわれているものの、島嶼地区の自殺率は全体的には10年前と変わらなかった。しかしながら、60歳代男性の自殺率は有意に増加していた。また、自殺の背景をみると、男性の増加、経済的理由による自殺の比率が有意に増加していた。増加にはいろいろな複合要因が絡み合っているものと思われるが、経済的理由の増加については、昨今の景気低迷が島嶼地区にも大きく影響していることがうかがえる。

一方、家族構成をみると、独居のみならず2人暮らしの自殺者が有意に多いという結果を得た。したがって、配偶者の存在のみでは自殺を防止するのは困難で、夫婦や家族相互の心の交流が自殺者減少のための重要な要素と思われる。

また、企団経験者が男女とも10％以上を占めることからすると、特に自殺未遂経験者を対象とした心理学的ケアなどの社会的対策によって自殺者数を減少できるのではないかと考える。

吉岡（1998）が指摘しているように、自殺者の減少をはかるためには、行政と民間が一致協力した防止対策活動を推し進める必要があるということを強調したい。

稿を終わるためにあたり、本調査に協力いただいた鹿児島県警察本部捜査第一課の皆様に対し深謝いたします。

文 献

吉岡尚文 1997. 日本人の自殺の実態把握と予防医学へのアプローチ，平成7年度→8年度科学研究費補助金（基盤研究(A) - (2)）研究成果報告書
吉岡尚文 1998. 日本人の自殺 - 我々にその減少をはかれるか？ -，日法医誌，52(5) : 286 - 293
Generally island has some suffocating factors for tourism. However Amami Oshima has many cultural heritages besides natural ones that have attracted tourists. Based on the cultural heritage resource management studies, Amami Oshima has a big potential of island tourism development by making efficient use of its archaeological and historical heritages. For example, two of the cultural resources in Amami should be focused. One is the ancient maritime trade route for commodities such as the trade ceramics and the south sea shells that connected Amami and other islands. Another is the museum network in Amami Oshima. Amami Oshima should aim for the multiple tourism composed of nature, history, culture and experience.

Key words: Amami Oshima, Island tourism, Tourism development, Historical heritage, Cultural heritage
新田栄治

など需要を創出しない。鹿児島県商工労働局観光課編『奄美観光イメージアップ調査報告書』の奄美に対するイメージ調査においても基本的に同じである。この調査書で列挙された奄美に対するイメージは「青い海」「温暖な気候」「豊かな自然」であり、上記の３Ｓと共通するといえる。

（2）特定の場所に集中する宿泊施設

（1）で述べたように、観光資源が海と砂浜に集約されるため、宿泊施設は海岸に集中する。そのため観光客は海岸部にある宿泊施設に宿泊せざるを得なくなるため、新たな観光客対象の宿泊施設はさらに海岸部に建設されることになる。その結果、宿泊施設の中心地の集中傾向はますます増幅する。2000年現在の奄美大島の宿泊施設は、笠利町東海岸に15、名瀬市海岸部に31、瀬戸内町海岸部に39などとなっており、海岸部での観光資源に乏しい自治体の間に宿泊施設数において極端な差が存在する。例えば、龍郷町には7、住用村では4。大和村では2、宇検村では2である。

（3）島内居住者による島内観光の少なさ

本土では、本土居住者による本土内観光が相当な需要をもつ。鹿児島県本土内観光が鹿児島県観光での大きな位置を占める。ところが、奄美大島では面積の狭さと人口の少なさのために、島内居住者による島内観光は少ない。圧倒的に島外からの観光客の重要性が大である。そのために、島外からの観光客を対象とする対策が最も要であるが、同じく島内居住者による島内観光の掘り起こしも視野に入れる必要がある。

（4）航空路網への極端な依存

奄美群島観光連盟と鹿児島県大島支庁による奄美観光の統計（奄美群島観光連盟・鹿児島県大島支庁2000）に見るとおり、島外からやってくる人々の交通手段は電気鉄道94.2%、飛行機で87.9%、航空機で78.9%が航空機であり、全体でも76.6%が航空機による（表1）。そのため、空港がある地域が交通機は唯一の出入口となる。その結果、島への出入口が単一になり、島内フローが限定的になる。奄美大島の場合にはジェット機の離着が可能な奄美空港のある笠利町が交通路の出入口としては圧倒的な位置を占めることになる。本土との航路の出入口である名瀬市は、人の交通路の出入口としてよりも物流の出入口としての役割が重要である。

（5）島内観光の単調化

島に発達する観光タイプが制度化され、ヴァラエティに欠ける。航空機や船のチケット、宿泊先の予約には制度化された旅行システムの世話をしなければならない。スケジュールを満たす宿泊施設の場合、現地宿泊施設は航空会社や旅行会社との提携となる。旅行スタイルが一様化しやすい。たとえば、海水浴、ダイビング、釣り。結果的に、これらの趣味の人しか来ないことになる。このような単調化した観光スタイルは一面では効率的である。

（6）マーケットの限定

島である以上、自家用車を利用して、ちょっと出かけるというわけには行かない。そのため安い旅行費用では行けないため、マーケットは限定される。本土居住者にとっては、奄美は遠く、航空路が高く、10万円程度で行ける南アジア地域や、5万円程度で行けるミクロネシアの外国旅行と費用がそれほど違わない。あるすればそれよりも高くつく。また、奄美的イメージである「青い海」「温暖な気候」「豊かな自然」は、沖縄、グアム、サイパン、プーケット、バンガロ等にはかない。同程度の金額で可能な海外の海洋リゾート地との競争は奄美にとって厳しいものがある。

２．従来の観光開発計画

鹿児島県によって平成6年度から3年間、奄美群島の観光振興に関する調査事業が実施された（鹿児島県商工労働局観光課1995—97）。その結果は以下のとおりであるが、問題点も指摘しておく。
表1. 奄美大島入域客・入域観光客数および発地別入域客数・輸送手段
（奄美大島観光連盟・鹿児島県大島支庁2000による）

<table>
<thead>
<tr>
<th>入域客および入域観光客数（推計）</th>
<th>海路</th>
<th>空路</th>
<th>入域観光客数</th>
</tr>
</thead>
<tbody>
<tr>
<td>136,723</td>
<td>135,507</td>
<td>132,002</td>
<td>131,995</td>
</tr>
<tr>
<td>415,067</td>
<td>440,714</td>
<td>443,866</td>
<td>435,149</td>
</tr>
<tr>
<td>386,790</td>
<td>397,340</td>
<td>404,205</td>
<td>391,929</td>
</tr>
</tbody>
</table>

発地別

<table>
<thead>
<tr>
<th>東京</th>
<th>海路</th>
<th>空路</th>
<th>合計</th>
</tr>
</thead>
<tbody>
<tr>
<td>年</td>
<td>1993年</td>
<td>1994年</td>
<td>1995年</td>
</tr>
<tr>
<td>1993年</td>
<td>2,940</td>
<td>1,202</td>
<td>4,142</td>
</tr>
<tr>
<td>1994年</td>
<td>2,882</td>
<td>35,934</td>
<td>38,816</td>
</tr>
<tr>
<td>1995年</td>
<td>1,294</td>
<td>38,767</td>
<td>39,140</td>
</tr>
<tr>
<td>1996年</td>
<td>1,395</td>
<td>31,175</td>
<td>34,570</td>
</tr>
<tr>
<td>1997年</td>
<td>1,958</td>
<td>36,446</td>
<td>38,404</td>
</tr>
<tr>
<td>1998年</td>
<td>1,621</td>
<td>35,500</td>
<td>37,121</td>
</tr>
<tr>
<td>1999年</td>
<td>2,148</td>
<td>32,854</td>
<td>35,002</td>
</tr>
<tr>
<td>2000年</td>
<td>1,967</td>
<td>31,898</td>
<td>33,865</td>
</tr>
<tr>
<td>合計</td>
<td>5.8%</td>
<td>94.2%</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>関西</th>
<th>海路</th>
<th>空路</th>
<th>入域観光客数</th>
</tr>
</thead>
<tbody>
<tr>
<td>年</td>
<td>1996年</td>
<td>1997年</td>
<td>1998年</td>
</tr>
<tr>
<td>1996年</td>
<td>8,808</td>
<td>61,846</td>
<td>69,812</td>
</tr>
<tr>
<td>1997年</td>
<td>9,193</td>
<td>61,846</td>
<td>71,039</td>
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<td>1998年</td>
<td>8,386</td>
<td>57,776</td>
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</tr>
<tr>
<td>1999年</td>
<td>8,514</td>
<td>53,565</td>
<td>62,019</td>
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<tr>
<td>2000年</td>
<td>6,827</td>
<td>49,715</td>
<td>56,542</td>
</tr>
<tr>
<td>合計</td>
<td>12.1%</td>
<td>87.9%</td>
<td></td>
</tr>
</tbody>
</table>

"イメージ形成上の課題：「海」のイメージ作りと人文資源の活用（芸能文化と郷土料理）" 「海」+「海」、周辺の離島観光地のないイメージ作りの提唱を行った。第1章(1)で記したように、3つの付加された他アトラクションの提唱である。芸能文化と郷土料理で新しいイメージが作れるか、すでに幾度も言われてきたが、うまくいかない。

"観光地の基本方向：個人・体験型、自然・文化型、環境調和型の観光地作り。

ハワイ・沖縄に対するバリ・奄美という二極対比モデルを提示した。理想モデルとしてバリ島を目指している。あわせてグリーンツーリズム、エコツーリズムを提唱する。経済効果はあるか。インドネシア政府による組織的、意図的な新たな伝統作り（例えば、ケババを初めとする舞踊など）と、バリ島を含む地域を含めて高級ホテル地帯に生まれたヌサドゥア地区に見られるような大規模観光開発が行われたバリとは単純な比較である。

バリアを目指すには、自治体による長期的観光戦略の構築と公共投資が必要である。

"イメージ・コンセプト：神秘、原色、躍動の島々』、田中一村と鳥取による情報発信を提唱する。意味不明の語彙の羅列といえる。

この調査に際して行われた消費者アンケートの結果では、奄美で楽しみそのものとして「温暖な気候」、「伝統工芸品」、「熱帯植物」、「美しい海」があがっている。また、旅行したい観光地のタイプとしては、「温泉地型」、「自然型」、「歴史・文化型」が60％以上を占める。

アンケート調査の結果が示することは、消費者の需要は自然と歴史・文化にある。奄美的自
然と歴史・文化をどのように観光資源化し、消費者にアピールするかにかかっているといえる。

3. 歴史的・文化遺産を活用した観光開発の可能性：文化財資源学の視点から

第2章で述べたように、消費者の観光に求める需要は、観光の自然と歴史・文化である。自然については今さら述べるまでもない。歴史・文化についてはその存在価値が認識されてこなかったきらいがある。歴史的・文化財を観光資源として活用し、あわせて歴史的・文化財の保護と地域住民の自らの歴史と文化に対する意識高揚をはかることは、将来の観光にとって重要なことである。

- 海の道：島と島を結びつける歴史的・文化財の存在とその観光資源化

自然の間に隠れて観光の歴史的・文化財はあまり知られていないが、近年重要な遺跡が発見され、観光の歴史的・文化遺産は注目を浴びている（鹿児島県教育委員会1995）。なかでも浅い海底から貿易陶磁器が大量に発見された倉木崎遺跡の中国陶磁器（12～13世紀）・浙江省龙泉窯系青磁、福建省同安窯系青磁、福建省系白磁、福建省泉州磁窯系陶器、江西省景德鎮系青白磁、福建省建窯天目など2300点を宇検村教育委員会1999から発されるイメージは、東シナ海を巡る中世中大航海時代、セラミック・ロードの中継点の一つとしての観光の姿を物語る。また、沖縄、奄美、種子島を結ぶ、絵画が彫刻された貝殻製装身具がある。笠利町サウサウ遺跡の貝殻製装身具（笠利町教育委員会1978）を持つイメージは南島と本土を結ぶ弥生時代の備の道、シェル・ロードの道の中ににある観光の姿である。これら考古学および歴史的・文化財の発掘とその観光資源化を計る。

- ミュージアム・ネットワークの設立と活用

2001年に完成した県立アマミパークをコアとし、笠利町立歴史民俗資料館（考古学）、名瀬市立奄美博物館（考古学）、原野農芸博物館（民俗学）、瀬戸内町立郷土館（民俗学）を結ぶ博物館ネットワークを作る。上記の博物館は奄美大島の南北ルートに位置しており、島内観光の拡散ルートとも一致させる可能性がある。島内には他にも小規模の博物館や博物館類似の観光施設がすでにある（大島総合、浜千鳥館、アイランズ・ステーション、シェルロード、野菜坊焼窯元など）。これらの小規模施設も含めてミュージアム・ネットワークを作ることにより、観光全体に博物館網が張り巡らされる。あわせてエコミュージアム構想（大原1999、小松1999）の成立の可能性を探る。

- 自然・歴史・体験の複合型観光の開発をもとめて

従来、奄美ではエコツーリズムが観光の主役であった。そこに、もうひとつ考古ツーリズムを付加することにより、これまで訪問しなかった歴史ファン、考古ファンを呼び込む可能性がある。奄美大島では考古遺跡と博物館との有機的に、しかも地理的バランスよく組み合わせることができる。遺跡があるところはいずれも美しい海浜やマンゴープープ原生林、サンゴ礁のあるところであり、考古ツーリズムと自然を楽しむ観光がうまく組み合わせることができる。倉木崎海底遺跡を約束として、ダイビングと海底の陶磁器を探し、沈没船探しを取り入れることにより、もっとも優しい地中海歴史ロマンを味わうことができる。与那国島地域遺跡のようなウノではなく、奄美の中世史の開拓につながる面白さである。

さらに、奄美特産の黒糖焼酎は醸造場がある龍郷町、名瀬市、瀬戸内町に全国で57銘柄もある。北部、中部、南部を歩くことにより、全57銘柄を味わい尽くすことも可能になる。歴史ファンを中心とした新たな観光対象者を開拓できるし、あわせて自然と酒を愛する人々を加えることができる。鹿児島県離島振興課の統計では奄美を訪れる人々の60％以上は航空路による。したがって空港のある笠利町が観光の起点、終点になる。笠利町、名瀬市、瀬戸内町は宿泊施設が多く、また民宿からリゾートホテルまで種類に富み、選択の幅が広いので、これ3地域が宿泊地になる。この3地域に博物館があるのももう一つが
油い。現実には2泊、あるいは3泊の日程が必要となる。解決すべき問題は島内の交通である。
考古遺跡を初めとする歴史的遺産を観光資源化する観光開発は佐賀県吉野ケ里遺跡や鹿児島県の戸遺跡の例を出すまでもなく、世界中で文化遺産の保存と経済開発に関係の困難な問題を解決するひとつの方法として行われている。奄美においてもその可能性を考慮すべきであるし、可能であると考える。

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Since Kurino on Yaku Island has been an important port from Edo period, Tsuguchi Guard Station of Satuma-Han has been established, and the landscape of the original fishing village has been preserved. In this paper, two rural houses of Edo period were selected from the existing large-scale fisherman’s houses as the research subjects. The features of these two buildings were described, and the significant value of the two houses as part of the scene was stated. In the end, a community development with emphasis on the history was proposed.

Key words: Landscape of Kurino, Fishing settlement, Fisherman’s house, Tsuguchi Guard Station, Producing district of dried bonito flakes
栄した当時の遺構が現存し、当時の景観を今尚温存させている。
集落の形態は栗生川に沿って、平行に主要道が通っている。その主要道と直角に5筋程の道が栗生川と結んでいる。その道は川に面して漁業が並び、集落を形成している。幸い、明治20年、大正末、昭和20年頃、昭和40年、平成2年・平成4年の屋敷割図が記されている。それらの図をもとに街路から集落の構造を調べると、以外に時代による変化が少ないことが分かる。簡単な図ではあるが各家の主人の名が記されている。その名からも人々の変動があまりなかったことが分かる。比較的変化の少ない集落で、河口から、少し上流に向い、栗生川に近く、中ノ川と門前川との間が最も古い集落を形成している。その古い集落の道路は先に述べたように、栗生川に平行な道とその道に直角に交わる5筋程の道が、川と陸地を結び、これが栗生の骨格を成している。敷地の大きさは栗生川に平行な道に面した敷地が大きく、川と陸を結ぶ道に面した敷地は比較的小さく、陸に向うにしたがって、更に小さくなることが分かる。5筋程の道は直線とならず、曲がったり、丁字路になったり、計画的に造られているというより、敷地を割り付けながら道を作っているといった方がよい。つまり、道路を先に計画して、後に敷地を割り付けたとはいえないということである。これは町屋が並ぶ都市とは基本的に異なる。

２．栗生の民家
1）岡留重一氏住宅
岡留重一氏住宅は栗生川から少し、陸に入った位置に、玄関を南々西に向けて（写真1）、文久3年（1863年）12月に建てられた。それは壁側の床（トコ）柱に札（写真3）が釘打ちされ、それに年号と屋久島栗生の住民であることを記し、大工が長左衛門であることが分かれる。昭和40年の屋敷割図に名前が記され、明治20年には「山崎清兵衛」とあり、山崎氏が建てたのかもしれない。

石垣で屋敷を囲み（写真2）、庭を道路に作る。この方法は麓の武家屋敷と類似する。住宅の最大の特徴は正方形の平面（図1）である。中央に棟を置き、その棟で前方と後方に分け、前方を接客空間、後方を居住空間とし、棟の前方に玄関があり、後方に裏口がある。次に梁間は3間梁を掛けその前後に1間ずつ下屋を出し、合計5間に切妻造の屋根を

図1 岡留重一氏住宅現状平面図

写真1 正面外観

写真2 石垣

写真3 年号を記す札
掛け桟瓦葺きである。後の改築や増築があるもののより当初の姿をとどめて価値が高い。

２）岡留純矩氏住宅
　岡留純矩氏住宅は重一氏住宅よりも更に陸側に位置し、弘化2年（1845年）12月に建った。その年号を記す札（写真7）が壁側の床（トコ）柱に釘で止められている。それには「弘化二年十二月吉日柱天二高々建立　屋久島栗生御民家主覚市　大工安佐太郎」と記す。
　住居の特徴は正面5間、側面5間の正方形をした平面である。それに広い12畳半の居間が棟を軸にしてその後方にある（図2）。その居間の奥に納戸、下手に台所、この3室が棟より後方で、前方に入り、次の間、玄関の間の3室が並び、土間が狭い。玄関は南々東に開け（写真4）、おもては中央に1間幅の広いトコがあり（写真5）、床は小竹の蓆子（写真6）である。押入れや便所を新しく設けたり、改造・増築の箇所も見受けられるが、よく当初の形態をとどめ、江戸期の住宅として価値を有す。

図2 岡留純矩氏住宅現状平面図

写真4 正面外観
写真5 床の間
写真6 小竹の蓆子の床
写真7 年号を記す札

3．町づくりへの提言
　栗生には江戸期からの港として、歴史的価値があり、その遺構から見て建築的価値もあ
る．周辺の人々からは親しまれ，文化的価値も有す．価値があることが何よりも大切であるし，地域の人々がその価値を認め，将来へつなげていく方がもっと大切かもしれない．

1）遺構を調査する

集落の住居・倉・石垣を含む調査をする．年代の古い民家2棟だけの調査をしたが，2棟だけではなく，現存する全住居の間取りを記し，各家の配置図に附属屋と石垣を記載する．この現状調査をまず行い，その後に，津口番所跡や蔵跡を推定し，藩の施設と漁業に携わる人々の住居がどんな分布をし，栗生川と港を含めた集落全体の景観をイメージできる配置図を作成する．

2）歴史を尊重し，町づくりに生かす

農村集落や漁村集落は各地域で似た様子を示している．それは新しく建った住居が似類しているからであろう．各地域にはそれぞれの独自性がある．その独自性を明らかにするためには歴史的建造物群が重要になる．津口番所，蔵，住居，石垣等が復元されて，江戸期の町を呈することができれば，栗生独自の町の景観を示すことになる．また，地域の人々の生活を尊重し，それが伝統的町並とどう調和させるかに努力することは当然であろう．新しい試みを企画するよりは，ありのままの現実から，現実を作りあげてきた原点に目を注ぐことで，つまり，歴史を目を向けたことで町づくりをする．そこには，栗生独自の町となるし，訪れる人々は他の地域では見られない感激を受けるであろう．

3）他の地域とのネットワーク

鹿児島県内には藩の津口藩所が24ヶ所あったが，その一つが屋久島栗生である．離島の口之永良部島，七島の口之島・中之島・宝島にもあった．出水市米ノ津，阿久根市駅元，それに志布志・甑島の里・中甑，手打にもあった．それぞれの地域は良港を有し，蔵を設け共通している部分もあるだろう．お互いにネットワークを作り，協力しあえば広がりができる．それぞれの地域の相違も見えてくる．時にはシンポジウムやフォーラムを開催できれば，これは町づくりに参考となるであろう．

4）伝統的建造物群保存地区にする

福岡県久留米市では保存条例を制定して，草野地区，矢作地区の伝統的建造物群を守っている．遺構として進まないこともある．経済も大変である．しかし，伝統的建造物群を守っていくことが大切であると決めた．自分達の町で何が大切か，それが決めば，種々な方法で実行していける訳である．そこで，栗生地区を伝統的建造物群保存地区保存条例を制定して，いかに歴史的町づくりをするにはどうすればよいかを，地域住民を中心に行政や研究者もみんなで協力していく．思いうように事が進まない．大変である．しかし，歴史的建造物の保存に基づいて，出発する時に，町の変遷過程を捉えることができる．この視点で歴史を生かした町づくりを考えていく．このことが重要であることを指摘し，その順序は1）遺構の調査から順に進めていく．

注1：鹿児島県教育委員会　平成2年　鹿児島の民家（離島編）
注2：　屋久町郷土誌編纂委員会　平成5年　屋久町郷土誌第一巻　村落誌　上
注3：　注2 46・50・56・62・70ページに明治20年・大正末・昭和20年頃・昭和40年・
平成2年の屋敷割を掲載している．
注4：　原口虎雄：昭和56年　津口藩所・異国船藩所
　鹿児島大百科事典　695ページ　南日本新聞社・鹿児島，1704年（宝永元年）御
答書に津口藩所24ヶ所が記されている．
南西諸島島嶺社会における女性霊性の民俗学的研究

徳 丸 亞 木

要 旨

本報告では、沖縄県宮古郡伊良部島におけるツカサ制度の調査研究を通じて、南西諸島島嶺社会における女性司祭制度の実態を、ツカサが伝える伝承やウガンノート等の資料に基づいて明らかにし、女性の誕生から死に至るまでの年齢階級各段階に応じた女性霊性の発現のありかたと、各段階における社会的役割とを考察する事を目的とする。

キーワード：ツカサ、ウガンノート、女性司祭制度、女性霊性、年齢階梯

A FOLKLORE STUDY OF THE WOMEN's SPIRITUAL PARTS ON AN ISLAND'S SOCIETY OF THE SOUTHWEST ISLANDS, JAPAN

Aki Tokumaru

Abstract

This study aimed at explain the actual conditions of the systems concerned with the female priests in the southwest islands, japan and study the expressions women's spiritual parts and functions in respective age-grade based on Tukasa's oral traditions and Ugan-note.

Key words: Tukasa, Ugan-note, Systems of the female priests, Women's spiritual parts, Age-grade system

女性霊性と女性司祭 民俗学、文化人類学においては女性霊性（民俗社会において女性が有すると信じられている霊的資質）に基づく様々な信仰事象をその研究対象の一つとしてきた。特に南西諸島はオナリ神信仰（姫、または姫が霊的にその男性兄弟を庇護するとした信仰）が一般的に展開する地域である。琉球王朝成立以降、その支配領域ではノロ制度が確立し、集落の中心地にある御嶽の祭祀や、共同体単位の年中行事などは女性司祭によって司られた。明治期に至り、琉球王朝の解体により公的制度としてのノロ制度は失われたが、南西諸島の一部では現在も、御嶽の祭祀などを中心として女性司祭の伝統が守られ、ユタなど女性シャーマンの活動も活発に継続されている。

伊良部島のツカサ制度 沖縄県宮古郡伊良部島各集落においては、現在においても（御嶽によっては数年前まで）、女性司祭によって共同体単位あるいは家族単位で御嶽が祭祀されている。御嶽に位置し漁業が盛んな佐良浜地区においては、村御嶽としてウハルス御嶽が祭祀されており、ツカサ（司）、ツカサンマと称される女性司祭が、上位世代の女性達によって、下位世代の女性達から3年の任期で選出されて来た。

佐良浜地区は、池間島からの移住民によって形成されたと伝えられる池間藩と、後に形成されたとされる前里藩とに二分されているが、ツカサ3名は、各隊毎に選出される。ツカサは、表1に示すごとく、最高位のツカサたるマヌマの他、カカランマ、ナカランマと称される2名の補助役からなり、この他、前ツカサを勤めた女性達がアニンマとして現ツカ
サ達の後見人役を務める。なお、2地区内の池間添が優位にあるとされ、計6名のツカ
サ達の中心となるのは池間添のフンマである。

表1. 佐良浜のウハルズ御嶽（村御嶽）に関わるツカサ
（他の里御嶽には各別にツカサが定められる）

<table>
<thead>
<tr>
<th>池間添（ナカムラ、上位）</th>
<th>前里添（ホンムラ、下位）</th>
</tr>
</thead>
<tbody>
<tr>
<td>アニンマ（後見人、3名）</td>
<td>アニンマ（同左）</td>
</tr>
<tr>
<td>フンマ（最高位のツカサ、1名）</td>
<td>フンマ（同左）</td>
</tr>
<tr>
<td>カカラマ（フンマの補佐役、1名）</td>
<td>カカラマ（同左）</td>
</tr>
<tr>
<td>ナカンマ（フンマの使い、荷物持1名）</td>
<td>ナカンマ（同左）</td>
</tr>
</tbody>
</table>

ツカサに就任出来るのは、佐良浜生まれの現居住者で旧暦9月のユートイで帳簿に記載された年齢47歳～55歳（ナカムラでは57歳）までの夫婦とも健康で子のある女性である。12月のイドニガイ当日池間添スンミジャー（選挙所）で籬を行って決定し、12月末日のヒュイに引き繋ぐ。旧正月にカンニガイ（神）願いのウタを暗唱する。籬で当たる前には、本人が家族に夢見でシラセがあると言う。ツカサの任にあたる女性司祭は、表2に示すウハルズ御嶽の祭祀に必要な儀礼手順や祝辞などを完全に暗唱する必要がある。

この表は、かつてツカサを務めたN女史が作成した自筆のウガノート（ウハルズ御嶽の年中行事祭式と神頌を記したもの）から作成した。表に記した行事の他、毎月一日にはツイタチニガイが行われる。また、個人のクリアアギーガイ（位上がり願い）や選挙の当選ニガイも年度によって行われている。アニンマを居着する年の8月にはクリアガリの祝いが後輩のツカサによって行われる（なお伊良部村役場「伊良部村史」昭和53年では、フンマが関わるものとして58のニガイが報告されている）。

表2. ウガノートに見るツカサの関わる共同体年中行事（伊良部佐良浜N女史）

<table>
<thead>
<tr>
<th>月日（旧）</th>
<th>行事名</th>
<th>ニガイの目的</th>
</tr>
</thead>
<tbody>
<tr>
<td>1月24日</td>
<td>マピツダミニガイ</td>
<td>結縁内健康安全の願い</td>
</tr>
<tr>
<td>1月26日</td>
<td>カリウダミニニガイ</td>
<td>航海安全の願い</td>
</tr>
<tr>
<td>1月28日</td>
<td>ウホユダミニガイ</td>
<td>豊作・豊年の願い</td>
</tr>
<tr>
<td>1月29日</td>
<td>ツイタチニガイ</td>
<td>毎月1日に行う願い</td>
</tr>
<tr>
<td>2月4日</td>
<td>マピツダミカサンバン</td>
<td>重ねてウフユを求める願い</td>
</tr>
<tr>
<td>2月7日</td>
<td>カリウダミカサンバン</td>
<td>重ねて航海安全を求める願い</td>
</tr>
<tr>
<td>2月9日</td>
<td>イドニガイ</td>
<td>井戸の願い</td>
</tr>
<tr>
<td>2月11日</td>
<td>ムシヌヌンニガイ</td>
<td>焼から虫を採って海に流す願い</td>
</tr>
<tr>
<td>2月13日</td>
<td>ハマニガイ</td>
<td>藻を焼却し波を海に撒く願い</td>
</tr>
<tr>
<td>2月25日</td>
<td>セイトガニガイ</td>
<td>小学校・中学校の安全を祈願する願い</td>
</tr>
<tr>
<td>3月5日</td>
<td>スマカリウニガイ</td>
<td>旅人の健康を祈願する願い</td>
</tr>
<tr>
<td>3月7日</td>
<td>オ Yöニガイ</td>
<td>水泳の安全の願い</td>
</tr>
<tr>
<td>3月15日</td>
<td>タビカリュウニガイ</td>
<td>不明</td>
</tr>
<tr>
<td>3月19日</td>
<td>ウホユダミヌカサンバン</td>
<td>豊作・豊年の重ねた願い</td>
</tr>
<tr>
<td>3月23日</td>
<td>マニヌパンツ</td>
<td>赤豆・黒豆の豊作の願い</td>
</tr>
<tr>
<td>3月24日</td>
<td>ムズヌパンツ</td>
<td>豆の豊作の願い</td>
</tr>
<tr>
<td>3月27日</td>
<td>カサヌパンニガイ</td>
<td>祇意が穏やかじる事を祈願する願い</td>
</tr>
<tr>
<td>4月15日</td>
<td>サンハニガイ</td>
<td>桧楓の願い</td>
</tr>
<tr>
<td>5月4日</td>
<td>ハアリヌマシアキ</td>
<td>ハーリー祭（船競争）安全祈願の願い</td>
</tr>
<tr>
<td>5月14日</td>
<td>イモノパンムツ</td>
<td>竜の豊作の願い</td>
</tr>
<tr>
<td>5月20日</td>
<td>タイリョニガイ</td>
<td>大漁の願い</td>
</tr>
<tr>
<td>5月24日</td>
<td>キビニガイ</td>
<td>養の豊作の願い</td>
</tr>
<tr>
<td>5月26日</td>
<td>ハナヒサダミニガイ</td>
<td>風邪を除ける願い</td>
</tr>
<tr>
<td>6月16日</td>
<td>アワビニガイ</td>
<td>豆の豊作の願い（3日間一睡もせず願う）</td>
</tr>
<tr>
<td>8月9日</td>
<td>ウラマンマクライアガイニガイ</td>
<td>ホンマの位が高まったのを祝う願い</td>
</tr>
<tr>
<td>8月22日</td>
<td>ウラマダツナワイニガイ</td>
<td>本村・中村のホンマ共同で行う願い</td>
</tr>
<tr>
<td>8月26日</td>
<td>パンプトツニガイ</td>
<td>腫腫な願い</td>
</tr>
<tr>
<td>9月2日</td>
<td>ミャクズツアラビ</td>
<td>男性の祭り</td>
</tr>
<tr>
<td>9月16日</td>
<td>ウウクイ</td>
<td>女性の祭り</td>
</tr>
<tr>
<td>10月1日</td>
<td>ヒヤズニガイ</td>
<td>伊良部のヒャーズ（ウガジョ）の願い</td>
</tr>
<tr>
<td>10月10日</td>
<td>ヒヤズニガイ</td>
<td>ヒユイトリ（日取り取り）</td>
</tr>
<tr>
<td>10月16日</td>
<td>イモビイユイサギ</td>
<td>苼のミキを捧げる願い</td>
</tr>
<tr>
<td>10月22日</td>
<td>ヒヤアズ</td>
<td>頭を立て</td>
</tr>
<tr>
<td>10月17日</td>
<td>マキニガイ</td>
<td>狂の願い</td>
</tr>
<tr>
<td>11月7日</td>
<td>タツナワイニガイ</td>
<td>今年の願いの成就を感謝する願い</td>
</tr>
<tr>
<td>11月11日</td>
<td>ハマニガイ</td>
<td>春のハマニガイの成就を感謝する願い</td>
</tr>
<tr>
<td>11月12日</td>
<td>トマニガイ</td>
<td>出雲ぎで島外に泊まる男性を守る願い</td>
</tr>
<tr>
<td>12月16日</td>
<td>カエルニガ</td>
<td>司が誰を被り杖をついて家々を巡りの悪いものを追い出す願い</td>
</tr>
<tr>
<td>12月22日</td>
<td>イドニガイ</td>
<td>井戸の願いの成就を感謝する願い</td>
</tr>
</tbody>
</table>

更に、ツカサに就任した女性は表3に示すごとく日常生活でも厳しくその行動を制限される。

表3. ツカサに関わる禁忌一覧

| 1 | フンマはシマから出てはいけない。 |
| 2 | フンマはシマの外を意識的に見てはいけない。クバガサを被る。 |
| 3 | ツカサ以外に仕事をしてはいけない（家事労働を除く）。 |
| 4 | 毎朝3時、ウハルズ御嶽に行き御嶽と東方を遙拝する。 |
| 5 | フンマが外を歩く時には必ず両手の平を上に向けて歩く。 |
| 6 | 頭上建帳をしてはいけない。タオル等を掛けてもいけない。 |
| 7 | 必ず黒を着る（キダヌキ＝フンマ、銀制暗＝下位のツカサ）。 |
| 8 | 髪を切ってはいけない。 |
| 9 | フンマは外を歩く時は白い服を着る。赤いものを身に付けてはいけない。 |
| 10 | フンマの袖に他人が触れてもはいけない。 |
| 11 | 雨具を身に着けてはいけない。 |
| 12 | 結婚式、葬式、出産のあった家へ行ってはいけない。 |
| 13 | フンマは一門墓には入らない（別に墓を作る）。 |
| 14 | ツカサが6人揃わないと自動車には乗れない。 |
| 15 | ツカサが揃ったら常にフンマ指示し、下位のツカサはそれに従う。下位のツカサはフンマの右を歩けない。 |
| 16 | フンマの家はカミの家であるから、常に清浄にし、悪い言葉を使わない。 |
| 17 | フンマが夫と性行為をした後は、身を清めた後、マウを伴む。 |

これらの禁忌には、現在守られていないものも含まれている。

伊良部島における女性の年齢階級と女性靭性に関わる社会的役割 ここでの部族住のある女性のライフヒストリーや資料から、同様に女性の年齢階級各段階における女性靭性
に関わる役割を表4として整理した。

<table>
<thead>
<tr>
<th>幼年期</th>
<th>誕生</th>
<th>10日目までの死者はアクマとなる</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>無経期</td>
<td>渔船の船室への毛髪提供</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(無経期少女の霊的資質による豊漁への期待)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>↓</td>
</tr>
<tr>
<td></td>
<td></td>
<td>中止</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(オナリの観念に基づく男性兄弟への霊的守護)</td>
</tr>
<tr>
<td>青年期</td>
<td>婚姻</td>
<td>(カミダーリー→ユタ・モノシリ)</td>
</tr>
<tr>
<td></td>
<td>ユミサーイ</td>
<td></td>
</tr>
<tr>
<td></td>
<td>出産</td>
<td></td>
</tr>
<tr>
<td></td>
<td>育児</td>
<td></td>
</tr>
<tr>
<td>主婦期</td>
<td></td>
<td>夫の漁船のニガインマ</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(夫婦関係を軸にした霊的守護の期待)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>マウ（個人・夫婦神）・火の神等イエの</td>
</tr>
<tr>
<td></td>
<td></td>
<td>カミ、祖先の祭祀によるイエの守護</td>
</tr>
<tr>
<td></td>
<td>47歳〜57歳</td>
<td>ユークインマ（10年間）</td>
</tr>
<tr>
<td></td>
<td></td>
<td>マウによる予兆（夢見）</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ウハルズ御嶽ツカサ（共同体の司祭者）</td>
</tr>
<tr>
<td></td>
<td></td>
<td>への就任（3年間）</td>
</tr>
<tr>
<td></td>
<td></td>
<td>仕事からの引退（家事労働を除く）</td>
</tr>
<tr>
<td></td>
<td></td>
<td>日常生活における禁忌の厳守</td>
</tr>
<tr>
<td></td>
<td></td>
<td>アニンマからの指導</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ウハルズ御嶽の祭祀</td>
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<td>共同体におけるウガンの実施</td>
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<td>アニンマ（ツカサの指導役）への就任（3年間）</td>
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<td>クライアガイニガイ（霊的位の上昇）</td>
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<td>共同体の女性達の後見人的立場</td>
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オナリの観念に基づく男性兄弟への霊的守護の機能など、生涯を通じてのものや、カミダーリーに始まる成巫過程を経てユタとなる女性の例などを除くと、同集落において女性霊性が顕著に発揮されるとする年齢階級各段階の社会的役割として次のものをあげることが可能である。1）無経期における遠洋漁船のフナダマへの毛髪提供。2）主婦期におけるマウ（自然石・珊瑚などを神木として屋内に祀られる個人・夫婦の守護神）や火の神、祖先の祭祀。3）夫が所属する漁船のニガインマ。4）47〜57歳にあたるユークインマの段階への関与と、その期間におけるツカサ職への選抜と就任。5）ツカサを退任した後の後見人であるアニンマへの就任。

無経期における遠洋漁船のフナダマへの毛髪提供は、初潮前の少女の霊的資質が豊漁を招くとする信仰に基づくものであり、この習俗は、鹿児島県南部の他、八丈島や三陸地方など本土の鯨漁漁民など遠洋への出漁漁民社会を中心として見られるものである。摂津郡坊津町、および枕崎市など鯨漁漁労活動の中心とした出漁漁民社会においては、豊漁を
招くと信じられている初潮前の少女の毛髪や、彼女が密かに作製した人形を、その船に込めて、その少女の霊性の庇護の下、大漁を願う習俗がごく近年においても見られた。伊良部島の鯨漁が開始される明治期において、その技術導入には鹿児島県人が関わったとされる（『伊良部村史』735頁）。伊良部佐良浜地区のフナダマに関する伝承は本土側出漁民社会のそれと類似する部分が多く、鯨漁技術の移入に伴い本土側出漁民社会における霊性観念とそれに伴うフナダマ祭祀習俗が移入された可能性がある。

夫が所有する漁船のニガイナマとしての役割も漁労に霊性の霊性が関わるとする観念に基づくものと言えるが、前述の1）の場合は、毛髪提供者たる少女と船主との血縁関係が必ずしも必要とされず、豊漁を招く霊力があるか否かにより少女が任意に選ばれ、不漁の際には毛髪提供者を変更する傾向が見られるのに対して、ニガイナマの場合は、夫・妻関係がまず前提であり、妻が夫の船の安寧・豊漁の願を立てる形でニガイの!儀礼が行われる（このニガイの実行には集団在住のユタが関与する）。

主婦期における家内の神祭祀は、家の司祭者としての役割を主婦が負う形を取る。地域的には父系出目集団が構成されており、男性原理による社会結合、系譜観念が示されるが、同時にニミサライと称される入契工婚もみられ、家父長制度下の社会に比較して女性の婚家からの拘束は弱い物と考えられる。女性の結婚に際しては、むしろ主体的な夫・妻関係に基づく婚家への帰属が行われている様に思われる。

47〜57年におよぶユクインの段階において、女性は社会的にも承認された特殊な年齢段階へ移入する。ツカサとして選出されるのは、この時期にある女性に限られ、選出された女性は、共同体の女性司祭として活動し、通常の女性の社会的な役割からは離れる事となる。ただし、この役割はその女性の家族、特に夫の理解とそれにその援助が無くても不可能なものとも考えられている。ツカサの役目につくと先に述べたごとく日常生活が様々な要請を受け、かつ責任も重大な為、近年集落の若い主婦達は、上位世代が就任を求める時もそれを避ける傾向があり、平成12年の段階で、フンマとして選ばれた女性の就任拒否によりウマルズ御祭の祭祀は行えなくなっており、その制度は崩壊の危機にあらるとも言える。しかし、女性司祭を勤める事は、かつては集落において下位世代から上位世代へと移行する重要なイニシアーションでもあった。

ツカサを退任した後はアニンマを三年間務めるが、その退任の祝いであるクライガイニガイは、ツカサを務めた女性の霊的俊位を上昇した事に対する祝いであると思われ、特にフンマを務めた女性の霊性は共同体全体から特別なものとしての承認を生涯に渡って得る事になる。この地域の墓制は、父系出目集団単位の一門墓の形態をとる。フンマは死後一門墓に入れられず、別個の墓を設けて埋葬される。そこからはフンマが父系出目集団に婚家により帰属した「嫁」の立場から離脱し、高い霊性を獲得した共同体全体の司祭者としての立場を死後も継続する事が示されている様に思われる。

また、フンマに対する尊敬の念は単に、精神的な側面のみに限られるのではない。例えば婦人会活動や生活改善活動等の社会活動において、ツカサを退任した女性達はリーダー的な役割を積極的に務め信頼を集めていている点も留意される。

小括　以上、伊良部島におけるツカサ制度と、女性の年齢段階各段階における霊性観念に関する社会的役割について簡略に報告した。未だ不十分な調査であり、今後は調査課題を示したにすぎない報告であるが、同島の女性霊性に関わる社会的役割については、ユタなど宗教教職業者の例を除くと、大まかによくの6点に類別出来よう。
１．初潮前少女の霊的資質に基づくフナダマへの毛髪提供による霊的庇護の役割。
２．オナリの男性兄弟に対する霊的庇護の役割。
３．妻の夫に対する霊的庇護の役割。
４．婚姻後の婚家家神の司祭者としての役割。
5）．ツカサとしての村御嶽の司祭者としての、共同体全体への霊的庇護の役割。
6）．アニンマ退任以降の霊的資質の昇華と現役世代の後見人的役割。

以降の調査では、これら女性霊性の観念を支える社会的背景と、父系出自集団など男性原理との対応関係についても考察を進めたい。
EVIDENCE OF SEASONAL AND GEOGRAPHICAL VARIATIONS IN ZOANTHUS PACIFICUS AND ITS ENDOSYMBIOTIC ZOOXANTHELLAE DUE TO ENVIRONMENTAL FACTORS

James D. REIMER, Shusuke ONO and Junzo TSUKAHARA

Abstract

Despite much progress, many questions regarding coral bleaching in cnidarians are still unanswered. One specific phenomenon that has received little attention thus far is the variability and change in zooxanthellae body types due to environmental changes. Our previous studies have shown that zooxanthellae are strongly affected by abnormal light and especially, abnormally high seawater temperatures. However, all previous research has been conducted in the lab, with samples from only one site. Confirmation of these hypotheses in the field from multiple sites would go a long way in helping solidify our previous theories, and shed light on other aspects of the cnidarian-zooxanthellae symbiosis.

To accomplish this samples of the encrusting anemone Zoanthus pacificus were collected each month from four field sites (Kokubu-Wakamiko (K), Sakurajima-Hakamagoshi (S), Yakushima-Kurio (Y), and Amami-Oshima-Kasari (A)). Immediately after sampling, endosymbiotic zooxanthellae were isolated from each sample and examined under a microscope using a hemocytometer, and classified by body type. % cover transect data was also collected. Initial (15 month results) show that the sites can be divided into Northern (K and S) and Southern (Y and A) Groups. The Northern Group shows little decrease in NZ during summer, but a significant drop in NZ during the winter months, and either no drop (A) or a slight drop (Y) in NZ during winter. (A) shows no drop in NZ ratios during winter, and (Y) shows a decrease in NZ (although not as dramatic as K or S). These results indicate that seawater minimum and maximum temperatures approach 17°C and 30°C, respectively, based on temperature readings taken from the field sites. This is supported by the transect data, which shows a marked decrease in % Zoanthus cover over winter at Y but not at A. Additionally, Zoanthus appears to be able to withstand short-term (up to 6 hours) intertidal temperatures ranging from 13°C to 37°C.

Key words: Zoanthid, Zooxanthellae, Body type, Temperature, Zoanthus, Bleaching, Seasonal variation

Introduction

Zoanthus and other cnidarians such as coral rely heavily upon endosymbiotic zooxanthellae as a source of energy. Even though the problem of coral bleaching (the expulsion and/or degradation of endosymbiotic zooxanthellae) has become a worldwide issue (GLYNN & DE ROZ, 1990; HOEGH-GULDBERG & SMITH, 1989), and many studies have been conducted on coral and zooxanthellae, there are still many unanswered questions. Previous studies in the lab on Zoanthus (REIMER et al. in review 2002) have shown that at 30°C and 33°C Zoanthus normal zooxanthellae (NZ)
become less frequent than at normal temperatures (23 °C), and the degraded zooxanthellae (DZ) form DDZ (dark degraded zooxanthellae) becomes more frequent. (For detailed explanations of zooxanthellae body types please see Figure 1, and Titlyanov et al., 1996, and Kuroki & van Woesik, 1999) There is also direct lab evidence of digestion of zooxanthellae by Zoanthus (Reimer et al. in review 2002). However, whether zooxanthellae digestion and coral bleaching occurs in Zoanthus under natural conditions in the field or not is unknown. As well, is there any variation in the upper critical temperature observed in the lab of 30 °C for the onset of bleaching and increase in DDZ with Zoanthus over a wide geographic range?

Fig.1. Body types of endosymbiotic zooxanthellae adapted from previous research (McLaughlin et al., 1966; Titlyanov et al., 1996; Kuroki & van Woesik, 1999). Definition of body types: 1) HZ - healthy zooxanthellae, characterized by their large (6-8 μm in diameter) circular shape, and greenish-brown color 2) PZ - proliferating zooxanthellae, HZ undergoing mitotic division 3) DDZ - dark degraded zooxanthellae, smaller in size and darker than HZ (usually approximately 3 μm in diameter) and more irregular in shape 4) TZ - transparent zooxanthellae, zooxanthellae that are characterized by a near or complete loss of color (photosynthetic pigments) 5) STZ/TDZ - small transparent zooxanthellae and transparent degraded zooxanthellae, very small in shape (less than 3 μm in diameter) and colorless 6) MTZ - mobile transparent zooxanthellae, characterized by their two flagella and bell-like shape, and 7) IZ - immature zooxanthellae, zooxanthellae with photosynthetic pigments but not yet full in size (approximately 4 μm in diameter).

Materials and Methods

Sampling

Samples of Zoanthus pacificus were collected each month from four field sites (Kokubu-Wakamiko (K), Sakurajima-Hakamagoshi (S), Yakushima-Kurio (Y), and Amami-Oshima-Kasari (A)). The four field sites are separated by a distance of almost approximately 400 kilometers
north-south. At each field site 5 locations at different depths and exposure were selected and one sample from each consistently collected. Collected samples were immediately placed in a cooler for transport.

Environmental data (pH, ocean temperature, salinity, conductivity, and dissolved oxygen content) were collected with a YSI Inc. Aquameter. Data was collected from each location at each site every month. The data was also supplemented by UV and temperature data from local weather stations.

Zooxanthellae Body Type Research

Immediately after sampling, endosymbiotic zooxanthellae were isolated from each Zoanthus sample by use of a 0.1-ml syringe and examined under a microscope at 400X using a hemocytometer. Zooxanthellae were classified into different body types (see Fig. 1 for a detailed explanation), and the results compared with environmental parameters (seawater temperature, salinity, DO, pH, etc.) over time. Counts were performed on each sample from each location at each site for five fields of view.

Transect Study

At both the Y and A sites, one inter-tidal location of dimensions 50 cm by 50 cm was selected. Photographs of each transect site were taken each month, and the percentage cover calculated using a computer-drawn grid. These data were compared over time against environmental data collected.

DNA classification of Zoanthus and zooxanthellae

Zoanthus and zooxanthellae both have been the subject of controversy with regards to classification, and no classification study of Zoanthus in southern Japan has yet been performed. Colonies of Zoanthus of oral disk color not reported in literature are numerous at all four sites. To confirm that our focus species is indeed Zoanthus pacificus and to shed light on the endosymbiotic zooxanthellae, classification to the DNA level is scheduled.

Samples of Zoanthus were collected from field sites in late August 2002. Collected samples were placed in marked bottles, and placed immediately into coolers away from direct sunlight exposure. Upon return to Kagoshima University labs, samples were wrapped in aluminum foil to prevent exposure to light, and placed in a deep freeze at -80°C.

DNA analysis of both Zoanthus and zooxanthellae is currently being performed at the JAMSTEC headquarters in Yokusuka, Japan, starting from September 2002. While initial results are known, it is expected that conclusive results will not be ready until spring/summer 2003.

Results

The results of the zooxanthellae body type analysis when compared with seawater temperatures are shown in Figure 2. A close examination of the graphs shows that there are two major patterns, a northern pattern with winter 2001~2 decreases in healthy zooxanthellae (NZ) shown by K (a) and S (b), and a southern pattern displayed by Y (c) and A (d) with healthy zooxanthellae decreases in abnormally hot summer 2001. As well, the southern group shows either only a slight drop (Y) or no drop (A) in NZ ratios in winter. All sites showed little or no decrease in NZ ratios is summer 2002, when ocean temperatures did not rise much above average expected levels.
Transect data of percentage cover of *Zoanthus* at Y and A are shown in figure 3. Both locations show a winter decrease in percentage cover that was not reflected in the zooxanthellae data. Summer data from 2002 is still being analyzed at the time of writing.

Fig.2. Monthly changes in NZ ratios at the four field sites. (a) Wakamiko, Kokubu, (b) Hakamagoshi, Sakurajima, (c) Kurio, Yakushima, and (d) Tomori Beach, Kasari, Amami-Oshima. Please note that black bars represent NZ values greater than 0.65 (thus 65% or higher NZ content), while white bars represent NZ values lower than 0.65, indicating stress.
Discussion and Conclusions

The results in figure 2 and 3 indicate a low-end critical temperature for *Zoanthus pacificus* at approximately 15 °C, which is the winter minimum seawater temperature for the K and S sites. *Zoanthus* survives at this temperature, but the ratio of healthy NZ zooxanthellae decreases, and *Zoanthus* colonies experience winter contraction even at the warmer Y and A sites further south.
Maximum seawater temperatures appear to be in the area of 30°C for *Zoanthus* at all sites, as *Zoanthus* NZ ratios at Y and A sites decreased during the abnormally hot 2001 summer. K and S sites showed no summer decrease despite being further north and seawater temperatures being only slightly cooler.

One factor not shown in these calculations is the fact that length of exposure is also important. While seawater temperatures may fluctuate between 15 and 30°C, *Zoanthus* at the Y and A sites are exposed during extreme tides, with many colonies not even in tidepools. A temperature of 13°C has been recorded in a tidepool at Y during January 2002, and outside air temperatures reached as low as 2°C. Conversely, at the A site in August 2002, a tidepool seawater temperature of 37.8°C was recorded, and air temperature at all sites regularly can hit 35-36°C in summer. It appears that *Zoanthus* and zooxanthellae can survive short (up to 6 hour) exposures to very extreme temperatures, but long-term differences of even 0.5°C can greatly impact their survival. Summer 2002 data from Y and A further supports this, as the normal seawater temperatures observed (up to 27.8°C) did not cause any decrease in NZ ratios, as opposed to summer 2001 data.

An important question that remains to be answered is whether or not the summer decrease in NZ at Y and A is a recent phenomenon or not. Coral bleaching and associated problems are assumed to be a result of global warming yet our research shows that, at least at K and S sites, some stress in winter appears to be naturally occurring. With ocean temperatures expected to continue to rise in the future, the naturally occurring pattern of winter stress may switch to the summer stress pattern seen in Y and A samples in the summer of 2001. How these trends impact cnidarians and their zooxanthellae remains to be seen, but the overall prognosis given the sensitivity of *Zoanthus* and NZ ratios to even a small change (as seen in summer 2001) is not good.

References

Evidence of Seasonal and Geographical Variations in Zoa
thhus Pacificus and Its Endosymbiotic Zooxanthellae Due to Environmental Factors


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GENETIC HETEROGENEITY FOUND IN CROPS PLANTED IN SMALL ISLANDS

Katsuyuki ICHITANI and Yoshimichi FUKUTA

Abstract

Some native crop cultivars planted in small islands differ genetically from those planted in other regions in Japan. Among such genes conferring genetic heterogeneity in small islands, Hwc2 gene in rice was examined. Frequency of Hwc2 gene has showed a latitudinalcline of Japonica types of the insular region. In this study, first, linkage analysis of Hwc2 locus was performed. Hwc2 gene cosegregated with ph gene on rice chromosome 4. This result was consistent with our previous study. Then, the significance of the chromosomal region of the Hwc2 locus and the genetic heterogeneity of crops in small islands are discussed.

Key words: Genetic heterogeneity, Hwc2, Linkage analysis, Rice

Introduction

Some native crop cultivars planted in small islands differ genetically from those planted in other regions in Japan. For example, KAWASE and SAKAMOTO (1982) examined phenol color reaction (see Materials and Methods) of 376 strains of foxtail millet, Setaria italica (L.) P. Beauv., collected from different areas throughout Eurasia including Japan. Strains that showed the positive phenotype of phenol color reaction were found in Tsushima, the Nansei islands, Taiwan, Philippines, and India with high frequency. However, these cultivars were rarely found in other regions. Another example is red rice. It was expelled from most of Japan, but it is still planted for religious purposes in Homan Shrine in the Tanegashima island, and Takuzutama Shrine in the Tsushima island (WATABE, 1993). Such genetic heterogeneity is thought to be closely related to routes of the crops and geographical heterogeneity of these small islands.

Weak growth occurring in hybrids derived from crosses between two normal strains is called hybrid weakness. F1 weakness of intraspecific hybridization has been reported in some cereal crops such as wheat Triticum aestivum L. (CALDWELL and COMPTON, 1943; TSUNEWAKI, 1970) and barley Hordeum vulgare L. (WIEBE, 1934; TAKAHASHI and HAYASHI, 1972). There are some hybrid weakness phenomena in rice, Oryza sativa L., (SATO, 1997). Among them, F1 weakness found in crosses of a Peruvian rice cultivar Jamaica and Japanese lowland cultivars is controlled by a set of complementary genes, Hwc1 and Hwc2 (AMEMIYA and AKEMINE, 1963). Hwc1 and Hwc2 are carried by Jamaica and Japanese lowland cultivars, respectively. Genotypes of Hwc1 and Hwc2 loci are Hwc1Hwc1hwc2hwc2 for Jamaica, and hwc1hwc1Hwc2Hwc2 for Japanese cultivars.

Cultivated Asian rice is classified into two groups, Indica and Japonica. Japonica cultivars comprise two varietal groups, temperate and tropical types, the latter including cultivars classified in earlier studies as Javanica types (GLASZMANN, 1987; MACKILL,
Distribution of $Hwc2$ gene-carrier was surveyed in Asian native cultivars (SATO and HAYASHI, 1983); the $Hwc2$ gene was prevalent among temperate Japonica, but not among tropical Japonica or Indica. Most Japanese native cultivars carry the $Hwc2$ gene while those from the Nansei islands and Taiwan carry $hwc2$ with relatively high frequency. These Japanese cultivars carrying $hwc2$ have many traits that are specific to tropical Japonica while most Japanese cultivars are temperate Japonica. Therefore, $hwc2$ gene in rice is among the genes conferring genetic heterogeneity in small islands.

We identified the chromosomal location of the $Hwc2$ locus by using 127 recombinant inbred (RI) lines segregating at the $Hwc2$ locus (ICHITANI et al., 2001). These RI lines are produced by continually selfing or sib-mating progeny of individual members of an $F_2$ population until homozygosity is achieved (BURRE and BURRE, 1991). Each RI line is fixed for a different combination of linked blocks of parental alleles; consequently, an RI family constitutes a permanent population in which segregation is fixed. Suppose that a hybrid weakness gene segregates in a set of RI lines. Crosses between RI lines and a line carrying the complementary hybrid weakness gene produce normal plants and weak ones showing hybrid weakness as in $F_2$ and backcross population. Plants showing weakness are difficult to analyze genetically. Therefore, $F_2$ or backcross is not an appropriate population for mapping $Hwc2$. The RI lines are appropriate for mapping $Hwc2$ because RI lines in themselves, not the hybrids expressing weakness, can be analyzed for further genetic study. Information about presence or absence of hybrid weakness phenomena can easily be combined to accumulate a genetic data set of each RI line. This confers great advantages over usual segregating populations such as $F_2$ and backcross.

The present study examines 27 more RI lines; the more accurate location is determined. Then, significance of the chromosomal region of the $Hwc2$ locus and genetic heterogeneity of crops planted in small islands are discussed.

Materials and Methods

A total of 191 RI lines have been developed by FUKUTA et al. (1999) from the cross between a temperate Japonica cultivar Akihikari and an Indica cultivar Milyang 23. Preliminary experiments indicated that Akihikari carries the $Hwc2$ gene while Milyang 23 carries neither $Hwc1$ nor $Hwc2$ (Fig. 1). Genotypes of 183 restriction fragment length polymorphism (RFLP) loci which almost cover the entire rice genome have been identified for $F_5$ individuals, from which each $F_6$ line was produced by the single seed descent method. Phenol reaction, one criterion to classify cultivars into Indica and Japonica (SATO, 1991), is controlled by a gene $Ph$ on chromosome 4 (NAGAO and TAKAHASHI, 1963). Milyang 23, like most Indica cultivars, carries the dominant allele $Ph$, changing hull color into black after soaking in phenol solution. On the other hand, Akihikari, like most Japonica cultivars, carries the recessive allele $Ph$, leaving hull color in a phenol solution unchanged. The genotype of each RI line at the $Ph$ locus has already been determined by ICHITANI et al. (2001). The 27 RI lines which had not been examined by ICHITANI et al. (2001) were crossed to the $Hwc1$ carrier Jamaica as a pollen donor. Then, they were sown on petri dishes containing 5-mm-deep tap water. They were left in the dark at 28°C for five days. Next, their roots were observed to find the genotype of RI lines at the $Hwc2$ locus. At least six hybrid seedlings were observed in each cross combination. Estimation of the genotype of each RI line and linkage analysis for RFLP, $Ph$ and $Hwc2$ followed ICHITANI et al. (2001).
The 27 RI lines were classified into three types: 10 lines fixed for $Hwc2$ allele, 12 lines fixed for the $hwc2$ allele, and 5 lines which had not reached fixation. The $Hwc2$ gene cosegregated with $ph$ gene on rice chromosome 4. Addition of this result to ICHITANI et al. (2001) led to the segregation ratio $58Hwc2Hwc2:81hwc2hwc2:15Hwc2hwc2$; this ratio deviated somewhat from 15:15:2, the expected ratio of gene constitution of $F_6$ lines bred through single seed descent method ($\chi^2 = 6.87331$, d. f. =2, 0.05>P>0.01). The result of linkage analysis indicated that $Hwc2$ and $Ph$ were located together between the two RFLP loci, $XNpb264$ and $XNpb197$, on the long arm of the chromosome 4. The genetic distance between $Hwc2$ and $Ph$ was modified by 0.11 cM to 0.49 cM from the 0.6 cM of ICHITANI et al. (2001). On the other hand, the genetic distance between $XNpb234$ and $Hwc2$ was longer than that in ICHITANI et al. (2001) by 0.15cM; the genetic distance between $Ph$ and $XNpb197$ was almost unchanged. The four loci, $Hwc2$, $Ph$, $XNpb264$, and $XNpb197$, were rearranged in the order of $XNpb264 - Hwc2 - Ph - XNpb197$.

Discussion

From a phylogenetic point of view, it is interesting that the two loci $Hwc2$ and $Ph$, both of which have been associated with varietal differentiation, are closely linked to each other. Many loci controlling morphological and physiological traits related to adaptability are located near the $Hwc2$ and $Ph$ loci (ICHITANI et al., 2001). Moreover, recent advances in molecular marker-assisted analyses have shown that the gall midge resistance gene $Gm2$ locus (CHAUDHARY et al., 1986; CAUSSE et al., 1994), quantitative trait loci (QTLs) for cool tolerance at the booting stage (SAITO et al., 1995), drought resistance (CHAMPOUX et al., 1995), and the number of large vascular bundles in the peduncle (SASAHARA et al., 1999) were all located near the two loci, even though the linkage between the two
loci and QTLs was indirectly obtained from that between these QTLs and molecular markers linked to \( Ph \). These facts suggest that these adaptability-gene combinations, rather than \( Hwc2 \) or \( Ph \), might cause or promote varietal differentiation. Genes on the \( Hwc2 \) and \( Ph \) loci might be mutated and be dragged by surrounding gene combinations.

One indication that the \( Ph - Hwc2 \) region may be involved in adaptation is seen in Japanese cultivars. AMEMIYA and AKEMINE (1963) reported that, unlike Japanese lowland cultivars, Japanese upland ones examined up to now carried \( hwc2 \). On the other hand, ISHIKAWA et al. (1992) reported that many Japanese upland cultivars carry \( Ph \) gene, though they carry the Japonica type allele at most isozyme loci and are classified as temperate Japonica. There is no information about correspondence between the two studies, but there is some possibility that Japanese upland cultivars conserve the \( Ph - hwc2 \) linkage block. Rice is easily infected with blast fungus under the upland condition. To cope with blast, upland cultivars carry blast resistance genes. Linkage between \( Ph \) and a blast resistance gene(s) was detected in some Japanese upland cultivars (MARUYAMA et al., 1983; HIGASHI and SAITO, 1985; GOTO, 1988). The linkage block containing \( Ph \) and a blast resistance gene(s) is thought to have derived from exotic cultivars, probably Indica, and have survived introgression with temperate Japonica genetic background. Tight linkage between \( Ph \) and \( hwc2 \) suggests that the \( hwc2 \) gene may have been dragged by \( Ph \) and a blast resistance gene(s). A similar linkage block containing a blast resistance gene(s) and an upland-cultivar-specific isozyme gene on chromosome 11 was suggested by ISHIKAWA et al. (1997).

Hybrid weakness genes may be thought to be useless for practical breeding; however, a breeding scheme utilizing such genes is proposed for preventing the spread of transgene and genetic contamination of cultivars (SAITO, 1997; SATO and INAMURA, 1989; YONEZAWA et al., 1990; MORISHIMA, 2001). There is a high probability that such potentially useful genes be identified in local cultivars planted in small islands. Moreover, genes can be tools with which origins and routes of crops can be traced. Local cultivars can be useful for ethnology and folklore, too. Skewed geographic distribution of the \( Hwc2 \) gene in rice presented a good opportunity to reevaluate the idea that rice and rice cropping had proceeded to Japan northwards along the Nansei islands or the path on the sea (\( kaijo no michi \)) proposed by YAGAGITA (1961). WATABE (1993) reported that a traditional method of using cattle to plow paddy fields in the Nansei islands is also seen in insular regions of Southeast Asia. WATABE (1993) also reported that a few native cultivars in the Yaeyama islands looked like Bulu, a group of tropical Japonica native cultivars grown in Indonesia. These findings shed new light on rice diffusion and rice cropping. However, most local cultivars planted in small islands tend to be replaced by improved cultivars and are in danger of extinction. Exploitation and conservation of genetic resources is required for the future.

References


CALDWELL, R. M. and L. E. COMPTON 1943. Complementary genes in wheat causing a


This study clarified we could effectively distinguish mixed water yam strains by observing the differences of morphology of the leaves and tubers in Yaku Island. However, there are considerable variations in morphology, so we may be able to more confidently distinguish strains by also employing the electrophoresis method using acetone powder.

**Key words**: Mixed strains, Polyacrylamide gel electrophoresis, Water yam, Yaku Island

### Introduction

What are generally called Yam in Japan are mostly Chinese yam (*Dioscorea opposita* THUNB., Naga-imo) or Japanese yam (*D. japonica* THUNB., Yamano-imo or Jinen-jyo), and both species are originally from temperate zones. However, among some 600 species of the *Dioscorea* genus plants (to which yam belong) said to exist worldwide, about 10 species are used for economic cultivation, most of which are originally from the tropical or subtropical zones. One of them, *D. alata*, or water yam in English, is called *Daijyo* in Japan. It is supposed to have originally come from Southeast Asia, but now can be found widely in Asia, Oceania, Africa and Central America. In Japan, it is cultivated in warm districts in the southwest and is mainly eaten uncoooked or processed into sweets and buckwheat noodles.

Farmers in Yaku Island, Kagoshima prefecture, started economic cultivation of water yam in the town of Kamiyaku in about 1986. Some 18 hectares are now cultivated in both the town of Kamiyaku and Yaku, and the cultivated area is increasing. A storehouse and a processing factory were built in the town of Kamiyaku in 1992, and today, water yam is processed into grated yam, frozen, and shipped in 100g packs throughout the year.

The cultivated strain *Solo Y am* which Kagoshima University introduced from Indonesia, is used because of its high viscosity and good taste (ISHIHATA et al., 1977, 1984). However, as the years under cultivation and the cultivated area increased, other strains were mixed with *Solo Y am* in cultivation. Compared to *Solo Y am* these strains have extremely low viscosity and change colors easily during processing and have thus caused some problems in producing grated yam.

The authors previously reported that morphology, the RAPD method (SHIWACHI et al., 2000), and tuber protein are effective methods for distinguishing water yam strains (ONJO et al., 1995). In this study, we investigated whether it was possible to distinguish mixed strains in Yaku Island, using comparatively easy and cheap morphology and tuber protein.

### Materials and Methods

Tubers were harvested, collected and stored at 15°C in a storehouse in the town of Kamiyaku
in December 2000. Nine tubers that differed in shape by the naked eye were chosen in February 2001 and used as samples in this experiment. First, the weight, width (maximum and minimum), and length of each tuber were measured. We then hollowed out the center of the tubers, measured water percentage and produced acetone powder. The water percentage of the tubers was determined by drying about 10g of fresh tubers at 120°C for 72 hours and then measuring the weight of the dried tubers. Next, the tubers were cut into 50 to 70g samples, sterilized them by a normal method, and then planted them in 10-liter cloth pots on May 10, 2001. We kept only one of the sprouted stems and cut the rest off. The selected stem was then trained onto a 1.2m prop. Following the standard given by Breeding Department of National Research Institute of Vegetables, Ministry of Agriculture, Forestry and Fishery (TAKAYANAGI et al., 1984), we investigated the morphological characteristics of the top on September 1, when it was a good growing season.

Acetone powder was produced as follows. We put about 15g of fresh tuber into an appropriately cooled nyubachi and quickly smashed it while pouring on acetone that had been cooled down to -20°C. It was then filtered and dried to obtain acetone powder and the powder was stored at -20°C. The amount of powder obtained is given by the weight % of powder to the weight of the smashed fresh tuber. With this acetone powder, we tried to distinguish the mixed strains using polyacrylamide gel electrophoresis. In both investigations, we used Solo Yam preserved and subcultivated by Kagoshima University as a control and tried to distinguish the mixed strains by comparing them to the nine tuber samples from Yaku Island.

Results and Discussion

1. Morphological and physiological characteristics of the top and the tuber

Table 1 shows the result of the morphological characterization of the top. No clear differences were observed among individuals in growth of stems and all parts above the ground. However, two samples, Y7 and Y8, did not exhibit the coloring of anthocyanin on the wing part of the stem, one of the characteristics of water yam. This anthocyanin coloring can be used as an indicator to distinguish the water yam strain (SHIWACHI et al., 2000). It was therefore presumed that Y7 and Y8 were not Solo Yam. We next looked at the morphology of the leaves. Although it was observed considerable differences among individuals for each investigation item, but there was no constant tendency. However, observing with the naked eye, it is noted that the leaf of Solo Yam was heart-shaped whereas those of Y2, Y7 and Y8 were wedge types. Measurements confirmed that only Y2, Y7, and Y8 leaves had widths of less than 7cm and shoulder widths of more than 4cm.

Tables 2 and 3 show morphological and physiological characteristics of the tubers. The flesh color of the tuber, color changes in cutting and viscosity vary to some extent according to the cultivation or storage conditions. The flesh color of the tuber and viscosity was thought to be within this variation. However, the color changes were remarkable in Y2, Y7 and Y8 and were considered to be bigger than the variation due to the conditions above. It was therefore possible that this was due to the characteristics of each individual. Next the tuber shapes were compared. The length/width ratios were large in Y2, Y6, Y7 and Y8, which were long and thin compared to Solo Yam. Water percentage of the tubers and the collection rates of the acetone powder differed in each individual.

2. Distinction by polyacrylamide gel electrophoresis

Fig. 1 shows the result of polyacrylamide gel electrophoresis. Y1, Y2, Y4, Y5, Y6 and Y9 appeared to be the same type as Solo Yam when detected band patterns were compared. However, a band that was not seen in Solo Yam was detected in Y2, Y7 and Y8 (arrows in Fig. 1). We hence
assumed that proteins in the tubers were different. From electrophoresis results, Y2, Y7 and Y8 would be different strains.

Judging generally from the results above of morphological, physiological and electrophoresis methods, we considered samples Y2, Y7 and Y8 to be of different strains.

Table 1-1. Morphological characters in 9 samples of cultivated yams collected from Yaku Island (Continued over).

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Plant vigor</th>
<th>Type of branches</th>
<th>Type of twining</th>
<th>Shape of cross section</th>
<th>Diameter (mm)</th>
<th>Wing Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y1</td>
<td>3</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>2.6</td>
<td>2</td>
</tr>
<tr>
<td>Y2</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2.5</td>
<td>2</td>
</tr>
<tr>
<td>Y3</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2.9</td>
<td>2</td>
</tr>
<tr>
<td>Y4</td>
<td>5</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>3.3</td>
<td>2</td>
</tr>
<tr>
<td>Y5</td>
<td>5</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>3.1</td>
<td>2</td>
</tr>
<tr>
<td>Y6</td>
<td>5</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>2.7</td>
<td>2</td>
</tr>
<tr>
<td>Y7</td>
<td>5</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>2.9</td>
<td>1</td>
</tr>
<tr>
<td>Y8</td>
<td>5</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>2.4</td>
<td>1</td>
</tr>
<tr>
<td>Y9</td>
<td>5</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>2.5</td>
<td>2</td>
</tr>
<tr>
<td>Solo Yam</td>
<td>5</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>2.7</td>
<td>2</td>
</tr>
</tbody>
</table>

The items and methods are based on discrimination for Yams of National Research Institute of Vegetables, Ministry of Agriculture, Forestry and Fisheries.

Table 1-2. Morphological characters in 9 samples of cultivated yams collected from Yaku Island (Continued from Table1-1).

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Length (cm)</th>
<th>Width (cm)</th>
<th>Depth of shoulder (cm)</th>
<th>Width of shoulder (cm)</th>
<th>Length of petiole (cm)</th>
<th>Index of leaf shape</th>
<th>Ratio of length of petiole and leaf length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y1</td>
<td>14.5</td>
<td>7.9</td>
<td>3.5</td>
<td>2.5</td>
<td>5.4</td>
<td>1.83</td>
<td>0.37</td>
</tr>
<tr>
<td>Y2</td>
<td>12.5</td>
<td>6.0</td>
<td>2.6</td>
<td>4.8</td>
<td>6.2</td>
<td>2.09</td>
<td>0.50</td>
</tr>
<tr>
<td>Y3</td>
<td>15.1</td>
<td>7.9</td>
<td>3.7</td>
<td>2.7</td>
<td>5.7</td>
<td>1.91</td>
<td>0.38</td>
</tr>
<tr>
<td>Y4</td>
<td>15.0</td>
<td>8.5</td>
<td>3.7</td>
<td>3.2</td>
<td>5.7</td>
<td>1.77</td>
<td>0.38</td>
</tr>
<tr>
<td>Y5</td>
<td>16.7</td>
<td>8.9</td>
<td>4.0</td>
<td>3.9</td>
<td>5.7</td>
<td>1.88</td>
<td>0.34</td>
</tr>
<tr>
<td>Y6</td>
<td>15.7</td>
<td>9.0</td>
<td>3.6</td>
<td>3.8</td>
<td>6.5</td>
<td>1.74</td>
<td>0.41</td>
</tr>
<tr>
<td>Y7</td>
<td>15.3</td>
<td>6.8</td>
<td>3.2</td>
<td>4.7</td>
<td>5.5</td>
<td>2.23</td>
<td>0.36</td>
</tr>
<tr>
<td>Y8</td>
<td>12.5</td>
<td>6.7</td>
<td>3.2</td>
<td>5.1</td>
<td>5.0</td>
<td>1.87</td>
<td>0.40</td>
</tr>
<tr>
<td>Y9</td>
<td>15.0</td>
<td>7.5</td>
<td>3.5</td>
<td>1.9</td>
<td>5.2</td>
<td>1.99</td>
<td>0.35</td>
</tr>
<tr>
<td>Solo Yam</td>
<td>14.2</td>
<td>7.1</td>
<td>3.3</td>
<td>3.2</td>
<td>4.5</td>
<td>2.34</td>
<td>0.32</td>
</tr>
</tbody>
</table>
Table 2. Physiological characters of tested tubers.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Fresh color</th>
<th>Changes of color</th>
<th>Viscosity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y 1</td>
<td>Cream</td>
<td>Non</td>
<td>Strong</td>
</tr>
<tr>
<td>Y 2</td>
<td>White</td>
<td>Red brown</td>
<td>Strong</td>
</tr>
<tr>
<td>Y 3</td>
<td>White</td>
<td>Non</td>
<td>Strong</td>
</tr>
<tr>
<td>Y 4</td>
<td>Cream</td>
<td>Brown</td>
<td>Middle</td>
</tr>
<tr>
<td>Y 5</td>
<td>White</td>
<td>Non</td>
<td>Strong</td>
</tr>
<tr>
<td>Y 6</td>
<td>White</td>
<td>Non</td>
<td>Middle</td>
</tr>
<tr>
<td>Y 7</td>
<td>White</td>
<td>Red brown</td>
<td>Middle</td>
</tr>
<tr>
<td>Y 8</td>
<td>White</td>
<td>Red brown</td>
<td>Middle</td>
</tr>
<tr>
<td>Y 9</td>
<td>Cream</td>
<td>Non</td>
<td>Middle</td>
</tr>
<tr>
<td>Solo Yam</td>
<td>White</td>
<td>Non</td>
<td>Strong</td>
</tr>
</tbody>
</table>

Table 3. Morphological characters, water contents and yield of acetone powder of tested tubers.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Tuber Length (cm)</th>
<th>Tuber Width (Max.) (cm)</th>
<th>Tuber Length / Width</th>
<th>Water content (%)</th>
<th>Yield of acetone powder(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y 1</td>
<td>10.0</td>
<td>8.9</td>
<td>1.1</td>
<td>82.6</td>
<td>18.4</td>
</tr>
<tr>
<td>Y 2</td>
<td>13.3</td>
<td>4.1</td>
<td>3.3</td>
<td>77.0</td>
<td>25.5</td>
</tr>
<tr>
<td>Y 3</td>
<td>14.4</td>
<td>7.9</td>
<td>1.8</td>
<td>83.3</td>
<td>19.6</td>
</tr>
<tr>
<td>Y 4</td>
<td>8.9</td>
<td>6.8</td>
<td>1.3</td>
<td>81.5</td>
<td>18.6</td>
</tr>
<tr>
<td>Y 5</td>
<td>13.3</td>
<td>8.4</td>
<td>1.6</td>
<td>82.9</td>
<td>19.1</td>
</tr>
<tr>
<td>Y 6</td>
<td>8.8</td>
<td>7.7</td>
<td>2.2</td>
<td>82.0</td>
<td>17.8</td>
</tr>
<tr>
<td>Y 7</td>
<td>19.0</td>
<td>8.5</td>
<td>2.2</td>
<td>76.8</td>
<td>22.4</td>
</tr>
<tr>
<td>Y 8</td>
<td>16.3</td>
<td>6.9</td>
<td>2.4</td>
<td>80.6</td>
<td>21.7</td>
</tr>
<tr>
<td>Y 9</td>
<td>12.7</td>
<td>7.2</td>
<td>1.8</td>
<td>85.3</td>
<td>16.2</td>
</tr>
<tr>
<td>Solo Yam</td>
<td>11.3</td>
<td>7.1</td>
<td>1.6</td>
<td>77.7</td>
<td>25.2</td>
</tr>
</tbody>
</table>

Fig. 1. Band pattern of tuber protein using polyacrylamide gel electrophoresis.
References


POSSIBILITY OF EARLY-SEASON CULTURE OF WATER YAM
(*Dioscorea alata* L.) IN YAKU ISLAND

Michio ONJO, Hironobu SHIWACHI and Mitsuru HAYASHI

Abstract

Early-season culture of water yam (*Dioscorea alata* L.) was required in Yaku Island, because of the long growing period, the concentrating work at the harvesting time, the lack of storehouse and so on. Thus we tried to search the early-maturing strains and use a plant growth regulator that promote the tuber enlargement. Then we found out the extremely early maturing strains introduced from high altitude area in the Kingdom of Nepal. On the other hand, foliar applications of gibberellins promoted the tuber enlargement. These results suggest the possibility of early-season culture of water yam. Further research would be required to use the new strains and the plant growth regulator.

Key words: Early maturing-strain, Early-season culture, Gibberellins, Water yam, Yaku Island

Introduction

Water yam (*Dioscorea alata* L.) is cultivated commercially in Yaku Island, and strains of Solo Yam that Kagoshima University introduced from Indonesia (ISHIHATA et al., 1977, 1984) are cultivated in the town of Kamiyaku. In normal cultivation, Solo Yam is planted from the beginning to the end of April and is harvested from the beginning to the middle of December when the tuber has matured, occupying the field for a long time since the cultivation takes so long. This has become a problem because it makes crop rotation with other crops difficult. In addition, as the work is concentrated at the time of harvest, labor supply and the lack of storage space are also causing problems. Breeding of an early-maturing strain with a short growth period may solve these problems. However, water yam has very rarely flowers, and hybridization has rarely been attempted anywhere in the world (ONWUEME, 1978). Thus, we searched for an early-maturing strain with early harvesting time and examined the possibility of chemical control with a plant growth regulator that might promote the tuber enlargement.

Materials and Methods

Experiment 1. Searching for an early-maturing strain

Searching for an early-maturing strain: We first tried to determine the earliness of the water yam strains that had been collected and preserved by at Kagoshima University since the latter half of the 1970s (ISHIHATA et al., 1977). We chose some representative strains, planted their seed tubers in the field at the beginning of May, and investigated the tuber enlargement by keeping records over time.

Late-maturing strains of water yam tend to be found in tropical lowlands where cultivation temperatures are less limited. We hence assumed that early-maturing strains could be found in the tropical or subtropical zone highlands where cultivation temperature is rather limited. Thus, we introduced
water yam strains cultivated in the highlands of the Kingdom of Nepal (600 to 1,800m above sea level) to Kagoshima and planted their seed tubers in the field at the beginning of May, as for the tubers of Kagoshima University, to investigate the tuber enlargement with elapsed time.

Experiment 2. Promoting tuber enlargement with a plant growth regulator

Use of a plant growth regulator: Preliminary examination showed that applying a general plant hormone, gibberellins (GAs), to foliage promoted water yam tuber enlargement. We then used two strains in the experiment, Arata a native of Kagoshima, and Solo Yam introduced from Indonesia. At the beginning of July, we applied GAs in concentrations of 0, 10, 100 and 1,000ppm to foliage to investigate the best GAs concentration for promoting tuber enlargement.

The tubers were planted in 10-liter cloth pots, and the stems were trained onto a 1.2m prop.

Results and Discussion

Experiment 1. Searching for an early-maturing strain

Fig. 1 shows how tuber enlargement of the preserved strains of Kagoshima University changed with time. The Oosato No.1 dried tuber weighed 3.1g on the 70th day after planting, while tubers of the other strains weighed less than 2g. This demonstrated that Oosato No.1 started tuber enlargement earlier than the other strains. Furthermore, Oosato No. 1 started rapid tuber enlargement around the 100th day after planting, whereas No. 36, Arata, and No. 59 started on the 100th to 130th day and Solo Yam on the 130th to 160th day. This proved that the strain of Oosato No. 1 started tuber enlargement about two months earlier than Solo Yam.

Based on the above result, we decided to use Oosato No.1, which started the tuber enlargement the earliest among the preserved strains, as a standard and compared it with the enlargement pattern of the strains introduced from Nepal (Fig. 2). Among the five strains that we had brought in from Nepal, N-1, N-3, N-5 and N-6 started tuber enlargement on the 70th to 100th day, which was about 15 to 30 days earlier than Oosato No.1.

N-1 in particular continued excellent tuber enlargement from the 100th day to the 160th day after planting, and the weight of the dried tuber on the 160th day at harvest time was 1.5 times that of Oosato No.1. This result clarified that four out of the five strains that we had brought in from Nepal started tuber enlargement even earlier than Oosato No. 1 that was native to Kagoshima.

N-1 and N-6 had been collected from villages that were more than 1,700m above sea level. The average temperature of August (January) at 1,740m above sea level is 20.4 °(9.0

![Fig.1. Changing in dry weight of new tubers in water yam collected from South-East Asia and Kagoshima, Japan.](image)
POSSIBILITY OF EARLY-SEASON CULTURE OF WATER YAM (*Dioscorea alata* L.) IN YAKU ISLAND

). Hence the latter half of the growing period of yam cultivated in these areas could be under quite low temperatures. Therefore, we can consider that earlier maturing strains would be found in regions high above sea level where the temperature falls quicker.

![Dry weight of new tubers during the growth period](image)

Fig.2. Changing in dry weight of new tubers in water yam introduced from Nepal.

Experiment 2. Promoting tuber enlargement with plant growth regulator

Table 1 shows the effect of GAs on tuber enlargement. We applied GAs at the beginning of July when tuber enlargement was stagnant. The fresh weight of the new tubers increased in both Arata and Solo Yam strains, which showed that GAs promoted tuber enlargement. The effect was particularly remarkable in 100ppm and 1,000ppm application divisions, the fresh weight of new tubers in the 1,000ppm division was 15 times that in the 0ppm division for Solo Yam and about twice for Arata. Whether this large diversion of promotion effect between the strains is due to their difference of sensibility to GAs or due to the variation of the growth stage at the time of application will be discussed in the future.

GAs is generally known as a plant hormone controlling the growth of a plant. It is widely used in agriculture, with seedless vines for example. It is safe and can be obtained cheaply anywhere. The fact that GAs promotes tuber enlargement will open up a way to use chemical control for early cultivation of water yams.

Table 1. Promotion effects of tuber enlargement by gibberellins treatment in water yam (*Dioscorea alata* L.).

<table>
<thead>
<tr>
<th>Gibberellins concentrations (ppm)</th>
<th>Fresh weight of new tubers (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Solo Yam</td>
</tr>
<tr>
<td>0</td>
<td>1.2a*</td>
</tr>
<tr>
<td>1</td>
<td>1.2a</td>
</tr>
<tr>
<td>10</td>
<td>2.3a</td>
</tr>
<tr>
<td>100</td>
<td>4.0a</td>
</tr>
<tr>
<td>1,000</td>
<td>18.7b</td>
</tr>
</tbody>
</table>

*:Different figures show the significant differences at 5% level.
It will then be necessary to examine the amount of harvest, viscosity and tastes of the strains introduced from Nepal. Furthermore, the possibility of combining existing strains and Nepal strains in actual cultivation and of chemical control of those strains using GAs needs to be discussed in the future.

References

POPULATION STRUCTURE AND GROWTH DYNAMICS OF *CASTANOPSIS SIEBOLDII* IN SECONDARY-AND OLD GROWTH-SUBTROPICAL FORESTS IN SOUTHERN JAPAN

Yasuhiro KUBOTA

Abstract

Population dynamics of *C. sieboldii*, based on comparing secondary and old growth stands in the subtropical forest, was investigated. The old growth forests showed higher recruitment rate of *C. sieboldii* than that of the secondary forests. Gain of stand biomass was smaller in the old growth forests, but their biomass lost to mortality was larger than that of the secondary forests. Above ground net primary productions ranged from 1.19 kg/ha yr to 1.57 kg/ha yr. Relatively high species diversity in the old growth stands may be maintained by competitive effects of the other species.

Key words: Demography, Competition, Net primary production, Regeneration, Species diversity

Introduction

Tree communities of Yanbaru are subtropical evergreen broad-leaved forests dominated by *Castanopsis sieboldii* (SUNAKAWA & YAMAMORI, 1964, OHYAMA & YAMAMORI, 1971, SUZUKI, 1979, HATSUSHIMA & NAKAJIMA, 1979, ITOW, 1985, Oono et al., 1997). Natural forests of Yanbaru, which is located in Okinawa Island of southern Japan, support many endemic and endangered birds and mammals (see review by ITO, 1997). The area of old growth forests are rapidly diminishing due to intensive logging, consequently, most of the current forested areas are secondary stands regenerated after clear cutting (U.S. Civil Administration of the Ryukyu Islands 1953). Regeneration dynamics of the secondary forests as well as maintenance mechanisms of the intact forests have become an important issue in the management of seral stands (AIDE et al., 1995, GARCIA-MONTIEL & SCATENA, 1994, AIBA et al., 2001). Nevertheless research on the dynamics of the subtropical forests with structural attributes similar to both humid tropical montane rain forests and warm-temperate evergreen broad-leaved forests is scant in comparison to the tropical forests of Southeast Asia (but see ZHUANG & CORLETT, 1997).

Comparative analysis of permanent plots with different age or history might provide insight into structural changes (UUTTERA et al., 2000). In order to reconstruct stand development over time, it is necessary to clarify differences of structural attributes in several stands (FINEGAN, 1992, 1996, GRAU et al., 1997, DENSLOW & GUZMAN, 2000), because demographic traits such as growth rate and mortality change with stand development (KOHYAMA, 1987, BORMANN & LIKERS, 1994, BAZZAZ, 1996). Differences in the spatial- and temporal-patterns of these traits are likely to drive stand dynamics (UMEKI & KIKUZAWA, 1999), may leading to a variation in species diversity in old growth stands.

This paper investigates the differences of the structures and dynamics between secondary and old growth forests in Yanbaru of Okinawa Island, southern Japan. The first object is to present an overview of the regeneration process of the most dominant species (*C. sieboldii*) from secondary
to old growth forests. The second is to examine the effects of competition among individual trees on the community dynamics. This is because intra-and inter-specific competition are important factors governing self-organization of forests (e.g., KOHYAMA, 1993, HARA et al., 1995, NAKASHIZUKA & KOHYAMA, 1995, KUBOTA & HARA, 1995). Most previous studies have presumed autogenic effects to be constant, irrespective of stand development. It is not clear whether the mode of competition among member species can be assumed to be constant throughout all the developmental stages. The first part examines the stability of competitive effects in secondary and old growth stands, and explores the community dynamics of this subtropical forest that bring the coexistence among Castanopsis sieboldii and a variety of subordinate species.

**Study Site I**

The study was conducted in Yanbaru (26° 44′ N, 128° 14′ E), the northern mountain part of Okinawa Island, southern Japan. This region is located between the warm-temperate and tropical zones (MIYAWAKI, 1980). Mean monthly temperature is 19 - 22 °C; mean daily temperatures in the warmest month (July) and the coldest month (January) are 27.3°C and 14.2°C, respectively. Precipitation ranges from 1900 to 4000 mm year⁻¹. Typhoons with strong winds and rain frequently strike the island between July and October. Winds are generally from the south or south-west in summer and from the north in winter. Stand canopies have been apparently shaped by the winds into a homogeneous, continuous surface. As a result, unlike the tropics, there is no emergent tree. The bedrock is composed mainly of tertiary sandstone, palaeozoic clay-slate, and a red-yellow forest soil that lacks humus layer develops (Forest Soil Division, GFES, 1976, KOJIMA, 1980). The study site is dominated by evergreen broad-leaved trees such as C. sieboldii, Distylium racemosum, and Schima wallichii. Nomenclature follows HATSUSHIMA & AMANO (1994).

**Methods**

**Stand selection and site condition**

In order to carry out intensive investigation of structural changes and growth dynamics in forests of different ages, four stands were selected from forested area based on the description by ITO (1997). In Dec. 1997 and Mar. 1998, one monitoring plot was established for each stand which are located within it on a slope at approximately 100 - 400 m elevation. Their areas range from 0.04 to 0.09 ha depending upon the topographic conditions and the stem density. Relatively small plot sizes were used in this study for minimizing topographical heterogeneity within a monitoring plot such as the presence of small ridge and valley (e.g., SHINJO et al., 1988, 1991, 1992, MIYAGI & SHINJO, 1989, 1990). Stands 1 and 2 are secondary forests of approximately 15 and 30 years, respectively. Both were subjected to clear cutting. In Stands 1, saplings of Styrax japonicus were planted just after logging, and no additional treatment such as mowing and thinning was conducted. The time of abandonment age of each stand was estimated from aerial photographs taken in 1977 and 1995, from the logging record of Kunigami Village, and from interviews with local inhabitants. The older Stand 3 is located in the Yona Experimental Forest of the Ryukyu University and the oldest Stand 4 is in Mt. Yonaha Cultural Properties Preservation Area (ITO, 1995). The former was once logged and naturally regenerated, and is currently more than 50-year-old, while the latter has been conserved for longer period.

In this region, most of the human operations were not recorded in detail because of the confusion during the World War II and the following occupation of the United States Military Forces. This makes the present vegetation exceedingly difficult to interpret. Therefore, in order to validate the comparative analysis among the four stands at different ages, we first examined their site conditions,
Forcing a core sampler systematically in plots, we collected topsoils (0 - 15 cm) from four to nine points beneath the litter layer. The visible fine to coarse roots, stones, and plant debris in the collected samples were removed, and soil pH (in distilled water) of the sampled topsoils was measured for each plot. Remnant soil samples were oven-dried at 105 \degree C for 48 h, and then total nitrogen contents were determined by the micro Kjeldahl procedure (BUCHI Kjeldahl Line B-324, Switzerland).

Randomization technique with the bootstrap resampling was used to test the significant differences of pH and the total nitrogen in topsoils among the stands. Test statistic was obtained by permuting the observed data of pH or total N of the stands and then calculating the sum of the deviations over the stands. We recalculated the statistic 1000 times, generating a distribution of the sum of the deviations over the stands. By comparing these two sums of the deviations over the stands to this generated distribution, a significance level can be determined (ADAMS et al., 1997).

Decomposition rate of leaf litter of *C. sieboldii* was examined as an index of mineralization rate by the litter bag technique. *C. sieboldii* leaf litters (5 g of air-dried) were enclosed in each bag (15 cm x 15 cm with 1 mm polyethylene mesh), and the bags were placed on the forest floor. The litter bags were collected every 3 months from April 2001 to May 2002. Leaf subsamples were oven-dried at 70 \degree C, and the mean dry mass remaining at each interval was expressed as a percent of the initial weight and adjusted to the exponential model: 
\[
W/W_0 = e^{-kt}
\]
where *k* (the decomposition rate) was estimated by the regression analysis. To test for significant differences among slopes, *k*, of the four stands, the ANCOVA was used.

Species richness and diversity

To compare species richness among the plots, the relationship between area and number of species was investigated. Resampling within a plot was repeated 500 times for each subsample size. Minimum sized subsample was set as a 2 x 2 m unit. The number of species was averaged to determine as a function of size of the subsample. To compare species richness among the stands, two jackknife estimators were used (PALMER, 1990, 1991). Species diversity was described by the Simpson diversity index, 1-\(D\) (LANDE, 1996), Shannon-Wiener information index, \(H\) and Pielou\'s equitability index, \(J\) \(D\) is the best index for comparative studies, because values of \(D\) are not affected by the sample size (tree density) and the confidence intervals become reasonably small with 50 - 100 individual samples (see review by LANDE, 1996). In order to avoid the sampling bias such as plot size, the \(D\) value was calculated at the 10 x 10 m subplot level, and then be averaged as a representative value at the plot level. Significance differences of the \(D\) value between the plots were examined by Mann-Whitney *U* test. Statistical analysis in terms of species richness and diversity was performed with the *PC-ORD*, version 4 software (MCCUNE & MEFFORD, 1999).

Stand structure and dynamics

Each plot was first covered with a 2 x 2 m grid system for field survey. Thus 1325 grid cells of 2 x 2 m were established in total. Three life stages were defined for tree species: (i) canopy trees [DBH (stem diameter at breast height 1.3 m) \(\geq\) 10 cm]; (ii) understory trees ( \(\leq\) 2 m in height and < 10 cm in DBH); and (iii) saplings (10 cm \(\leq\) height < 200 cm). All living canopy and understory trees, including all multiple stems, were tagged and identified by species. The saplings were also tagged in systematically chosen grid cells. The height, DBH, and the location of all the stems were measured. When a stem had an irregular shape at 1.3 m height, the measurement was taken at the nearest higher point where the stem was cylindrical. Either steel measuring tapes
or calipers was used to measure DBH of the tree to the nearest 1 mm or 0.1 mm, respectively. DBHs of these tagged trees were remeasured in March 2000, and the new recruits of saplings (< 2 m height) which exceeded the minimal census size (height $\frac{D_{i}}{2}$ m) were measured for DBH and identified by species. Significant difference of the sapling density, the understory density, and the canopy tree density among the stands was examined by Kruskal-Wallis test using the data at the 2 x 2 m grid level.

The relationship between DBH ($x$) and absolute growth rate ($y$) was given as logistic growth function:

$$y = \frac{a}{1 + b^{*}exp(-c*x)}$$

which is specific to the tree species in early growing stage (Ford, 1975, Kikuzawa, 1988, Hara et al., 1991). Fitting of this model was carried out by non-linear regression analysis (Quasi-Newton method) using absolute growth rate as the dependent variable and DBH as the explanatory variable (Non-linear regression module; program from STATISTICA™ for Windows (Stat Soft Inc.)). The parameters of the model are shown in Fig. 3. To test for significant differences in three parameters of the regression functions between-species or -stand, the procedure described by Dobson (1990, pp.116-119) was used. For instance, if we test a difference of parameter $a_{all}$ in logistic growth functions between Species 1 and Species 2, we estimated parameters, $a_{all}$, $b_{all}$, and $c_{all}$ for the pooled species by non-linear regression analysis, calculating the sum of the independent contributions of the residual of observed values from the expected ones weighted by the residual of observed values ($D_{i}$). Next we estimated parameter, $a_{sp1}$, for Species 1 separately using $b_{all}$ and $c_{all}$ fixed as above estimated as the pooled species, calculating the sum of the independent contributions of the residual of observed values from expected ones weighted by the residual of observed values ($D_{2}$). In this way, differences of three parameters among the species and among the stands were compared.

The mortality and recruitment rates were calculated by using a logarithmic model (Condit et al., 1995, Sheil & May, 1996). The mortality rate (% year$^{-1}$) is the log-transformed value of the number of initial live trees in 1997 (or 1998) divided by the number of surviving trees during 1997-2000 and by 2 (or 3) (years). The recruitment rate (% year$^{-1}$) is the log-transformed value of the number of live trees at the end of the study divided by the number of surviving trees during 1997-2000 and by 2 or 3 (years). Significant differences of the observed mortality and the recruitment among the stands were tested based on the sum of the deviations of the observed values from that of the resampled values generated by the bootstrap method (1000 iterations). The significant level was determined from the probability of randomized statistic equal to or larger than that of the observed statistic.

**Net primary production**

In order to estimate net production of the stands and seed dispersal of *C. sieboldii*, litter fall was collected in five 0.99 m$^2$ plots with a horizontal area of 0.95 m$^2$ from 1997 to 2002 in each plot. Litter fall was usually collected every three months from October 1997 to February 2002. The contents of each trap were dried at about 70 oC. After drying, the collections were sorted into five fractions: leaves, small wood, seeds, frass and unclassified materials. All the sorted collections were dried at 70 oC and weighted separately for each trap.

For *C. sieboldii*, the number of dispersed seeds was counted in the four plots from October 1997 to February 2002. Seed production in the plots was calculated by extrapolating the average density of seeds per trap area to the total plot area. Then analysis of variance (ANOVA/MANOVA module; program from STATISTICA™ for Windows (Stat Soft Inc.)) was used to test differences of seed production between-year and between-stand.
Biomass was estimated by the following equations:
\[ \ln w_t = 0.92\ln D^2H - 3.21 \quad (P < 0.0001, \quad r^2=0.97), \]
\[ \ln w_b = 1.02\ln D^2H - 5.37 \quad (P < 0.0001, \quad r^2=0.82), \]
\[ \ln w_L = 0.82\ln D^2H - 5.62 \quad (P < 0.001, \quad r^2=0.71), \]
\[ \ln L_A = 0.856\ln D^2 - 1.583 \quad (P < 0.001, \quad r^2=0.83), \]

and
\[ w = w_t + w_b + w_L , \]
where \( D \) and \( H \) are DBH (cm) and height (m), respectively, and \( w_t, w_b, \) and \( w_L \) are the dry weights (kg) of stem, branches, and leaves per tree, respectively, and \( L_A \) is leaf area (m\(^2\)) per tree, and \( w \) is the total above-ground dry weight of the tree. These regression equations were obtained from the studies done on the Yona Experimental Forest of the Ryukyu University (Kawanabe, 1977). Above ground net primary production of stand biomass (ANPP) was calculated with the method proposed by KIRA and SHIDEI (1967) and CLARKI et al. (2001a):
\[ \text{ANPP} = \text{Y} + \text{L} + \text{G} \]
where \( \text{Y} \) is the difference in standing live biomass between one measurement period and the next (including ingrowth). Above ground biomass of the minimum sized tree (2 m in height, \( w = 0.01 \text{ kg per tree} \) that recruited during the interval is removed from \( \text{Y} \). \( \text{L} \) is the amount of litter/branch fall during the interval. \( \text{G} \) is the amount of losses to herbivory that is calculated from the model (FURUNO & SHIRAI, 1970, YODA, 1971):
\[ G = 1.2E \]
where \( E \) is the amount of frass.

Measurement of competitive effect

In order to assess competitive effects, we analyzed the crowding index of individual trees, which is the cumulative foliage area of neighbor trees higher than the focal tree (KUBOTA & HARA, 1996, HARA et al., 1995). It expresses the asymmetric competitive effect on the focal tree, in other words, the shading effect. The crowding index of individual trees was calculated at three neighborhood radii, 2 m, 3 m, and 5 m to find the best value for analyzing between-tree interaction (see below). Periodic (wrapped-around) boundary conditions, i.e. opposite edges of the plot were joined to form a torus were employed (YOKOZAWA et al., 1998), because trees close to the plot edges had neighbors outside the plot that were not measured.

Trees were grouped into \( C. \) sieboldii and the other species to better describe the community dynamics, because \( C. \) sieboldii was very dominant and practically determined the structure of the stand (SHINZATO et al., 1986). We calculated crowding indices of \( C. \) sieboldii and other species (pooled) trees, respectively. To examine inter- and intra-specific competitive effects between \( C. \) sieboldii and the other species, multiple linear regression analysis was conducted using DBH increment of each tree as the dependent variable and the log-transformed DBH and the crowding index as the explanatory variables for pooled data of each species (Multiple-linear regression module; program from STATISTICA™ for Windows (Stat Soft Inc.)). The DBH increment was Freedman-Turkey-transformed to have a constant variance of residuals. Then inter- and intra-specific competitive effects of \( C. \) sieboldii and other species were investigated. Significance of the estimated values was tested by using a forward stepwise method at \( P < 0.05 \), and comparison of the estimated coefficients with possible values they take if individuals were randomly distributed in each stand. In this case, the null hypothesis is that bivariate spatial interactions between two groups of \( C. \) sieboldii and other species is independent. Based on the highest and the lowest values of competitive effects obtained from the randomized points, ninety-five percent confidence envelopes were drawn (DUNCAN,
Results

Stand structure

Topsoils (15 cm) at all the sites were weakly acidic ranging from 4.07 to 5.21. Total N was quite low, although total N of Stand 4 was slightly higher than that of the other stands. No significant difference in soil acidity (pH) and total N among the four stands were shown (Table 1, \(P > 0.1\) by randomization test based on the resampling data using the bootstrap method with 1000 iterations), although stand biomass and tree density do vary with stand history. Decomposition rate also did not differ significantly between the four stands (ANCOVA, \(P > 0.9\)). Significant correlations among log-transformed tree density, above-ground biomass, and mean above ground tree weight (Table 2, \(P < 0.05\)) can be ascribed to a difference of the stand ages among the plots, rather than the differences of the site conditions.

*C. sieboldii* commonly dominated throughout secondary and old growth forests (Table 2). Species richness with jackknife estimators was higher in younger secondary forests than in old growth forests (Fig. 1, Table 3). Stand 1 had the greatest number of species in spite of its smaller plot area. High species richness in secondary forests was due to the occurrence of light demanding pioneer tree species such as *Eucapheis japonica*, *Mallotus japonicus*, *Ligustrum luhiense* and *Pittosporum tohora*. But species diversity was slightly higher in old growth forests (Mann-Whitney U test, \(P < 0.05\), Table 3), which is consistent with the findings that species diversity increases with forest age in old forests (age \(\geq 50\) yr) of Yanbaru reported by ITO (1997).

| Table 1. Description and site data for secondary forests and old growth forest. |
|-----------------|-----------------|-----------------|-----------------|
| **Plot**        | **Stand-1**     | **Stand-2**     | **Stand-3**     |
| **Age (yr)**    | 15              | 30              | 50-100          |
| **History**     | Clear cut       | Clear cut       | Old Growth      |
| **Altitude (m)**| 340             | 200             | 300             |
| **Bedrock**     | Tertiary sandstone, | Tertiary sandstone, | Tertiary sandstone, |
|                 | palaeozoic clay-slate, | palaeozoic clay-slate, | palaeozoic clay-slate, |
|                 | yellow soil     | yellow soil     | yellow soil     |
| **pH (H₂O)**    | 4.91            | 5.21            | 4.07            |
| **Total N (%)** | 0.23            | 0.12            | 0.18            |
| **Decomposition rate (k)** | 1.94          | 1.63            | 1.58            |
| **T₁/₂ (years)**| 0.36            | 0.43            | 0.44            |
| **1** Based on KOJIMA (1980) |
| **2** pH. Values were not different among the stands (randomization test with the bootstrap resampling (1000 times), \(P < 0.526\)) |
| **3** Total N. Values were not different among the stands (randomization test with the bootstrap resampling (1000 times), \(P < 0.126\)) |
| **4** Decomposition rate of leaf litter is calculated from a negative exponential model: \(Wt/Wo = e^{-kt}\) (OLSON, 1963). |
| **5** Half-life time (T1/2) for litter was calculated from the Olson equation. |
In the secondary forests (Stands 1 and 2) the size (DBH) structure of *C. sieboldii* showed almost bell-shaped distributions with positive skewness and bimodality (Fig. 2). The percentages of sprouting stems in the secondary forests were almost 40%. In contrast, the old growth forests (Stands 3 and 4) showed inverse J-shaped DBH distributions. These DBH distributions significantly differed from one another (Kolmogorov-Smirnov two-sample test, \( P < 0.025 \)). Sapling density of *C. sieboldii* was different among the stands. Most saplings of the secondary forests were sprouted ones, while those of the old growth forests were originated from seeds. Sapling density of the old growth forests were greater than those of the secondary forests (Table 2, Kruskal-Wallis test, \( P < 0.01 \)).

However note that tree density in understory weakened in old growth stands. These differences imply the differences of regeneration and forest stratification in developmental stages.
Fig. 1. Relationship between the number of species and area in a subtropical forest, Okinawa Island, southern Japan. Subsampling was repeated 500 times for each subsample size. The number of species was averaged to determine as a function of size of the subsample. To compare species richness among the stands, two jackknife estimators were used (Palmer, 1990, 1991). Species richness estimated by jackknife estimators is shown in Table 3. Secondary forests (Stands 1 and 2) and old growth forests (Stands 3 and 4) are shown as broken lines and solid lines, respectively.

Table 3. Number of observed species (S), number of species estimated by the first order jackknife estimate (Jack1), number of species estimated by the second order jackknife estimate (Jack2), and species diversity indices of trees in 900 m² plots of Yanbaru. Trees of which height was > 2.0 m. In order to avoid the sampling bias such as plot size, the D value was calculated at the 10 x 10 m subplot level, and then be averaged as a representative value at the plot level.

<table>
<thead>
<tr>
<th>Plot</th>
<th>S</th>
<th>Jack1</th>
<th>Jack2</th>
<th>I-D</th>
<th>H'</th>
<th>J'</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stand 1</td>
<td>56</td>
<td>73</td>
<td>83</td>
<td>0.924</td>
<td>4.501</td>
<td>0.772</td>
</tr>
<tr>
<td>Stand 2</td>
<td>53</td>
<td>70</td>
<td>75</td>
<td>0.891</td>
<td>4.027</td>
<td>0.721</td>
</tr>
<tr>
<td>Stand 3</td>
<td>49</td>
<td>57</td>
<td>56</td>
<td>0.935</td>
<td>4.612</td>
<td>0.821</td>
</tr>
<tr>
<td>Stand 4</td>
<td>48</td>
<td>51</td>
<td>51</td>
<td>0.952</td>
<td>4.831</td>
<td>0.870</td>
</tr>
</tbody>
</table>

(1) \( \text{Jack}^1 = S + r_1*(n-1)/n \), where \( S \) is the observed number of species, \( r_1 \) is the number of species occurring in one sample unit, and \( n \) is the number of sample units.

(2) \( \text{Jack}^2 = S + r_1*(2n-3)/n - r_2*(n-2)/(n*(n-1)) \), where \( r_2 \) is the number of species occurring in exact two sample units (Palmer 1990, 1991).

(3) \( D = \sum_{i=1}^{s} \left\{ n_i (n_i - 1) / N(N - 1) \right\} \)

(4) \( H' = -\sum_{i=1}^{s} P_i * \log_2 P_i \) where \( n_i \) is the number of trees and \( P_i \) the relative frequency of trees of the \( i \)-th species in each plot.

(5) \( J' = \frac{H'}{H'_{\text{max}}} \) where \( H'_{\text{max}} = \log 2S \).
A total of 895 seeds (38 seeds/m² yr) of Castanopsis sieboldii during 1998-2001 was counted in the four plots. Stand 1 had no seed-rain for these four years. The total estimated seed productions over all the four sites were 2, 17, 95, and 0 seeds/m² in 1998, 1999, 2000, and 2001, respectively. In the old growth forests (Stands 3 and 4), seed production of Castanopsis sieboldii was significantly different between years (P < 0.05, Repeated-Measures ANOVA). The largest seed production in 2000 was regarded as a masting, and in this mast year, the density of seeds tended to be greater in the old growth forests than in the secondary forests (Table 4), although the significant difference among Stands 2, 3, and 4 was not detected (P > 0.05, ANOVA). The old growth forests showed higher recruitment rate than that of the secondary forests (P < 0.001 by randomization test)(Table 4). Mortality of Castanopsis sieboldii and the other species at the stand level was not different among the stands (P > 0.09 by randomization test).

Gain of stand biomass was smaller in the old growth forests, but their biomass lost to mortality was larger than that of the secondary forests (Table 5). Most dead trees in the secondary forests were standing dead and belong to small size classes. But in the old growth forests (Stands 3 and 4), high mortality was observed in the large size class, which was due to a typhoon in September 1999. As a result, above ground net primary productions (ANPP) as the sum of the amount of litter fall, gain of stand biomass, and lost to predation, ranged from 1.19 kg/ha yr (Stand 3) to 1.57 kg/ha yr (Stand 1).
The results of non-linear regression analysis with Quasi-Newton method are shown in Fig.3. All the three parameters in the logistic growth function were different between C. sieboldii and other species.

Seed production in stand was investigated during 1997 - 2001, and values are the mean (+ S.D.) of four years. Differences between years and stands were tested by ANOVA.

Mortality and recruitment rates were estimated by using a logarithmic model of CONDIT et al. (1995), SHEIL & MAY (1996), and CONDIT et al. (1999). Then significant difference was tested by randomization test with the bootstrap resampling (1000 times).

Table 4. Regeneration dynamics of subtropical forests based on seed dispersal, calculated recruitment and mortality of secondary forests and old growth forests.

<table>
<thead>
<tr>
<th>History</th>
<th>Plot (age)</th>
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<tbody>
<tr>
<td></td>
<td>Stand-1 (15)</td>
</tr>
<tr>
<td></td>
<td>Stand-2 (30)</td>
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<tr>
<td></td>
<td>Stand-3 (50-100)</td>
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<tr>
<td></td>
<td>Stand-4 (100&lt;)</td>
</tr>
<tr>
<td>Clear cut /Secondary</td>
<td>Clear cut /Secondary</td>
</tr>
<tr>
<td>Clear cut /Secondary</td>
<td>Old Growth</td>
</tr>
<tr>
<td>Clear cut /Secondary</td>
<td>Old growth</td>
</tr>
<tr>
<td>Seed dispersal density of C. sieboldii (yr, m$^3$/m$^2$)</td>
<td>0</td>
</tr>
<tr>
<td>Recruitment rate of C. sieboldii (%/yr)</td>
<td>0.85</td>
</tr>
<tr>
<td>Recruitment rate of other species (%/yr)</td>
<td>2.01</td>
</tr>
<tr>
<td>Mortality rate of C. sieboldii (%/yr)</td>
<td>2.51</td>
</tr>
<tr>
<td>Mortality rate of other species (%/yr)</td>
<td>2.22</td>
</tr>
</tbody>
</table>

# Seed production in stand was investigated during 1997 - 2001, and values are the mean (+ S.D.) of four years. Differences between years and stands were tested by ANOVA.

# Mortality and recruitment rates were estimated by using a logarithmic model of CONDIT et al. (1995), SHEIL & MAY (1996), and CONDIT et al. (1999). Then significant difference was tested by randomization test with the bootstrap resampling (1000 times).

Table 5. Patterns of dynamical traits and net primary production in the subtropical forests, Okinawa Island, southern Japan.

<table>
<thead>
<tr>
<th>History</th>
<th>Plot (age)</th>
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<tbody>
<tr>
<td></td>
<td>Stand-1 (15)</td>
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<td></td>
<td>Stand-2 (30)</td>
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<tr>
<td></td>
<td>Stand-3 (50-100)</td>
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<tr>
<td></td>
<td>Stand-4 (100&lt;)</td>
</tr>
<tr>
<td>Clear cut /Secondary</td>
<td>Clear cut /Secondary</td>
</tr>
<tr>
<td>Clear cut /Secondary</td>
<td>Old Growth</td>
</tr>
<tr>
<td>Clear cut /Secondary</td>
<td>Old growth</td>
</tr>
<tr>
<td>Gain of stand biomass (kg/m$^2$, yr)</td>
<td>0.7954</td>
</tr>
<tr>
<td>Loss of stand biomass (kg/m$^2$, yr)</td>
<td>0.0453</td>
</tr>
<tr>
<td>Growth of stand biomass (kg/m$^2$, yr)</td>
<td>0.7501</td>
</tr>
<tr>
<td>Litter fall (kg/m$^2$, yr)</td>
<td>0.76 ± 0.08</td>
</tr>
<tr>
<td>Loss of stand biomass by predation (kg/m$^2$, yr)</td>
<td>0.0153 + 0.0006</td>
</tr>
<tr>
<td>Net primary production* (kg/m$^2$, yr)</td>
<td>1.5707</td>
</tr>
</tbody>
</table>

* Above ground net primary production of stand biomass (ANPP) was calculated based on the method of CLARK et al. (2001), the sum of the amount of fine litterfall, increment of stand biomass, and lost to consumers.

Tree growth and competition

The results of non-linear regression analysis with Quasi-Newton method are shown in Fig.3. All the three parameters in the logistic growth function were different between C. sieboldii and
the other species regardless of the stand ages. Population of *C. sieboldii* had larger $a$ (0.33 - 0.74) in the logistic growth function, which means the upper limits of absolute growth rate, than that (0.13 - 0.46) of any other species (Fig. 3) ($P < 0.0001$ by Log likelihood ratio test between *C. sieboldii* and the other species in each stand), implies that individual trees of *C. sieboldii* grew faster, especially in the canopy. Also the three parameters differed among the stands ($P < 0.0001$ by Log likelihood ratio test based on pair-wise among the three parameters in the stands). The non-linear regression by the logistic function gave higher $r^2$-values in the secondary forests than those in the old growth forests. For *C. sieboldii* in the secondary forests (Stands 1 and 2), the growth rates of DBH indicate strong size-dependent growth patterns. On the other hand, the old growth forests (Stands 3 and 4) showed size-dependent asymptotic growth patterns with large variances ($1 - r^2 > 0.73$).

Competitive effects on individuals were detected at 5 m neighborhood radius, rather than at 2

![Graphs showing relationships between DBH and absolute growth rate](image)

**Fig.3.** Relationships between DBH and absolute growth rate of DBH for individual trees of *Castanopsis sieboldii* (solid lines and open circles) and other species (broken lines and solid circles). Individual stems of Stand 1 and 2 are divided into DBH size class at 1- and 5cm intervals, whereas those of Stand 3 and 4 at 1-, 5- and 10-cm intervals so that each DBH class contains at least about 10 stems. The function form of the relationship between DBH ($x$) and absolute growth rate ($y$) is given as logistic growth model:

- Stand 1, *C. sieboldii*, $y = 0.74/(1 + 15.95*exp(-0.38*x))$ ($r^2 = 0.43$),
  other species, $y = 0.42/(1 + 10.05*exp(-0.32*x))$ ($r^2 = 0.22$);

- Stand 2, *C. sieboldii*, $y = 0.76/(1 + 24.39*exp(-0.19*x))$ ($r^2 = 0.47$),
  other species, $y = 0.46/(1 + 10.73*exp(-0.15*x))$ ($r^2 = 0.05$);

- Stand 3, *C. sieboldii*, $y = 0.50/(1 + 888.55*exp(-0.32*x))$ ($r^2 = 0.27$),
  other species, $y = 0.38/(1 + 7.67*exp(-0.09*x))$ ($r^2 = 0.05$);

- Stand 4, *C. sieboldii*, $y = 0.33/(1 + 1.34*exp(-0.42*x))$ ($r^2 = 0.03$),
  other species, $y = 0.13/(1 + 3.17*exp(-0.77*x))$ ($r^2 = 0.08$).

Fitting of this model was conducted for absolute growth rate of each stem as the dependent variable and DBH as the explanatory variable for each of *C. sieboldii* and other species.
or 3 m radii, which is almost consistent with the distance (max. 5.8 m) of the crown spread for canopy trees of *C. sieboldii*. In the following, therefore, only the results of 5 m radius were discussed below. The mode and the intensity of intra-and inter-specific competition are shown in Table 6. These effects are assessed by the *P* level and 95 % confidence limits based on the randomized simulations. At first, multiple linear regression analysis was conducted using the forward stepwise method at *P* < 0.05. Competitive effects were expressed as the coefficients of the model between Freedman-Turkey-transformed DBH growth rate of each individual tree as the dependent variable, and log-transformed DBH and crowding indices of *C. sieboldii* and the other species as the Table 6.

Table 6. Intra- and Inter-specific competitive effects among species on the growth rate of DBH of individual trees of secondary forests and old growth forests.

<table>
<thead>
<tr>
<th></th>
<th>Inter-specific competition</th>
<th></th>
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<th>Intra-specific competition</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>From <em>C. sieboldii</em> to</td>
<td>From other species</td>
<td>Between trees</td>
<td>Between trees</td>
<td></td>
</tr>
<tr>
<td></td>
<td>other species</td>
<td>to <em>C. sieboldii</em></td>
<td>of <em>C. sieboldii</em></td>
<td>of other species</td>
<td></td>
</tr>
<tr>
<td>Stand 1 (secondary)</td>
<td>ns</td>
<td>-0.202*</td>
<td>-0.313**</td>
<td>-0.240*</td>
<td></td>
</tr>
<tr>
<td>Stand 2 (secondary)</td>
<td>ns</td>
<td>-0.320*</td>
<td>-0.570**</td>
<td>-0.216*</td>
<td></td>
</tr>
<tr>
<td>Stand 3 (old growth)</td>
<td>-0.122*</td>
<td>-0.602**</td>
<td>ns</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>Stand 4 (old growth)</td>
<td>ns</td>
<td>-0.400**</td>
<td>ns</td>
<td>ns</td>
<td></td>
</tr>
</tbody>
</table>

Multiple linear regression analysis was conducted. The DBH increment as the dependent variable was Freedman-Tukey transformed to have a constant variance of residuals.

* Denote significant values at *P* < 0.05 based on the multiple linear regression analysis.

+ Denote values out of random at 95 percent based on the randomized simulation.

Figures in parenthesis are 95 percent confidence intervals for competitive coefficients calculated from the nineteen simulations using the random point process.

Then these coefficients were compared with 95 % confidence limits of that coefficient generated by multiple linear regression analysis using randomized dispersion of individual trees. Like this procedure is more accurate/conservative to ascertain the mode/intensity of competition.

As a result, the mode of competition was quite different among the four stands. In the secondary forests (Stands 1 and 2), *C. sieboldii* showed the evidence of intraspecific competition, although competition in Stand 1 was weak (because the competitive effect among *C. sieboldii* trees was almost equal to the highest value of that generated by randomized dispersion of individual trees). Interspecific competitive effects of the other species on *C. sieboldii* and intraspecific competitive effects within the other species trees were smaller than 95 % confidence limits calculated by the randomized simulations. In the old growth forests (Stands 3 and 4), interspecific competition of *C. sieboldii* was detected. Intraspecific competitive effects of *C. sieboldii* or other species were not entered into the regression, indicating the growth of *C. sieboldii* was regulated by other species.
Discussion

Oliver (1980) and Oliver and Larson (1996) proposed a conceptual model describing the reconstruction process from establishment, thinning, and transition to the steady state following disturbances, based on the dendrochronology of individual trees in a cool-temperate forest. DensoLOW and Guzman (2000) investigated the variation of stand structure in a tropical moist forest according to the 4-phase model of the secondary succession: stand initiation, stem exclusion, understory reinitiation, and old growth. In short, the debate on the development process of forests is often based on the chronosequence of plots of various stand ages (Foster, 1990, Brown & Lugo, 1990, Kitayama et al., 1995, Grau, et al., 1997, Steininger, 2000), which is feasible rather than monitoring stand development over several decades.

In this study, although trees of *C. sieboldii* in the secondary forests have just reached the reproductive stage, the understory of the stands was not fully reinitiated (e.g., lower recruitment rate of *C. sieboldii*) (Table 4), thus the secondary forests developing following clear cutting seem to be in a relatively early developmental phase. We could find a symptom of reinitiation in Stand 2, which had a little amount of seed production and saplings originated from seeds. On the other hand, the old growth forests had the inverse J-shaped DBH distributions and the high sapling density, can be realized at a late developmental phase with understory reinitiation (e.g., higher recruitment rate of *C. sieboldii*). If we use assumptions of a chronosequence analysis to demonstrate structural and dynamical differences between the secondary and old growth forests, it might be possible to illustrate regeneration dynamics over stand development, like those described in previous studies. Note that this does not necessarily indicate that these stands developed as a *successional continuum* in terms of species composition.

High density forests with small mean above-ground biomass (Stands 1 and 2) are at an early developmental stage, while low-density forests with high biomass (Stands 3 and 4) are mature. Moreover *C. sieboldii* is a dominant species throughout developmental phases, determining the canopy structure of the subtropical forests (c.f., Shimizu et al. 1988). These results imply that stand biomass composed of *C. sieboldii* and a variety of subordinate species develops with competition such as self-thinning among trees (Yoda et al., 1963). In order to reveal the community dynamics, it is reasonable to examine the mode of competition between *C. sieboldii* and the other species. For example, Yamamoto (1994) suggested that population structure of Castanopsis spp. shifts to the regeneration niche of a pioneer species, due to interspecific competition of Distylium racemosum co-occurring in the late developmental stage.

Our present study showed that competitive effects and growth patterns are different among developmental phases of forests (Kohyama, 1987). In particular, canopy trees of *C. sieboldii* in the secondary forests grew faster than those of any other species (Fig. 3). This enables the cohort of *C. sieboldii* to regenerate in open sites and to reach the canopy quickly, undergoing intraspecific competition (that may be attributable to the high density of sprouting stems) (Table 2). Thus, relatively high ANPP (Table 5), which is comparable to that of montane tropical forests reviewed by Clark et al. (2001b), seems to reflect on growth and sprouting abilities of *C. sieboldii*.

In the late developmental stage, however, *C. sieboldii* gave no indication of intraspecific competition, and interspecific competition prevailed, which suggests that *C. sieboldii* is regulated by suppression from other species. In the old growth forests, weak domination of *C. sieboldii* in the understory [despite plenty of seed dispersal, sapling density and recruitment (Table 2, 4)] may be a result of the severe interspecific competitive effects from canopy trees of other species to understory trees of *C. sieboldii*. Comparison between the secondary forests and the old growth forests reveals a
trend toward the steady state with gap disturbance which plays a role in regeneration dynamics of understory trees. For example, the growth rate of biomass decreased with increasing stand age (Table 5). This may be explained by the reason that the gain of stand biomass is canceled by the loss of biomass due to gap disturbances, especially in the old growth stand. This is also reflected by weak size-dependent growth with a large variance of $C. sieboldii$ in the old growth forests, which may be caused by heterogeneity in terms of light environment (Fig. 3). The present results suggest that relatively high species diversity in the old growth stands can be maintained by competitive effects of the other species, which reduces the monopolization of $C. sieboldii$, and by gap disturbances which gives opportunities of regeneration for the other species.

In conclusion, structural attributes and growth dynamics showed different patterns between the secondary and the old growth forests, although the observed patterns qualitatively differ only among the four stands. Variation in the mode and the intensity of competition may reflect on the degree of the heterogeneity of the stand structures through the forest development, and the shifting from intra- to inter-specific competition, which probably associates with the spatial structure of trees. Because spatial dispersion such as clustering/regularity of individual trees has a large influence on detectability of competitive effects among individual trees [reported in detail in a following paper (SHIMATANI & KUBOTA, manuscript in review)]. Compositional convergence representing the domination of $C. sieboldii$ with a variety of subordinate species can be understood as the combined effect of stand structure and the mode of competition.

Acknowledgements

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SIZE COMPOSITION OF SEA SURFACE CHLOROPHYLL a CONCENTRATION IN KAGOSHIMA BAY

Toru KOBARI, Akimasa HABANO and Toshihiro ICHIKAWA

Abstract
Size fractionated chlorophyll a concentrations at sea surface were investigated from May 2001 to May 2002 at the two stations in the inner and center area of Kagoshima Bay. Chlorophyll a concentrations in the inner area were much higher than those in the center area. Highly fluctuated chlorophyll was observed at both stations and was resulted from a rapid increase of micro-sized phytoplankton. Pico- and nano-sized phytoplankton were more predominated in the center area, although micro-sized phytoplankton was abundant in the inner area.

Keywords: Size composition, Chlorophyll a concentration, Kagoshima Bay

Introduction
Kagoshima Bay is a large semi-enclosed bay located at the southernmost of Kyushu, southwestern Japan. Although nutrient-poor waters, Kuroshio water, are influential in the center area, water exchange is highly limited in the inner area because of narrow and shallow channel and depth more than 100 m. Thus, size composition of phytoplankton is important. In the present study, we investigate size composition of chlorophyll a concentration at two different areas in Kagoshima Bay.

Materials and Methods
Oceanographic observations and water samplings were weekly to biweekly carried out from April 2001 to May 2002 during T/S Nansei-Maru cruises. Sampling stations were conducted around the deepest parts of the inner and center areas (Fig. 1). Depth was 225 m at Station 10 and 135 m at Station 23, respectively.

Water temperature was determined with a thermometer at sea surface and a reversing thermometer attached with Nansen bottle at other depths. Water samples for chlorophyll a concentrations were taken using a plastic bucket. Each water sample (200-1000 ml) was filtered through plankton net (mesh opening: 20 μm) and Whatman GF/F filter (pore-size: 0.7 μm). From mid-November, Millipore JM membrane filter (pore-size: 5 μm) was also used. Chlorophyll pigments on the filters were extracted in n, n-dimethylformamide (SUZUKI & ISHIMARU, 1990). Chlorophyll extraction was made by direct immersion of the filters into the solvent at -5.5 °C under dark condition overnight. Chlorophyll a concentration was measured with Turner Designs fluorometer (TD-700) by fluorometry (HOLM-HANSEN et al., 1965).
Results and Discussion

Temperature

Water temperature at both stations showed a similar pattern (Fig. 2). Surface temperature increased above 28°C from July to August and made a large difference of temperature at other depths. Sea surface temperature was reached maximum in early August, and was 30.7°C at Station 10 and 31.0°C at Station 23, respectively. Surface temperature decreased after October and no stratification occurred from January to March. Minimum sea surface temperature was 15.2°C at Station 10 in January and 14.4°C at Station 23 in February, respectively. Bottom temperatures were near constant at 15°C at Station 10 and 17°C at Station 23 throughout the year.

Fig.2. Seasonal changes in temperature (°C) at sea surface, subsurface (25 and 50 m) and near-bottom from 2001 to May 2002 in the center area (Station 10: left) and in the inner area (Station 23: right).
Size composition of chlorophyll a

Sea surface chlorophyll a concentrations at Station 23 were much higher than those at Station 10 (Fig. 3). Highly fluctuated chlorophyll was observed at both stations and was associated with a rapid increase of micro-sized phytoplankton. Because actively growth of large phytoplankton have been well known in the nutrient-rich waters (PARSONS et al., 1984), there might be spontaneous nutrients input from the rivers caused by rainfall throughout the year. However, seasonal variation patterns were pronounced for micro-sized phytoplankton and they were predominated in May to June, October to December, and February to March. On the other hand, pico- and nano-sized phytoplankton were abundant in July to September, January to February, and April to May. In general, small phytoplankton was more predominated in the center area, although large phytoplankton was abundant in the inner area. According to the results of ICHIKAWA et al. (1999), the volcanic ashes from Mt. Sakurajima accelerated the formation and downward export of large particles in Kagoshima Bay. These results suggest that large amounts of phytoplankton are exported downward as a carbon source without grazing and decomposing by zooplankton. Considering the limited water exchange and the predominant of large phytoplankton in the inner area, excess nutrients input might rapid accelerate not only harmful algae bloom in the surface but also depletion of oxygen at the near-bottom.

![Fig. 3. Seasonal changes in sea surface chlorophyll a concentrations (mg m⁻³) and relative composition of pico-, nano- and micro-sized phytoplankton from May 2001 to May 2002 in the center area (Station 10: left) and in the inner area (Station 23: right).](image-url)
Acknowledgements

We are grateful to Professor Hiroshi Suzuki and crew of T/S Nansei-Maru for their help in field samplings.

References


The infra-littoral zone of the Taisho Lava Field at Hakamagoshi, Sakurajima has strong tidal and ocean currents, which, when combined with volcanic rock from the lava flow, result in the presence of an abundance of soft corals and other marine life (ONO & TSUKAHARA, 2000, ONO et al., 2002). To investigate the effects of the new man-made sand beach at Hakamagoshi on marine life in the surrounding marine environment, a transect survey has been conducted, along with core samples. Our results show this abundance is relatively unchanged since the recent construction in the area. Core samples from our survey are also typical of other core samples taken at Hakamagoshi, showing that construction influences on the seafloor were yet to be seen as of the time of this survey. A longer-term study with more data should help clarify the impact of construction on the Hakamagoshi inter-tidal zone.

Key words: Sakurajima, Hakamagoshi, Man-made sand beach, Infra-littoral zone, Transect survey, Sediment composition

Introduction

The infra-littoral zone of the Taisho Lava Field at Hakamagoshi, Sakurajima has strong tidal and ocean currents, which, when combined with the volcanic rock from the lava flow, result in the presence of an abundance of soft corals and other marine life (ONO & TSUKAHARA, 2000, ONO et al., 2002). However, the north part of Hakamagoshi includes a harbor with ferries that connect Sakurajima with Kagoshima City. Recently, construction and add-ons in this area have proceeded at a rapid pace. In June 2000 a new National Resort Inn (Kokumin Shukusha) on the waterfront at Hakamagoshi was opened (Fig. 1), and a complementary man-made sand beach swimming area was opened next to the Inn in March 2002 (Fig. 2).

Similarly, several years ago, across Kagoshima Bay, at Iso Beach in Kagoshima City, a large amount of sand from different areas was brought in to enlarge Iso Beach. Ocean currents carried this extra, imported sand to the surrounding infra-littoral area, resulting in the covering, decrease and/or disappearance of large numbers of marine life (Kubota, personal communication). From this experience, it is thought that man-made sand beaches have a drastic and debilitating effect on nearby infra-littoral ecosystems.

To investigate the effects of the new man-made sand beach at Hakamagoshi on marine life in the surrounding marine environment, a transect survey has been conducted, along with core samples.
Materials and Methods

Transect Survey

As shown in Figure 1, the area of study was the beach and infra-littoral area directly in front of the National Resort Inn. This field site is located approximately 200m south of the newly constructed sand beach swimming area. The survey was conducted on April 14, 2001. The line transect survey
was conducted as explained in LOYA and SLOBODKIN (1971) and LOYA (1972). The area of the survey was from the extreme low tide line straight out from shore 40m. Every 10m along this line (at 10, 20, 30, and 40m from shore) a 10m line was drawn centered on the line from shore, extending out perpendicular 5m on either side from the line. All soft coral, anemones, hard corals, and other species present along these lines were noted. As well, seawater temperature, depth, and visibility were noted as the survey was being done. Photographs were taken with an underwater camera to help double check survey results at a later date.

Core Samples and Sediment Composition

To investigate the composition of the seafloor of the survey site, 3 core samples were taken during the survey at three spots along the transect line extending from shore. Core samples at 13m (depth 3m), 27m (depth 6m), and 40m (depth 9m) were taken. Core samples were placed in 5% formalin seawater, and analyzed by the Emery settling-tube method.

Results

Because the Taisho Lava Field at Hakamagoshi is relatively new (produced in 1914 by the big eruption named Taisho Dai-funka), the terrain of the field site is quite rough, with many grooves and bumps (see Figure 3). Much marine life can be seen on the various outcroppings and rocks.

![Fig.3. Geomorphological profile along the base line from shore and the profile of the transect line.](image)

(1) Line Transect Study Results

Line transect study results are shown in Figure 4.

From the extreme low tide-line to 10m, the seafloor reaches a depth of 3m. Marine life covered 29% of the transect at 10m, consisting largely of *Antheopsis*, *Entacmaea*, *Zoanthus*, *Stereonephythya*, and *Pavona*.

From 10 to 20m, depth reached 5m, and marine life cover was 27% at 20m, consisting of *Antheopsis*, *Zoanthus*, *Stereonephythya*, *Faviidae*, *Pavona*, and the table coral *Acropora*.
From a distance of 20 to 30m, the ocean floor dropped to 6.5m, and marine life cover reached 35%. Lithophyllum cover alone consisted of 13% cover. As well, Faviidae, Pavona, Porites, Entacmaea, and Zoanthus. Stereonephthya, which was extremely common near shore (especially at 10m distance) was not seen at all.

The seafloor between 30 and 40m reached a depth of 9m, and largely consisted of sediment. Accordingly, marine life cover was much lower than the other transect areas at only 17%, with the number of colonies 10 less than any other 10m line. Faviidae, Lithophyllum, Montipora, and Pavona were all relatively common.

When compared to data collected by ONO and TSUKAHARA (2000) and ONO et al. (2002) for this field site over the last 20 years, the % cover is generally lower than what is usually seen, but overall the results are quite similar.
(2) Core Sample and Sediment Composition Results

Core samples from all three locations showed little change in the amount of mud present (see Figure 5). The amount of sand was much greater at the third sampling location (40m from shore) than at either of the two locations closer to shore.

In the future investigation of the influence of typhoons and strong wind and wave action on the sand beach and the surrounding study area is planned.

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衛星データを用いた屋久島の環境モニタリング

石黒 悦爾・下境田 光徳

要 旨
森林における立木量の定期的な推定は二酸化炭素の吸収材としてますます重要性を増している。これまでの立木量の推定には、多大な労力、時間、危険と費用を伴ってきた。そこで、現地調査や定期的な調査が困難な屋久島の一部を解析対象地に選定し、30m×30m のL-5/TM データを用いた立木量の推定を試みた。解析指標として、大気補正処理を行っていないNDVI_NC、大気補正処理行ったNDVI_ACと地形補正処理のB4GCを用い、現地調査データとの関連性を検討した。

キーワード：屋久島、リモートセンシング、ランドサット、立木量、環境モニタリング

ENVIRONMENTAL MONITORING ON YAKU ISLAND USING SATELLITE DATA

Etsuji ISHIGURO and Mitsunori SIMOSAKAIDA

Abstract
As the Earth environment has been changing drastically, the development of monitoring technique has become important and required. We focused to estimate the standing tree volumes because of that tree are absorption of carbon dioxide. For measuring the tree standing tree volume, ground truth and air photo has been used, traditionally. However former method was required huge human power and risks and latter method was very expensive and skill.

This study focused to develop the easy method to estimating these tree volumes using satellite data. Ground truth data and processed satellite image data were compared to clarify the accuracy.
Key words: Yaku island, Remote sensing, Landsat, Tree volume, Environmental monitoring.

はじめに
近年、二酸化炭素濃度の増加による地球温暖化の問題が急に論議されている。森林は木材資源としてだけでなく、二酸化炭素の吸収体としての役割や国土保全・水源涵養などの環境保全に果たす機能が再認識されるなど森林に対しての捉え方が変化している。このような現況下で、森林における立木量の定期的な推定はますます重要性を増している。

立木量の推定には、実際、山林に入って胸高直径などの林分要素を測定する方法が用いられている。しかし、この方法では全ての樹木に対しての適用が不可能で、さらには人手を要するため、多大な労力・時間と危険を伴うという問題点を抱えている。また、航空写真を用いて冠径を測定し、これから立木量の推定を行う方法も用いられているが、測定費用が高価で定期的な観測が難しく、しかも写真の判読には熟練を要するなどの問題がある。人工衛星データは、航空写真に比べて空間分解能は劣るが、航空写真では利用で
きない近赤外・熱赤外などのデータも利用できる。また、同時に広範囲を測定し、時系列的解像度が可能である。

屋久島は、標高ならびに天候の変化も著しくしかも多様な植生の垂直分布が観測され、さらに観測からは少ない閉鎖性という特質を持ち、世界自然遺産に登録されている貴重な地球資源である。これらの状況を背景に、本研究では、実地調査を基に得られたデータを用いた立木量の推定を試みた。

供試材料ならびに解析方法

供試対象地

解析対象地として選定した屋久島は、北緯30度28分、東経130度30分、鹿児島市から南方へ約135kmに位置するほぼ円形の島で、島面積はおよそ503km²、周囲約132km、東西約28km、南北約24kmである。その島は円錐形の地形をなしており、九州一の宮之浦岳（1,935m）をはじめとし、1,000mを超える急峻な山々が40峰以上連なり、洋上アルプスとも呼ばれている島である。海岸線から山頂にかけて、亜熱帯、暖温帯、亜高山帯と変化し富んだ気候である。降水量は平地でも年間4,000mmに達する多雨地域である。絶対高さにはスギをはじめ、モミ、ツガなどの針葉樹に加えて、多種の広葉樹が生育している。このような国立林の一部を解析対象地に選定した。

2 供試衛星データ

屋久島は1年中雨の日が多く、また衛星データは雲の影響を受けやすいため、同時に雲の影響の少ないデータを選択する必要がある。使用可能な衛星データとしてはLandsat/TM、SPOT/HRV、NOAA/A VHRR等が考えられるが、空間分解能、観測周期等を考慮して、Landsat-5/TM（以後、L-5/TMと略記）を使用することにした。

また、対象地域の季節的な変化ならびに経時的な変化を検討するため、以下の観測日のデータを使用した。

1：1984年7月18日  2：1997年4月1日
3：1998年8月26日  4：2000年1月4日

3 供試現地調査データ

解析に使用する衛星データ（1984年と1998年）の現地データとして九州森林管理局作成の森林調査簿 [1987年（昭和62年分）、2000年（平成13年分）] を使用した。解析対象としての試験区は、屋久島全体から偏りなく抽出し、特別保護区、第1種特別地域、第2種特別地域、第3種特別地域に属する12林班とした。使用した林班における材積データを表1に示す。

解析方法

1 幾何補正

人工衛星が撮影した画像には内部歪みと外部歪みに起因する幾何学的な歪みを生じる。そこで、内部歪みはセンサ上に起因するもので、光学カメラにおけるレンズ系やフィルムの平面性、スキャシ速度や視野角の変動などがあげられる。また、外部歪みは対象物ならびに衛星上起因するもので、地表面の起伏、地球の曲率や衛星の高度、姿勢、速度の変動などによる影響である。

ERDAS IMAGINEのGround Control Point (GCP) Editor機能を用いて幾何補正を行った。まず、衛星データ画像および国土地理院発行の数値地図25,000(地図画像)を画面上に表示し、橋、道路などの構造物を目標に画像全体に偏りなく、画像基準点、地上基準点を選定した。

次に、入力した両座標値から座標変換行列を算出した。この時、変換後の画像誤差の計
衛星データを用いた屋久島の環境モニタリング

算には、二乗平均誤差 (Root Mean Square Error: RMS Error) を用いた。これらの作業を各々 4 つの衛星データに対して行った。この時、GCP は画像内で偏りなく 40 個以上選定し、Total RMS Error が 0.3 pixel 以下に、距離にすると 9m（= 0.3 x 30 m）以下になるように設定した。

2 大気補正

真空中を伝播してきた太陽光エネルギーが大気圏内に入射する際に一部が大気によって反射される。ここで、大気に入射する際の反射エネルギーは、各バンドの電磁波強度の最小値（以下、ペダリストと略記）と等しいと考えられる。そこで L-5/TM データの大気補正として、LP(0) を取り除くため、各バンドのペダリスト値は幾何補正前の L-5/TM データのヒストグラムから決定した。

表 1 使用した林班における材積データ（1987）

<table>
<thead>
<tr>
<th>林班</th>
<th>小班</th>
<th>林齢 (年)</th>
<th>総材積 (m³)</th>
<th>スギ材積 (m³)</th>
<th>スギ割合 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>い</td>
<td>270</td>
<td>23555.3</td>
<td>7773.2</td>
<td>0.33</td>
</tr>
<tr>
<td>22</td>
<td>ろ</td>
<td>260</td>
<td>35880.0</td>
<td>10046.4</td>
<td>0.28</td>
</tr>
<tr>
<td>22</td>
<td>は</td>
<td>260</td>
<td>22742.4</td>
<td>9551.8</td>
<td>0.42</td>
</tr>
<tr>
<td>231</td>
<td>い</td>
<td>160</td>
<td>34320.0</td>
<td>7893.6</td>
<td>0.23</td>
</tr>
<tr>
<td>267</td>
<td>い</td>
<td>160</td>
<td>62419.5</td>
<td>13732.2</td>
<td>0.22</td>
</tr>
<tr>
<td>228</td>
<td>い</td>
<td>150</td>
<td>104419.0</td>
<td>20883.8</td>
<td>0.20</td>
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<tr>
<td>263</td>
<td>い</td>
<td>160</td>
<td>35958.6</td>
<td>3595.8</td>
<td>0.10</td>
</tr>
<tr>
<td>104</td>
<td>い</td>
<td>155</td>
<td>61687.5</td>
<td>4318.1</td>
<td>0.07</td>
</tr>
<tr>
<td>105</td>
<td>い</td>
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<td>49727.5</td>
<td>3978.2</td>
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<tr>
<td>14</td>
<td>い</td>
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<td>564.3</td>
<td>564.3</td>
<td>1.00</td>
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<tr>
<td>14</td>
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<td>83645.1</td>
<td>50187.0</td>
<td>0.60</td>
</tr>
<tr>
<td>17</td>
<td>は</td>
<td>260</td>
<td>21697.2</td>
<td>13018.3</td>
<td>0.60</td>
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<tr>
<td>80</td>
<td>い</td>
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<td>38082.0</td>
<td>20945.1</td>
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</tr>
<tr>
<td>80</td>
<td>ほ</td>
<td>10</td>
<td>338.4</td>
<td>304.6</td>
<td>0.90</td>
</tr>
<tr>
<td>86</td>
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<td>22550.0</td>
<td>12402.5</td>
<td>0.55</td>
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<td>86</td>
<td>ろ</td>
<td>270</td>
<td>9252.0</td>
<td>2775.6</td>
<td>0.30</td>
</tr>
<tr>
<td>86</td>
<td>と</td>
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<td>3426.5</td>
<td>1027.9</td>
<td>0.30</td>
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<tr>
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<td>1723.2</td>
<td>0.40</td>
</tr>
<tr>
<td>101</td>
<td>へ</td>
<td>50</td>
<td>5895.7</td>
<td>3537.4</td>
<td>0.60</td>
</tr>
</tbody>
</table>

3 解析指標

1) NDVI

植物の光合成は675nm前後の波長をクロロフィルが吸収している。また、近赤外域の波長帯は植物の水分量に関係することが確かめられている。一般に、植物の分光反射特性曲線は、400nmから700nmの可視領域では10〜20%と低く、700nmから1,100nmの近赤外領域では40〜70と高い反射率を示すことが多い。このような特性を利用し、植生の有無・多少・活性度を示す種の植生指標が提唱されている。その中で最も広く利用されている植生指標は以下に示す正規化植生指標 Normalized Difference Vegetation Index: NDVI である。
この値が大きいほど植物量が多い、または活性度が高いといわれている。そこで、大気補正を行っていないデータによるNDVI処理(NDVI_{NC})と大気補正を行ったデータを用いたNDVI処理(NDVI_{AC})を行い、現地調査結果と比較した。

2）：B4_{GC}
大気効果や地形効果の簡易的な除去法の一例として、古海らはパターン展開法を提唱している。これは、L-5/TMの7バンドの内、空間分解能が異なるBand 6を除いた6つのバンドの情報を利用し、地表・土壌・水の3成分で表示し、解析する手法である。この方法では、2000年度恒久地に適用したが、NDVI_{NC}とはほとんど同じ相関関係を示した。この解析において、L-5/TMの各バンドの和は、地形的な影響を取り除くことが示されたので、各バンドの和と植物の水分量を用いたBand4の比を新たな解析指標(B4_{GC})とした。ここで、分母には全バンドの代わりにBand 2 + Band 3 + Band 4を用いた。

B4_{GC} = B4/(B2 + B3 + B4)
この時の各バンドのデータは、大気補正を行ったL-5/TMデータを用いた。また、上記のバンド間演算には、ERSDAC（Earth Remote Sensing Data Analysis Center）が作成した衛星画像解析ソフトNavigator（以前E-Naviと略記）を用いた。

4）解析結果の検証
衛星画像内で120m x120m（4pixel x 4pixel）のブロックエリアを設定し、エリア内の平均輝度を求めた。このエリアを解析対象区域の林班内に数地点設定し、林班内の平均輝度とした。これらの処理はE-Naviで表示したブロックエリアを、Dibasのスクリーンキャプチャ機能を用いてPhotoshopに転送し、エリア内の平均輝度値を算出する手法を用いた。この結果、森林調査簿と林班図の現地データを用いて位置合わせを行った。
このようにして算出した各指標の平均輝度値と森林調査簿に記載されているスギ材積と林齢との関係を、単回帰分析ならびに重回帰分析を行って種々の指標を用いて作成した画像の解析精度を検証した。

1）：単回帰分析
目的変数にスギ材積を、説明変数にB4_{GC}の平均輝度値を用いて単回帰分析を行った。

2）：重回帰分析
目的変数にスギ材積を、説明変数にスギ林齢とNDVIなどの解析指標の平均輝度値を用いて重回帰分析を行った。

結果及び考察

1）L-5/TMデータの幾何補正
観測日の異なる4つの衛星データを比較・解析するために幾何補正を行った。幾何補正後のL-5/TMデータを図1に示す。これらのL-5/TM画像は、Band 2に青を、Band 3に緑を、Band 4に赤を割り当てたトゥルーカラー（true color）で表示した。
幾何補正前後で画面の傾斜が異なったのは、前者が衛星の進行方向に直交して撮影したのに対し、後者はUTM系の座標に一致させたからである。この結果、異なる観測日のデータでも、同一地点の情報を利用することが可能となった。
全ての画像は画像全体で0.3pixel以下の誤差となり、実距離では9m(=0.3x30m)以下となることが確認された。さらに、数値地図画像と比較した結果、橋や道路、空港などが良く一致していた。
2 L-5/TMデータの大気補正

大気圏内に入射する際に太陽光の一部が反射され、センサに入射する電磁波強度 LP ( ) を取り除く大気補正処理を行った。ここでベデスタル値は、表2に示すように幾何補正前のL-5/TMデータのヒストグラムから決定した。

補正前後の画像は視覚的には顕著な違いは認められないが、NDVIなどのバンド間演算処理を行うと、この差異が明確になることが小野ら20）によって報告されている。

表2 ベデスタル値

<table>
<thead>
<tr>
<th>年月日</th>
<th>B1</th>
<th>B2</th>
<th>B3</th>
<th>B4</th>
<th>B5</th>
<th>B6</th>
<th>B7</th>
</tr>
</thead>
<tbody>
<tr>
<td>1984/7/18</td>
<td>72</td>
<td>24</td>
<td>19</td>
<td>12</td>
<td>6</td>
<td>105</td>
<td>2</td>
</tr>
<tr>
<td>1997/4/01</td>
<td>54</td>
<td>15</td>
<td>13</td>
<td>5</td>
<td>1</td>
<td>104</td>
<td>1</td>
</tr>
<tr>
<td>1998/8/26</td>
<td>56</td>
<td>17</td>
<td>13</td>
<td>6</td>
<td>1</td>
<td>98</td>
<td>1</td>
</tr>
<tr>
<td>2000/1/04</td>
<td>38</td>
<td>11</td>
<td>9</td>
<td>5</td>
<td>1</td>
<td>89</td>
<td>1</td>
</tr>
</tbody>
</table>

3 解析指標

1）NDVI画像

NDVI画像は、道路や海、河川などの植生がない地点は黒く、植生がある地点は白く表示される。また、植生のある地点であっても濃淡の度合いによって、植物の活性度差が表
されている。ここで、植生が存在する地域が黒く表示されているのは、方位や標高差により生した影の影響や電磁波が透過できない雲の影響を受けていると推察される。

一般に、大気補正処理を行わないデータを用いてNDVI画像が作成されるが、屋久島のように標高差のある地域ではNDVI画像は地形の影響を受ける。そこで、大気補正処理を行ったデータを用いてNDVI画像を作成し、地形による影響を検討した。

同じ観測年月のNDVI画像をそれぞれ比較すると、大気補正処理を行った画像（NDVI_{AC}）はNDVI_{NC}画像よりも濃淡が顕著になり、植生の有無や活性度を明確に反映し、さらに、山肌などの地形の情報が取り除かれていることが確認された。

2）B_{4GC}画像

B_{4GC}画像は、NDVI画像と同様に植生が認められない地点は黒く、植生が認められる地点は白く表示される。また、植生が認められる地点であっても、濃淡の度合いによって、植物の活性度差が表されている。

各B_{4GC}画像において、白黒の濃淡が顕著に示され、さらに、平面画像として表されたことから、大気効果または地形効果が取り除かれたことが確認された。

図3 B_{4GC}画像

4 解析結果の検証

1）単回帰分析

スギ材積を目的変数、各B_{4GC}を説明変数として単回帰分析を行った。各観測日によるB_{4GC}とスギ材積の関係を検討すると、各観測日ともB_{4GC}とスギ材積の相関が極めて低く、L-5/TMデータにおいて季節的な関係を見出すまでには至らなかった。

また、スギ材積の年次変動を無視し、同じ季節（1984年と1998年）の平均値度との関係を検討した。スギ材積（1987年と2000年）を目的変数、各解析指標（B_{4GC} NDVI_{AC} NDVI_{NC}）を説明変数として単回帰分析を行った。各解析指標とスギ材積との相関は、極めて低い値を示し、満足する関係は得られなかった。

2）重回帰分析

スギ材積と各解析指標の関係を単回帰分析した結果、高い相関を得ることができなかった。一方、スギ材積とスギの林齢には何らかの関係があると考え、スギ材積の推定に林齢を取り入れた解析を行った。そこで、スギ材積を目的変数、各観測日によるB_{4GC}と林齢を説明変数とした重回帰分析を行った。これらの結果は、いずれの観測日についても高い相関を示さなかった。しかしながら、単回帰分析では相関係数が0.0001から0.0453であったのに対し、重回帰分析では相関係数が0.2622から0.3338となり、いずれも相関が高くなった。

衛星データを用いた屋久島の環境モニタリング

せが最も高い相関を示した。解析指標は樹木の活性度に影響を受けるため、指標値は夏が最も高い値を示した。この季節による指標値の変化は、NDVI値が季節により変動し、夏に最も高い値となったとの報告とも一致している。しかしながら、本解析結果は、指標値が高い値であることも観測月日と現地データとのタイムラグがより重要であり、樹木のような永年植物に対しても衛星の観測に同期した地上データの取得が必要であることを再確認することとなった。

また、単回帰分析の場合と同様にスギ材積の年次変動を無視し、同じ季節の1984と1998のL-5/TMデータにより算出した各解析指標 (B4GC NDVIAC NDVIC) と林齢を説明変数とし、スギ材積目的変数とした重回帰分析を行った。単回帰分析では相関係数が0.0036から0.0075であったのに対し、重回帰分析では相関係数が0.2540から0.2740となり、いずれも相関が高くなった。ここで、相関が最も低かったのはNDVICであり、次いでNDVIACとB4GCとなった。このことからL-5/TMデータには大気の影響が大きく作用されることが明らかとなり、大気補正の重要性が再確認された。また、NDVIACとB4GCの相関係数にほとんど差異が認められなかったことより、B4GCによる地形補正に問題を残した。

総括

地球環境において森林は、様々な役割を果たしている。ゆえに、森林における立木量の定期的な推定により、森林の状態を把握することは重要である。しかしながら、これまでの立木量の推定には、大々的な労力、時間、危険と費用を伴ってきた。そこで、現地調査や定期的な調査が困難な屋久島の一部を解析対象に選定し、30m x 30mのL-5/TMデータを用いた立木量の推定を試みた。解析指標として、大気補正処理を行っていないNDVIC大気補正処理行ったNDVIACと地形補正処理のB4GCを用い、現地調査データとの関連性を検討し、以下の結果を得た。

1. 解析指標値はNDVI値と同様に季節により変動し、夏に最も高い値となった。
2. 解析指標値が高い値であることよりも観測月日と現地データとのタイムラグがより重要であり、樹木のような永年植物に対しても衛星の観測に同期した地上データ取得の必要性が示された。
3. 単回帰分析：各解析指標とスギ材積との相関は極めて低い値を示した。
4. 重回帰分析：単回帰分析よりも高い相関を示したが、実用に供するまでは至らなかった。これらの原因としては、解析対象区域内には様々な様生が存在することや標高差による地形の影響を完全に取り除くことができなかったことが挙げられる。
5. L-5/TMデータには大気の影響が大きく作用されることが明らかとなり、大気補正の重要性が再確認された。
6. NDVIACとB4GCの相関係数にはほとんど差異が認められなかったことより、B4GCによる地形補正に問題を残した。

今後は地表分解能が1m x 1mであるIKONOSのような高解像度の衛星データの使用、解析対象領域の増加、同一时期地上調査等を行う必要性があると考えられる。また、標高差のある屋久島では、地形の影響を如何に抑えることができるかが今後の課題であり、植物の特性や地理情報などを折り込んだ多面的解析が必要であると考えられる。

謝辞

現地データの提供を賜りました屋久島営林署の皆様に深く感謝いたします。
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に伴う大規模灌漑地域の長期経年変化の解析・評価について」の共同研究によってご提供頂きました。ここに深く感謝の意を表します。

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DISTRIBUTION CHARACTERISTICS OF POLYMORPHIC ALLELES AMONG THE POPULATIONS OF THE NANSEI ISLANDS, JAPAN

Kazutoshi Ago

Abstract

The characteristics of the distribution of blood group polymorphism alleles among the populations of the Nansei Islands, Japan, were examined using currently available blood group data, such as red cell types, enzyme types and serum protein types. 1. A comparison of genetic diversity was made between the Amami-Oshima and Tanegashima populations, and the neighboring large populations such as the mainland of Kagoshima and the main island of Okinawa. Gene diversity in the island populations is similar to that of Kagoshima and Okinawa. 2. Geographical clines of allele frequency of blood groups in Japanese populations are discussed. Clines constructed using the Nansei Islands data support the dual structure model hypothesis for the origin of the Japanese more strongly than previously described clines. 3. Two rare alleles, TF Damami and AHSG 5, which are uniquely distributed in the Nansei Islands, are described.

Key words: Nansei Islands, Island population, Blood groups, Geographical cline

Introduction

The Nansei Islands form an archipelago stretching between the mainland of Kagoshima and Taiwan, and are potentially important in tracing the origin of the Japanese people. I investigated the distribution of blood group alleles with the purpose of revealing the genetic characteristics of this area and to gather basic data for forensic practices. In this paper, on the strength of the data accumulated so far, I discuss the genetic homogeneity of the Tanegashima and Amami-Oshima populations, geographical clines of allele frequencies in Japanese populations and rare variants distributed specifically in the Nansei Islands.

The Genetic Homogeneity of Tanegashima and Amami-Oshima Populations

Gene diversity, meaning the degree of genetic homogeneity in each population, was calculated by the following equation (ROYCHoudhury & NEI, 1988) using the available data (AKAISHI & Kudo, 1975; Ishimoto, 1975; Omoto, 1975; Roychoudhury & NEI, 1988, AGO et al., 1998a, b).

\[ H = 1 - \sum_{i=1}^{k} x_i^2 \]

where \( x_i \) is the frequency of the \( i \)-th allele in the population and \( k \) is the number of alleles. Comparison of gene diversity among populations from Amami-Oshima, the mainland of Kagoshima and the main island of Okinawa was carried out using eight blood group loci. As shown in Table 1, the average value of the Amami-Oshima population (0.415) laid between those of the Kagoshima and Okinawa populations (0.4064 and 0.4189 respectively) and statistically significant differences were not observed. The average value of the Tanegashima population (0.5044) was also similar to those of populations
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from Kagoshima, Amami-Oshima and Okinawa (0.4950, 0.5157 and 0.5054 respectively), as shown in Table 2, and there are also no statistically significant differences. These results indicate that Amami-Oshima and Tanegashima have sufficiently large populations to maintain allele heterogeneity and avoid island effects usually associated with isolated populations. Similar investigations on islands with small populations, such as Yakushima, Okinoerabu and Yoron, are necessary, but data from these areas are not currently sufficient to allow detailed analysis.

Table 1. Comparison of gene diversity between Amami-oshima and neighboring populations.

<table>
<thead>
<tr>
<th></th>
<th>Amami-oshima</th>
<th>Kagoshima*</th>
<th>Okinawa</th>
</tr>
</thead>
<tbody>
<tr>
<td>GC</td>
<td>0.6574±0.0075</td>
<td>0.6506±0.0084</td>
<td>0.6578±0.0080</td>
</tr>
<tr>
<td>TF</td>
<td>0.3998±0.0084</td>
<td>0.3693±0.0145</td>
<td>0.3942±0.0119</td>
</tr>
<tr>
<td>AHSG</td>
<td>0.4213±0.0156</td>
<td>0.3754±0.0147</td>
<td>0.3913±0.0120</td>
</tr>
<tr>
<td>HP</td>
<td>0.3565±0.0091</td>
<td>0.4009±0.0119</td>
<td>0.3752±0.0094</td>
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<tr>
<td>AP</td>
<td>0.3482±0.0176</td>
<td>0.3523±0.0135</td>
<td>0.3960±0.0114</td>
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<tr>
<td>PGD</td>
<td>0.1130±0.0160</td>
<td>0.1440±0.0134</td>
<td>0.1456±0.0126</td>
</tr>
<tr>
<td>PGM1</td>
<td>0.4243±0.0141</td>
<td>0.3743±0.0130</td>
<td>0.4125±0.0120</td>
</tr>
<tr>
<td>ABO</td>
<td>0.6003±0.0081</td>
<td>0.5846±0.0012</td>
<td>0.5782±0.0014</td>
</tr>
<tr>
<td>Average</td>
<td>0.4150±0.0586</td>
<td>0.4064±0.0545</td>
<td>0.4189±0.0536</td>
</tr>
</tbody>
</table>

*the mainland of Kagoshima

Table 2. Comparison of gene diversity between Tanegashima and neighboring populations.

<table>
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<tr>
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<th>Tanegashima</th>
<th>Amami-oshima</th>
<th>Kagoshima*</th>
<th>Okinawa Honto</th>
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</thead>
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<tr>
<td>TF</td>
<td>0.4013±0.0124</td>
<td>0.3998±0.0084</td>
<td>0.3693±0.0145</td>
<td>0.3942±0.0119</td>
</tr>
<tr>
<td>AHSG</td>
<td>0.3959±0.0120</td>
<td>0.4213±0.0156</td>
<td>0.3754±0.0147</td>
<td>0.3913±0.0120</td>
</tr>
<tr>
<td>ABO</td>
<td>0.5845±0.0074</td>
<td>0.6003±0.0081</td>
<td>0.5846±0.0012</td>
<td>0.5782±0.0014</td>
</tr>
<tr>
<td>Average</td>
<td>0.5044±0.0620</td>
<td>0.5197±0.0642</td>
<td>0.4950±0.0721</td>
<td>0.5054±0.0670</td>
</tr>
</tbody>
</table>

*the mainland of Kagoshima

Geographical Clines of Allele Frequencies in Japanese Populations

The dual structure model of Hanihara (1991), describing the origin of the Japanese people, is currently thought to offer a reasonable explanation. It is thought that the modern Japanese consist of the Ainu and Ryukyus peoples descended from the Jomon people and the Hondo Japanese, who mixed with immigrants from the Korean Peninsula during the Yayoi era. Therefore, differences in genetic traits exist in the eastern and western parts of the Japanese Islands. Geographical clines in allele frequencies have so far been reported in the ABO system (Fujita et al., 1978), the GPT type (a red cell enzyme type; Ishimoto & Kuwata, 1974) and the GC type (a serum protein type; Yuasa et al., 1983). It is thought that these clines provide evidence in support of the differences in genetic traits mentioned above. In previous studies, clines starting from northern regions, such as Aomori, were examined. However, if genetic traits were influenced by immigrants from the
Korean Peninsula, clines starting from western areas, such as the northern part of Kyusyu, Yamaguchi and Kinki, should be examined. As shown in figure 1 for the clines of the ITI alleles, two types of cline originating from Aomori and Yamaguchi were examined. Linear clines originating from Aomori similar to the ABO, GPT and GC clines described in previous reports were observed (figure 1A). Clines from Yamaguchi, shown in figure 1B, demonstrate that different clines exist in the eastern and western parts of the Japanese Archipelago (AG0 et al., 2000). V-shaped and inverted V-shaped clines were similarly observed in the GC and TF types (AG0 et al., 1998a, b), adding further support to the dual structure model hypothesis.

Fig.1. Geographical clines of ITI gene frequencies in Japanese populations. Distances were measured from Aomori in (A) and from Yamaguchi in (B).

Rare Variants Specifically Distributed in the Nansei Islands

I discovered that two rare alleles, TF Damami (AG0 et al., 1998a) and AHSG 5 (TAMAKI et al., 1996) appear to be distributed exclusively within the Nansei Islands. As for the above mentioned TF type, three phenotypes, TF C1, TF C1C2, TF C2, which are controlled by the TF C1 and TF C2 alleles, were commonly observed in Japanese populations. Rare variants controlled by the TF B and TF D alleles were also observed. These phenotypes are shown in figure 2. Most of the TF D variants in Japanese populations are TF Dchina. In Amami-Oshima, a TF D variant, tentatively named TF Damami, was frequently observed. TF Damami was also observed in each sample from Yakushima and Okinoerabu. TF Damami moved slightly faster than TF Dchina on the electrophoretogram shown in figure 2. In the AHSG type (a serum protein type) AHSG 1 and AHSG 2 are common alleles. The AHSG 5 allele is extremely rare throughout most of Japan, but not in Amami-Oshima, Tokunoshima, Okinoerabu, Okinawa, Miyako and Ishigaki. The frequency of the AHSG 5 allele in these areas was greater than 1% that can be called polymorphic frequency. The distribution of the AHSG 5 allele indicates that it is specific to the Nansei Islands.
Conclusion

Our study of geographical clines of polymorphic alleles, and of rare alleles that are uniquely distributed within the Nansei Islands, suggests that the genetic makeup of people from this area can help us to understand the origin of the modern Japanese people. Additional data should provide greater insight in the future.

References


Fig. 2. Three common phenotypes controlled by TF C1 and TF C2 and rare variants by TF B and TF D alleles (Dchi: Dchina, Dama: Damami).
A DATABASE OF THE PEST INSECTS FOUND ON ISOLATED ISLANDS IN KAGOSHIMA PREFECTURE, JAPAN

Yositaka SAKAMAKI

Abstract

A pest insect database for isolated islands in Kagoshima Prefecture was developed and made available for public use via the World Wide Web. Most of the insect fauna in this island area is unique and differs from that of central Japan. However, there are few publications with sufficient photographs or biological notes on agricultural pest insects living on such islands. By browsing the database, farmers and non-experts with little knowledge of pest insects can easily search for and identify a pest and get information on the method to control it.

Key words: Pest insect, Database, Isolated islands, Kagoshima, World Wide Web

Introduction

The isolated islands in Kagoshima and Okinawa prefectures, which are located at the southwestern end of Japan, have a subtropical climate. Many tropical crops and fruits that are not grown on the mainland are cultivated on these isolated islands, which are a poorly defended gateway to southwestern Japan for pest insects invading from Southeast Asia. The islands are also a source of tropical crops and fruits. Invading pests may find suitable host plants and successfully colonize such islands. To protect plants in Japan, it is important to enumerate the pest insect fauna on these islands, because we need to identify which species might extend their distributions. In the last century, some notorious pest insects have invaded these islands from Southeast Asia, the Philippines, and Oceania, including the sweet potato weevil (*Cylas formicarius*), coconut weevil (*Rynchophorus ferrugineus*), melon fly (*Dacus cucurbitae*), and sweet potato vine borer (*Omphisa anastomosalis*), and some crops have suffered severe damage in Kagoshima and Okinawa (SAKA, 1988).

Moreover, many species of migratory pests swarm and invade Japan from the Philippines and southern China every year, including the rice leaf roller (*Cnaphalocrocis medinalis*), brown delphacid (*Nilaparvata lugens*), and army worm (*Spodoptera litura*) (KIRITANI, 2001). They attack many crops in summer and autumn, but are unable to overwinter in Japan. However, greenhouses and the heat island phenomena will help them to colonize and overwinter in Japan.

Every year, a few new pest species are discovered in Japan, and these are reported in special reports from the plant protection office in some prefectures. New crops are introduced to Kagoshima and Okinawa prefectures from tropical areas every year. With the rapid proliferation of information on insect fauna and the introduction of new crops from tropical areas, farmers and pest management experts find it increasingly difficult to identify a pest insect using only printed publications. This paper presents a database system that focuses initially on pest insects distributed in mainland Kagoshima Prefecture and on the islands of Tanegashima, Yakushima, Amami-Oshima, Tokunoshima, and Okinawa. The database includes photographs of pest insects that attack crops, which should aid in pest identification.
The Database

Data were extracted from the literature, primarily from a Japanese atlas and papers published in Japanese journals. Minor data sources included research bulletins and reports from agricultural experiment stations. I took most of the photographs. Each database record consists of 13 fields (Table 1) and includes the scientific and Japanese common names of the pest, the names of the host plant(s), distribution on and off the islands, literature references, photographs of the pest, and control methods.

Table 1. Description of the fields contained in the database.

<table>
<thead>
<tr>
<th>Field</th>
<th>Content of the field</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Taxonomic order of pest insect</td>
</tr>
<tr>
<td>2.</td>
<td>Taxonomic family of pest insect</td>
</tr>
<tr>
<td>3.</td>
<td>Scientific name of pest insect</td>
</tr>
<tr>
<td>4.</td>
<td>Author name describing the pest insect</td>
</tr>
<tr>
<td>5.</td>
<td>Japanese common name of pest insect</td>
</tr>
<tr>
<td>6.</td>
<td>Scientific name of host plant (crop)</td>
</tr>
<tr>
<td>7.</td>
<td>Japanese common name of host plant (crop)</td>
</tr>
<tr>
<td>8.</td>
<td>Distribution of isolated islands in Kagoshima Pref. and Okinawa</td>
</tr>
<tr>
<td>9.</td>
<td>Primary literature on pest damage and distribution</td>
</tr>
<tr>
<td>10.</td>
<td>Secondary literature</td>
</tr>
<tr>
<td>11.</td>
<td>Taxonomic and ecological notes</td>
</tr>
<tr>
<td>12.</td>
<td>Photograph</td>
</tr>
<tr>
<td>13.</td>
<td>Methods for controlling the pest</td>
</tr>
</tbody>
</table>

The database was developed using the commercial database program FileMaker Pro. 5.0. Currently, the database holds about 1,000 records, with photographs of over 50 important pests. Most of the pests are lepidopteran insects (over 900 species). The records can be searched either by inputting key words or by choosing key words from pop-up menus.

Even a beginner with no knowledge of pest insects can find a pest insect by searching for pest information in the database using key words. The database has been designed to fit the needs of farmers, and focuses on pest insects that are distributed on islands in Kagoshima and Okinawa prefectures. There are many publications on pest insects in central Japan; however, few of the insects described in such publications are distributed on isolated islands. There are few publications with sufficient photographs and biological notes on common agricultural pest insects living on islands. Unfortunately, the database does not yet contain sufficient good photographs of living pests attacking crops, but the number of photographs will be increased to facilitate effective use of the database by farmers and non-experts.

Browsing the Database on the WWW

The Japanese version of the database is available on the World Wide Web. Anybody can access it and browse the records. The database is stored on a server at the Kagoshima University Research Center for the Pacific Islands, and is linked to its homepage (http://cpi.kagoshima-u.ac.jp/index.html).

The main menu of the database offers the user five search methods: a key word search (input words) or pop-up menus for searches by the taxonomic order of the pest insect, taxonomic
Fig. 1. Top page exhibited on WWW.

Top page gives search menu. Key words can be inputed in top two blank, and some key words can be selected lower four pop-up menu. In this example host plant name Satsumayimo (サツマイモ) is inputted as a key word.

Fig. 2. A list of search result.

The taxonomic order name, Japanese common name of each pest insect and that of host plants are shown. Button combined square and circle in a left end of each record is linked to detailed information page of each species.
family Japanese common name, and host name (Fig. 1). If any of the last four search methods are selected, all the user need do is choose an item on a menu. If the key word search is selected, the user can search records by inputting information, such as island name, insect name, host name, and so on. For example, if a user inputs the word サツマイモ which is the Japanese word for sweet potato, the database exhibits a list of 14 records associated with sweet potato (Fig. 2). The list includes four fields (family name, Japanese common name, scientific name, and host plant in Japan) and one button per record. Each button is linked to detailed information on each species, including photographs. The original database file developed with FileMaker Pro can be manipulated in a manner similar to WWW browsing.

At present, 90% of the records in the database are for lepidopteran insects. More records for insects in other orders will be added in the near future, and an English version of the database will also be added. I plan to extend the database to include islands in neighboring prefectures and surrounding countries in the future.

Finally, I wish to sincerely thank Dr. K. TSUDA for critically reading this manuscript.

References


Molluscan fauna of intertidal rocky shores were investigated at Mageshima Island, which is located 12 km west of Tanegashima Island, Kagoshima Prefecture, Japan. Eighty-four species belonging to 31 families were sampled and they included many subtropical species. Some characteristics of this fauna showed that intertidal rocky shores of Mageshima Island were environmentally comparable to cobble shores.

Keywords: Fauna, Intertidal, Mollusca

Introduction

Mageshima Island is located 12 km west of Tanegashima Island and has a 12 km coastline and is 8.5 km in surface-area. It is a flat island with a maximum elevation of 71 m. Historically, this island had no residents and was used as a base for fishing or as a farm except from 1951 to 1980, when more than 500 people reclaimed the island and resided to cultivate sugarcane. The coast of the island is known for a good abalone fishery. Therefore, we can expect that this island has a preferable environment for coastal organisms because of very low human impact on intertidal shores and having subtidal shores which can persevere rich abalone resources.

There have been some studies dealing with terrestrial flora and fauna of Mageshima Island (SASAKI et al., 1960; NAKAMINE, 1976). One subspecies of sika deer, Cervus nippon mageshima, was described from this island (KURODA & OKADA, 1950). Flora and fauna were also studied along the coast of the island (ARAKAWA, 1955; TANAKA, 1976; ITOHO, 1979), and it has been known to have various algal species including some tropical species (TANAKA, 1950). However, coastal fauna and flora were rarely studied after residents abandoned the island.

In this study, we investigated intertidal molluscan fauna on some rocky shores of this island to gain some insight about the coastal fauna and their environmental condition.

Methods

Preliminary surveys were carried out on September 1998 at five shores of Mageshima Island. One person surveyed rocks in the intertidal area for 30 to 60 minutes at each shore during low tide and noted species name.

We selected two shores located on the east and west coast of the island based on data from the preliminary survey areas and surveyed again on August 2000. Cross-shore transects were set from the upper to lower reaches of the intertidal zone. All molluscan species along these lines were sampled and fixed in 10% seawater formalin.
Table 1. List of molluscan species in intertidal rocky shores of Mageshima Island.

<table>
<thead>
<tr>
<th>Family</th>
<th>Species</th>
<th>Family</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ischnochitonidae</td>
<td>Ischnochiton comptus</td>
<td>Muricidae</td>
<td>Muricodrupa fusca</td>
</tr>
<tr>
<td>Chitonidae</td>
<td>Acanthopleura gemmata</td>
<td>Muricodrupa sp.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Acanthopleura loochooana</td>
<td>Morula granulata</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Acanthopleura japonica</td>
<td>Morula musiva</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Onithochiton hirasei</td>
<td>Morula nodicostata</td>
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<tr>
<td>Acanthochitonidae</td>
<td>Acanthochiton rubrolineatus</td>
<td>Morula anaxeres</td>
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<td>Patellidae</td>
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<td>Lottiidae</td>
<td>Diodra quadriradiatus</td>
<td>Columbellidae</td>
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<td>Patelloida saccharina</td>
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<td>Patelloidea pygmaea</td>
<td>Buccinidae</td>
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<td>Strigatella scutula</td>
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<td>Nodilittorina radiata</td>
<td></td>
<td>Pinectada maculata</td>
</tr>
<tr>
<td></td>
<td>Nodilittorina trochoides</td>
<td></td>
<td>Pinectada martensii</td>
</tr>
<tr>
<td></td>
<td>Nodilittorina vidua</td>
<td>Isognomonidae</td>
<td>Isognomon acutirostris</td>
</tr>
<tr>
<td></td>
<td>Nodilittorina sp.</td>
<td></td>
<td>Isognomon perna</td>
</tr>
<tr>
<td>Rissoidae</td>
<td>Zetina affinis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cypraeidae</td>
<td>Cypraea annulus</td>
<td>Pinnidae</td>
<td>Pinna muricata</td>
</tr>
<tr>
<td>Ranellidae</td>
<td>Cymatium tenuiliratum</td>
<td>Ostreidae</td>
<td>Saccostrea mordax</td>
</tr>
<tr>
<td>Epitoniidae</td>
<td>Gyroscala lamellosa</td>
<td>Carditidae</td>
<td>Cardita variegata</td>
</tr>
<tr>
<td>Eulimidae</td>
<td>Eulima sp.</td>
<td>Veneridae</td>
<td>Periglypta reticulata</td>
</tr>
<tr>
<td>Muricidae</td>
<td>Cronia margaritico</td>
<td></td>
<td>Gafrarium dispar</td>
</tr>
</tbody>
</table>
A total of 84 species belonging to 31 families were sampled during this survey (Table 1). This number is almost equivalent to the total number of species in nine coasts of the Satsuma Peninsula (YANO, 2001). Since the latter study dealt with an area more than ten times as larger than this study, we can say that Mageshima Island has a more diversified intertidal molluscan fauna than that of the Satsuma Peninsula. Intertidal molluscan fauna in Mageshima Island was also more diversified than that of Chiringashima Island at the mouth of Kagoshima Bay, which is an uninhabited island. The latter has 57 molluscan species including 42 gastropoda.

Among 84 molluscan species in Mageshima Island, 61 were gastropoda, while only 17 species of bivalves were sampled. Since most rocky shores of Mageshima Island also had cobble stones, we sampled few settlement species including many intertidal bivalves. Among 61 gastropod species, at least 26 were carnivorous including many subtropical species belonging to Muricidae and Conidae. The ratio of carnivorous species to all gastropod species in Mageshima Island (26 to 61) was almost equivalent to that of the intertidal cobble shores found in Sakurajima Island (7 to 23) (INADOME, 2002). Since a large ratio of carnivorous species are characteristic to molluscan fauna in cobble shores, it can be said that the environmental conditions of intertidal rocky shore in Mageshima Island were intermediate between that of a rocky shore and a cobble shore.

Three species of gastropoda (Acanthopleura gemmata, Nerita helicinoides tristis and Pusia dichroa) are reported to be distributed only south of Amami Island. Some other species, e.g., Nerita plicata have their northernmost limit of distribution at Tanegashima Island. These species were also sampled from the southern part of the Satsuma Peninsula and thought to be an irregular distribution without any reproductive capacity. In Mageshima Island, they have enough density to have reproductive capacity and to be able to conserve their population.

Acknowledgements

We deeply thank Mr. S. TATSUZAWA for giving us a chance to investigate the uninhabited island. We are also grateful Mr. Gregory NISHIHARA for his kindly corrections on the manuscript.

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矢野泰人 2001. 鹿児島大学水産学部卒業論文. [YANO, Y. 2001. Bachelor Thesis in Faculty of Fisheries Kagoshima University.]
A survey was conducted to investigate the population and group size of Kuchinoshima feral cattle and their environment in 2001 from the viewpoint of the conservation of rare and endangered animal genetic resources. A total of 32 cattle including adults, the young and suckling calves were found in the southeastern area of the island between August and November, 2001. There were 13 cattle with 4 types of coat color, i.e. black, black and white, brown, and brown and white in August, whereas there was no brown animals in November. The cattle formed 5 groups at least comprising 3-12 individuals. All the ticks collected by dragging a flannel cloth (0.7 ㎡ 1 m) on the pasture were identified as unfed larvae of *Haemaphysalis flava* in August, while *Haemaphysalis flava* and *Haemaphysalis longicornis* were almost equally found in November. In addition, the
tick population in August was larger than that in November. Two watering places besides
the one at Seramma hot spring were found in the habitat.

In conclusion, the number of Kuchinoshima feral cattle has been decreased since
1999, which may be influenced by a scarcity of watering places, a decrease in the amount
of herbage available caused by extension of a paved road and/or infection of external
and internal parasites.

Key words: Animal genetic resources, Habitat, Indigenous domestic animals,
Kuchinoshima feral cattle, Ticks

緒言

鹿児島県トカラ列島においては、トカラ馬、トカラ山羊および口之島野生化牛などの稀
少動物遺伝資源が野生化あるいは半野生化状態で生息している。とくに、口之島野生化
牛（以下、野生化牛）についてはトカラ馬のように鹿児島県文化財（天然記念物）に指定さ
れていないものの、わが国原生の在来牛の形質を有する（西中川，1991）ことから、形態
学、遺伝学、生態学など学術的に貴重な遺伝資源として注目されている。

この野生化牛は日本在来家畜調査団の林田・野澤（1964）によって初めて存在が確認され
られ、それ以降、数回に亘って断続的な生息調査が行われてきた（富田，1980；五百部・木
の約720haに生息しており、黒毛和種の放牧地とは別に島住民によって保護されている。
野生化牛は全島の共有財産であり、全島民合意の上、公共的支出をまかなうため必要に
応じて島外へ出荷されている。黒毛和種ほど高い市場性はないものの、産業基盤の少ない
本島にとって野生化牛の販売は貴重な現金収入源であり、島民の生計の一部となっている。
中西ら（1998；未発表）は1995年より現地で野生化牛の生息調査を継続的に行った結果、
生息頭数は49～66頭で年次推移し、最近は減少傾向にあるものと推測している。したがっ
て、野生化牛の適切な保護対策を講じるには生息頭数や生息環境に関する情報蓄積が必要
である。

そこで本研究では、稀少動物遺伝資源としての野生化牛を適切に保護するための基礎的
知識を得る目的で、現地に赴き、個体識別によって生息頭数を推定するとともに、生息環
境（飲水場の状況、小型ピロプラズマ病を媒介するマダニ類の生息個体数）を調査した。

材料および方法

1．調査期間

2001年8月16～17日（5:00～7:00およ
び16:00～19:00）と同年11月3～7日
の2回
（延べ観察日数7日間）調査を行った。

2．調査地の概況

鹿児島県トカラ列島にある口之島は北緯29度59分30秒、東経129度55分に位置し、面積
13.3km²、周囲20.4kmの火山島である（図1および2）。人口は2000年現在173人あり、主
な産業は畜産（黒毛和種繁殖経営）、水産業および離島振興法による公共事業である（十
島村役場，2001；下野・山田，1995）。野生化牛は島南東部と西部に広がる黒毛和牛放牧
地を東西2つのゲートで隔てている南東部約720haに生息している。
３．調査方法

これまでの調査結果（中西ら，1998；未発表）および島民からの聞き取り調査結果から、
島内一帯を基本に3ヶ所の調査地点（第1地点：トシラ，アカズラ，三千木；第2地
点：メイケンタオ；第3地点：トワタオ，イワヤ）を設けて定点観察法と移動直接観
察法（田名部ら，1996）の併用により目視観察するとともに，ウワデーラ，テラジリ，
セランマ，赤池においては移動直接観察法に従って観察した。発見した個体の写真撮影と
ビデオ録画を行った後，性別，体格，成長区分，毛色，斑紋の形状，角の形状，角輪など
の形態的特徴から個体ごとの牛籍簿を作成することにより個体識別を行い，生息頭数を推
定した。同時に，死亡個体の確認も行った。

調査期間中に複数回確認した同一個体群の発見場所を1／20,000のメッシュ地図上にプ
ロットし，群の数およびそのサイズ（1群当たりの構成頭数）を推定した。

野生化牛が確認された島内一帯を沿った3地点（8月）および5地点（11月）で1地
点につき3または5ヶ所，フランネル法（0.7×1.0mのフランネル布を1ヶ所当たり10m
曳して布に付着したマダニの個体数を記録）によりマダニ個体数を調べ，布に付着した
一部を無作為に採取した後，グリセリンアルコール入り容器に保存して持ち帰り，その種
類を同定した。マダニ個体数については，3または5ヶ所の数値を10点当たりに換算し，
対数変換を行った後，検定による統計処理を行い，地域間差を検討した。

野生化牛生息域内で飲水場となり得る沼沢地や水溜りを探し，その数と枯渇状態を調べ
た。

結果および考察

調査期間中に確認した野生化牛の頭数とその内訳は表1に示すとおりである。8月の観

野生化牛の群の数とそのサイズを図3および4に示した。8月にはA〜Cの3群，11月にはA〜Eの5群が確認され，8月と11月のA群の構成員3頭はすべて同一個体であり，8月におけるB群のうちの1頭は11月のC群の構成員と同一個体であった。また，8月におけるC群のうちの1頭は11月のC群の別構成員と同一であり，1頭の牛で季節的な群間の移動が起こっていた。メッシュ地図上の位置から，8月のB群と11月のC群，8月のC群と11月のD群はそれぞれ同じ群と推定され，今回の調査では少なくとも2つの群（トシリーアカズラ，トウデーラ，トメイケンタオ，トトイワンタオーイワヤ，ト赤池）が存在し，そのサイズは3〜12頭であることが判明した。五百部・木村（1984）は野生化牛の群のサイズが1〜8頭，中西ら（1998）は少なくとも5群存在し，そのサイズが3〜8頭と報告している。本研究においても群が確認されたが，そのサイズは3〜12頭と若干大きかった。

表1. 口之島東南部で生息を確認した野生化牛の頭数とその内訳

<table>
<thead>
<tr>
<th>毛色</th>
<th>成牛</th>
<th>成長区分</th>
<th>哺乳子牛</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>雄</td>
<td>雌</td>
<td>不明</td>
</tr>
<tr>
<td>黒毛</td>
<td>4</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>黒毛白斑</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>稀毛</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>稀毛白斑</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>小計</td>
<td>2</td>
<td>7</td>
<td>9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>毛色</th>
<th>成牛</th>
<th>成長区分</th>
<th>哺乳子牛</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>雄</td>
<td>雌</td>
<td>不明</td>
</tr>
<tr>
<td>黒毛</td>
<td>4</td>
<td>10</td>
<td>16</td>
</tr>
<tr>
<td>黒毛白斑</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>稀毛</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>小計</td>
<td>6</td>
<td>13</td>
<td>2</td>
</tr>
</tbody>
</table>
図3．2001年8月における口之島野牛化牛の群の数とそのサイズ
図中島内一周道路上の短い太線は東・西ゲート

図4．2001年11月における口之島野牛化牛の群の数とそのサイズ
図中島内一周道路上の短い太線は東・西ゲート
表2. フランネル法*によるマダニ採取個体数

<table>
<thead>
<tr>
<th>地域名</th>
<th>調査時期</th>
<th>2001年8月17日</th>
<th>2001年11月5日</th>
</tr>
</thead>
<tbody>
<tr>
<td>アカズラ</td>
<td>—**</td>
<td>9,960</td>
<td></td>
</tr>
<tr>
<td>三千木</td>
<td>13,867a</td>
<td>1,900b</td>
<td></td>
</tr>
<tr>
<td>メイケンタオ</td>
<td>4,647</td>
<td>2,180</td>
<td></td>
</tr>
<tr>
<td>セランマ(1)</td>
<td>8,667</td>
<td>1,300</td>
<td></td>
</tr>
<tr>
<td>セランマ(2)</td>
<td>7,767c</td>
<td>1,980d</td>
<td></td>
</tr>
</tbody>
</table>

*0.7〜1.0mのフランネル布を1カ所につき10m曳引して布に付着したマダニの個体数を記録
**欠測値

a,b P < 0.05, c,d P < 0.10 (対数変換後にt検定)

フランネル法によって採取したマダニ個体数を表2に示した。8月においては三千木で最も多く、採集したマダニ類はすべてキチマダニ（Haemaphysalis flava）であった。11月においてはアカズラで最も多く、キチマダニとフタトゲリマダニ（Haemaphysalis longicornis）が地点によって個体数に多少違いがあるものの、ほぼ同じ割合で採取された。また、マダニ個体数は11月よりも8月で多い傾向を示し、季節による違いが示唆された。キチマダニは小型ビロブラジウス症を媒介しないが、フタトゲリマダニは本症を媒介する（神尾, 1998）とされており、野生化牛あるいは黒毛和種で本症が発生した場合の他方への感染が危惧され、蔓延を防止するための衛生対策を講じる必要性が考えられた。

野生化牛の生息地内にはセランマ温泉の泉源以外、2カ所の水場が確認され、水際で観察されたフィールドlabel（足跡や排泄物）から野生化牛はそこで飲用しているものと推察された。ただし、水量は比較的少なかったため、前報（中西ら, 1998）でも指摘したように、夏季高圧豆雨時の水場の枯渇が懸念された。

以上のことから、2001年における野生化牛の生息確認頭数は1999年までの頭数よりも減少しており、これには夏季高圧豆雨時の水場の枯渇、道路のコンクリート舗装に伴う飼料資源（路肩のイネ科草本）の減少、外部および内部寄生虫による感染症の蔓延などが影響しているものと推察された。

謝辞

本研究を遂行するに当たり、聞き取り調査にご協力いただいた口之島島民の方々に衷心より感謝する。

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NECROSIS AND REGENERATION OF THE SKELETAL MUSCLE WITHOUT A MARKED HEMORRHAGE INDUCED IN THE RAT BY ENVENOMATION OF TRIMERESURUS FLAVOVIRIDIS VENOM AND ITS COMPONENTS, PHOSPHOLIPASE A2 ISOZYMES

Motoo KITANO, Masato HIRANO, Takashi ISHIHARA, Taketomo HASHIMA, Eri UMEMURA, Aichi YOSHIDA, Shosaku HATTORI, Naoko UEDA, Motonori OHNO

Abstract

A histopathological study of the lesions caused by sublethal doses of Trimeresurus flavoviridis (Tf) venom injected into the anterior thigh muscle (quadriceps femoris muscle; QFM) of rats was done. A dose of 50μg of Tf venom (crude venom, and three kinds of the phospholipase A2 isozymes of Tf venom; [Asp^{49}]PLA₂, BPI and BPII) produced a large area of necrosis in QFM. Myonecrosis was evident 30 minutes after the injection, and over the following 72 hours the necrotic muscles remained acellular and devoid of inflammatory reaction except at the very edge where liquefaction necrosis associated with inflammatory infiltrate was marked from the beginning. Blood vessels in and around the necrotic foci were often involved in inflammatory changes and thrombosis, to some degree. However, marked hemorrhage was never noted. Phagocytosis of debris proceeded from the periphery, and after 24 hours the muscle was replaced by granulation tissue containing many regenerating myoblasts. Interestingly, the myonecrogenic Tf venom itself may cause marked and extensive activation of muscle fiber regeneration, and the venom seems to be a great myotoxin but not a hemorrhagic toxin for the rat.

Key words: Trimeresurus flavoviridis(Tf), Envenomation, Myotoxin, Skeletal muscle, Quadriceps femoris muscle (QFM), Myonecrosis, Regeneration, Myoblast, PhospholipasesA2 isozymes, Hemorrhage

Introduction

Envenomation of Trimeresurus flavoviridis (Tf) snake venom causes two main symptoms, one local and the other systemic in humans. The local symptoms are severe pain, swelling, hemorrhage and necrosis in compliance with the bitten extremity, result in permanent disability or amputation (HOMMA and Tu, 1971). In the Amami islands of Kagoshima Prefecture, this accident accounts for about 90% of snake bites. Subsequently, experimental pathological studies with the venoms of the snake have centered on local muscle necrosis and on local hemorrhage (HOMMA and Tu, 1971).

We have examined the short term effects of the various components of Tf venom on rat skeletal muscle, quadriceps femoris muscle (QFM), with closer attention to impairment, necrosis and regeneration of muscle fibers, the latter occurring even at the earlier stages. Moreover, the rats have shown a strong resistance to hemorrhage by envenomation of Tf venom. Renewed interest in this venom has stemmed from our recent studies of its action on muscle and vascular wall of the rat and from its fractionation of the venom, which may shed light on the pathogenesis of local
lesions caused by the snake bites.

This article is written based upon an oral presentation to Symposium I *Habu (Trimeresurus flavoviridis)* in Amami Islands at the 26th Kyushu Regional Meeting of the Japanese Society of Tropical Medicine, held on January 26, 2002, in Kagoshima. Interested readers may refer to the original publication for detailed data (KITANO et al., 2001).

**Materials and Methods**

**Venom and its phospholipase A₂ isozymes**

*Tj* venom was collected in Amami-Oshima island and lyophilized. Its phospholipase A₂ (PLA₂) isozymes, [Asp⁴⁹]PLA₂, BPI and BPII, the latter two being [Lys⁴⁹]PLA₂s, were separated by conventional chromatographies at Sojo University (LIU et al., 1990; KIHARA et al., 1992). The crude venom and PLA₂ isozymes were weighed and dissolved in sterile physiological saline just before use.

**Experimental design**

Young adult female and male rats of F344, Dark-Agouti, Wistar/Furth strains were divided into two to five groups, each group consisting of 6 rats (total; 90) (Table 1).

The rats were anesthetized with pentobarbital sodium (Nembutal). The crude venom and three PLA₂ isozymes (50μg each) in 100μl physiological saline were injected into each rat of four groups at the upper two-thirds of the right QFM. The fifth group, the control rats, were similarly injected with 100μl of only physiological saline.

The animals were allowed to survive for the periods ranging from 30 minutes to 72 hours and were sacrificed under ethyl ether anesthesia. Both the right and left hindlimbs, the visceral organs and brain were immersed for several days in 10% buffered formalin (pH 7.4), and processed for paraffinic embedding. The sections of 5-6 μm thickness were stained with hematoxylin and eosin for histopathological examination.

**Histopathological Findings**

The muscle tissue injected with only physiologic saline had a typical histology of skeletal muscle with no abnormality in muscle fibers, nerves or blood vessels.

In the rats inoculated with toxins, no significant differences were detected among the four kinds of toxins, among three strains of rats and among female and male rats, so we preferred to describe here all together.

There was a more or less marked sign of liquefaction necrosis with a depressive or atrophic features of the muscle masses of QFM in the venom-injected right hind leg. A close examination of the injected QFM revealed an absence of marked hemorrhage except for a few rats (Fig. 1).

As early as 30 minutes after the inoculation of *Tj*-venom, there were groups of affected cells accompanied by the decrease of fine cytoplasmic structures to some degree, which were located in the periphery of the muscle. At this time edema without inflammatory cells were observed, and many of the skeletal muscle cells presented edematous swelling.

Six hours after injection, the necrosis of muscle fibers in QFM was indicated by nuclear pyknosis and fragmentation of the myofibrils into homogenous eosinophilic masses separated by empty-looking segments. The earliest alterations seem to take place in the periphery of the necrotic focus where a very mild inflammatory infiltrate was observed at this time.

After the elapse of 24~48 hours there was widespread myonecrosis (Fig. 2); the myofibrillar
**Table 1. Experimental rats with snake venom injection into the QFM.**

<table>
<thead>
<tr>
<th>Venom of snake (Pf)</th>
<th>Duration</th>
<th>N of rat*</th>
<th>Skeletal muscle fibers and endomysium</th>
<th>Perimysium, epimysium and surrounding connective layers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Necrosis</td>
<td>Inflammatory infiltration</td>
</tr>
<tr>
<td>Crude venom</td>
<td>30m</td>
<td>6</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>6h</td>
<td>6</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>24h</td>
<td>6</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td></td>
<td>48h</td>
<td>6</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td></td>
<td>72h</td>
<td>6</td>
<td>+++</td>
<td>++</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>30</td>
<td></td>
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<tr>
<td>[Asp49] PLAs</td>
<td>24h</td>
<td>6</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>48h</td>
<td>6</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Total</td>
<td></td>
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</tr>
<tr>
<td>BPI</td>
<td>24h</td>
<td>6</td>
<td>++</td>
<td>++++</td>
</tr>
<tr>
<td></td>
<td>48h</td>
<td>6</td>
<td>++</td>
<td>++++</td>
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<tr>
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</tr>
<tr>
<td>BPIi</td>
<td>24h</td>
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<td>++</td>
<td>++++</td>
</tr>
<tr>
<td></td>
<td>48h</td>
<td>6</td>
<td>++</td>
<td>++++</td>
</tr>
<tr>
<td></td>
<td>72h</td>
<td>6</td>
<td>+</td>
<td>+++</td>
</tr>
<tr>
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<td>Control (physiological saline)</td>
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<td>6</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>24h</td>
<td>6</td>
<td>-</td>
<td>-</td>
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<tr>
<td></td>
<td>48h</td>
<td>6</td>
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<tr>
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<td>Rat, total N</td>
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*One group consists of male and female rats of three strains (F344, Dark-Agouti, Wistar/Furth). However, there is neither strain nor sex differences in the essential histopathological changes among venom kinds and duration.

**Inflammatory changes are noted in the medium-sized vascular walls. Th means thrombosis.**

# Necrotic changes are noted in the fatty tissue around the fascia.
material in necrotic cells was more amorphous and its distribution within the cellular space was more homogeneous, instead of being dense and clumped masses (Fig. 3). A marked and dense inflammatory infiltrate was present outside the necrotic cell nests. There was little hemorrhage at this or later times, although edema was considerably marked. Simultaneously, regenerative proliferation of myoblasts. The regenerating cells were spindle in shape with scanty basophilic cytoplasm and a central nucleus, some revealing mitotic activities at 48 hours (Fig. 4). Muscle regeneration was observed in the peripheral fibers of necrotic muscles, but the inner parts of those muscles appeared still necrotic. The regenerating cells gradually became hypertrophic with an acidophilic light cytoplasm at 72 hours. Muscle regeneration was observed in the peripheral fibers of necrotic muscles, but the inner parts of those muscles appeared still necrotic. The regenerating cells gradually became hypertrophic with an acidophilic light cytoplasm at 72 hours. The muscle tissue examined histologically 8 weeks after the onset of muscle necrosis was characterized by the presence of abundant regenerated muscle cells with centrally-located nuclei and a diameter similar to that of normal muscle cells, indicating that regeneration took place successfully (data, not shown).

There was little hemorrhage through the whole duration. Most blood vessels looked normal, but in some animals inflammatory infiltrate was noted in the vascular walls and platelet thrombi were found in some medium-sized veins and arteries, occasionally forming occlusive masses. There were several peripheral nerves showing marked edema of the endoneurium, but no apparent structural disintegration was found.

Fig.1. A large necrotic lesion in the QFM of a F344 male rat 48 hours after the inoculation of the crude venom of Tf. Note the severe and extensive atrophy of the skeletal muscles of the anterior thigh due to liquefaction necrosis (arrow heads). Slight focal hemorrhage is noted in the necrotic area.

Fig.2. Massive necrosis of the QFM of a F344 male rat 48 hours after the inoculation of the crude venom of Tf. Marked reactive changes (Re) are seen in the peripheral areas of the necrotic layer, most of which is composed of exudated inflammatory cells and regenerated myoblastic cells. There is no detectable hemorrhage in this case.
Necrosis and regeneration of the skeletal muscle without a marked hemorrhage induced in the rat by envenomation of Trimeresurus flavoviridis venom and its components, phospholipase A\(_2\) isozymes

**Discussion**

Thirty minutes after the injection of \(Tf\) venom, initial changes of muscle fiber necrosis was widespread in QFM, where most blood vessels looked normal and contained no thrombi. These findings show that necrosis is an early event, which probably results from a direct action of the venom on the muscle fibers.

On the other hand, muscle necrosis by the local inoculation of various kinds of snake venoms is usually followed by the rapid phagocytosis of debris at the periphery of the necrotic area. The clearing of necrotic material by phagocytes was followed by a rapid regeneration process. Myoblasts were observed 24 hours after the onset of myonecrosis, and by 8 weeks regeneration was complete. The success of regeneration after myonecrosis induced by \(Tf\) myotoxin might be due to the fact that neither nerves nor blood vessels are markedly affected by this toxin, since adequate blood supply and innervation are essentially requirements for the muscle regeneration (QUEIROZ et al., 1984; GUITIERREZ et al., 1989).

The most striking effects produced by the injection of many snake venoms, including venom
of $T_I$, are local, consisting of marked hemorrhage, myonecrosis, and edema in animals (OHSAKA et al., 1960; OKONOGI et al., 1960; LOMONTE et al., 1994). It is well known that the pathological signs characteristic of $T_I$ bite in humans, rabbits and mice are marked by extensive hemorrhage and necrosis (OKONOGI et al., 1960). Our experimented rats, however, failed to demonstrate that hemorrhage was a predominant sign of snake venom injection. We used three strains of rats and four kinds of preparations of $T_I$ venom for our experiments. In spite of the difference of strains of rats and kinds of venom-preparations, we could not note marked hemorrhage in and around the injection area, although a few rats showed focal slight hemorrhage in the necrotic areas.

It is of great interest whether or not the same principle is responsible for necrosis and hemorrhage. Many researchers stated that hemorrhage is due, at least in part, to the action of myonecrotic enzymes, such as phospholipase A2 (LOMONTE et al., 1994). Concerning local hemorrhage, our results did not agree with the general view that snake venoms produce bleeding at the site of injection. Pathological observations indicated that the easily discernible local changes produced in the humans, rabbits and mice by $T_I$ bite injury were hemorrhage. However, in the present experiment, $T_I$ venom did not give rise to any prominent bleeding locally, but produced myolysis with edema, in the rats.

Some investigators have suggested that proteolytic enzymes are factors in hemorrhage and necrosis (OHSAKA et al., 1960; OKONOGI et al., 1960). Our observations concerning the degree of hemorrhage and necrosis were not always in parallel with proteolytic activities. Furthermore, there is a report that a crystalline trypsin produces local hemorrhage and almost no myonecrosis (HOMMA and TÜ, 1971). This seems to indicate that both changes depend not only on proteolytic enzymes, but also on other enzymes or factors.

A few reports have described the occurrence of vascular lesions in a poisonous snake bite (MANDELBAUM et al., 1989; MATSUI et al., 2000; ESTEVAO-COSTA et al., 2000). It was confirmed that the venoms containing both myonecrogenetic and hemorrhagic activities, crotalinae and vipersinae venoms, inflicted damage on the arteries and that the venoms devoid of hemorrhagic activity, elapidae venoms, fail to cause significant changes in the arterial walls. The important changes responsible for developing arterial lesions appear to be the injury of the endothelium and the disintegration of the media. It has been reported that $T_I$ venom attacks the endothelium and smooth muscles of the media when the venom is injected close to the arteries. This suggests that both hemorrhagic and myonecrogenetic factors play an important role in the involvement of local blood vessels (MATSUMI et al., 2000).

In conclusion, the $T_I$ venom seems to be a great myotoxin but not a hemorrhagic toxin for the rat. Simultaneously the myonecrogenic $T_I$ venom itself may cause marked and extensive activation of muscle fiber regeneration.

Acknowledgements

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NECROSIS AND REGENERATION OF THE SKELETAL MUSCLE WITHOUT A MARKED HEMORRHAGE INDUCED IN THE RAT BY ENVENOMATION OF TRIMERESURUS FLAVOVIRIDIS VENOM AND ITS COMPONENTS, PHOSPHOLIPASE A2 ISOZYMES


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