Potential for Gulf of Mexico Deepwater Petroleum Structures to Function as Fish Aggregating Devices (FADs) – Scientific Information Summary and Bibliography

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Gulf of Mexico OCS Region
PROJECT COOPERATION

This study was performed to meet information needs identified by Minerals Management Service (MMS) in concert with the U.S. Geological Survey.

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### ACRONYMS

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<tr>
<th>Acronym</th>
<th>Full Form</th>
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<tbody>
<tr>
<td>AR</td>
<td>artificial reef</td>
</tr>
<tr>
<td>AT</td>
<td>Association Thoniere</td>
</tr>
<tr>
<td>AFS</td>
<td>American Fisheries Society</td>
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<tr>
<td>BACI</td>
<td>before after control impact</td>
</tr>
<tr>
<td>CD-ROM</td>
<td>compact disk read-only memory</td>
</tr>
<tr>
<td>CPUE</td>
<td>catch per unit effort</td>
</tr>
<tr>
<td>CTD</td>
<td>conductivity-temperature-depth</td>
</tr>
<tr>
<td>DCP</td>
<td>despositifs de concentration des poissons (French term for FAD)</td>
</tr>
<tr>
<td>DPS</td>
<td>deepwater petroleum structure</td>
</tr>
<tr>
<td>EDF</td>
<td>Electricité de France</td>
</tr>
<tr>
<td>EEZ</td>
<td>Exclusive economic zone</td>
</tr>
<tr>
<td>ESP</td>
<td>Explained Sums of Peaks</td>
</tr>
<tr>
<td>FAD</td>
<td>Fish aggregating device</td>
</tr>
<tr>
<td>GOM</td>
<td>Gulf of Mexico</td>
</tr>
<tr>
<td>GTS</td>
<td>Global Telecommunications System</td>
</tr>
<tr>
<td>HTML</td>
<td>Hypertext Markup Language</td>
</tr>
<tr>
<td>IATTC</td>
<td>Inter-American Tropical Tuna Commission</td>
</tr>
<tr>
<td>ICCAT</td>
<td>International Commission for the Conservation of Tunas</td>
</tr>
<tr>
<td>IFREMER</td>
<td>Institut Français de Recherche pour l’Exploitation de la Mer</td>
</tr>
<tr>
<td>IPFC</td>
<td>Indo-Pacific Fishery Commission</td>
</tr>
<tr>
<td>IPTP</td>
<td>The Indo-Pacific Tuna Development and Management Programme</td>
</tr>
<tr>
<td>LIDAR</td>
<td>light detection and ranging</td>
</tr>
<tr>
<td>MBACI</td>
<td>multiple before after control impact</td>
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<tr>
<td>MMS</td>
<td>Minerals Management Service</td>
</tr>
<tr>
<td>MT</td>
<td>metric ton</td>
</tr>
<tr>
<td>NOAA</td>
<td>National Oceanic and Atmospheric Administration</td>
</tr>
<tr>
<td>ORSTOM</td>
<td>Institut Français de la Recherche Scientifique pour le Développement en Coopération</td>
</tr>
<tr>
<td>PIRATA</td>
<td>Pilot research moored array</td>
</tr>
<tr>
<td>PTR2</td>
<td>Regional Tuna Programme 2</td>
</tr>
<tr>
<td>PFRP</td>
<td>Pacific Fisheries Research Program</td>
</tr>
<tr>
<td>PVC</td>
<td>polyvinyl chloride</td>
</tr>
<tr>
<td>SCUBA</td>
<td>self contained underwater breathing apparatus</td>
</tr>
<tr>
<td>SD</td>
<td>Southern Division (American Fisheries Society)</td>
</tr>
<tr>
<td>SPC</td>
<td>Secretariat of the Pacific Community (formerly South Pacific Commission)</td>
</tr>
<tr>
<td>SWIOP</td>
<td>Southwest Indian Ocean Fishery Development and Management Programme</td>
</tr>
<tr>
<td>TAO</td>
<td>Tropical Atmosphere Ocean</td>
</tr>
<tr>
<td>USAID</td>
<td>U.S. Agency for International Development</td>
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<tr>
<td>USGS</td>
<td>U.S. Geological Survey</td>
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EXECUTIVE SUMMARY

Fish aggregating devices (FADs) have been extensively used throughout the world oceans, with a major portion of the total tuna commercial catch now being caught from around them. In 1997, MMS identified the issue of new deepwater petroleum structures (DPSs) in the Gulf of Mexico (GOM) potentially acting as FADs and thus impacting pelagic fish and fisheries.

USGS conducted a project to research, compile, analyze, and synthesize existing scientific information about FADs, fish aggregation, fish attraction, and related processes and phenomena pertinent to GOM DPSs. The project included involvement and participation of U.S. and international FAD scientists through a scientific meeting and follow-up information exchange on the topic of the potential for GOM DPSs to function as FADs.

A computerized bibliographic database containing 465 references pertinent to GOM DPSs was compiled. This bibliography is provided in alphabetically and numerically ordered formats. The bibliography is indexed by key words (148 key words). Abstracts of important, pertinent references are included.

The bibliographic database will be disseminated in various formats, including Acrobat (.pdf), rich text (.rtf), and HTML as a USGS Open File Report (CD). A separate CD with the bibliographic database in Papyrus 7.0 format will be available on request.

Only 30% of the available references were peer-reviewed journal articles or published books; the rest were unpublished proceedings, reports or other gray literature. Less than 15% of the technical key word entries were those categorized as directly related to scientific understanding of FADs and fish aggregation/attraction; most of the remainder were focused on FADs fisheries or fishery-related issues.

FADs can be broken into two, probably differently functioning, main categories, drifting FADs and moored (anchored) FADs. Drifting FADs are now widely used in tuna purse-seine fisheries around the world. Moored FADs have been used most extensively in the Pacific and Indian Oceans and the Mediterranean Sea.

A number of major hypotheses have been proposed in the literature to explain FADs, but only a few (e.g., attraction due to presence of forage species) have been discounted; the rest remain largely untested. This demonstrates the unresolved nature of FADs science.

Tunas, particularly yellowfin tuna, bigeye tuna, and skipjack tuna, are the species that are most aggregated by FADs, and they can be expected to aggregate to GOM DPSs. Tuna aggregations and recreational fishing around GOM DPSs (e.g., Exxon “Hoover/Diana” complex) have already been reported. Other pelagic species may aggregate around GOM DPSs, but probably to lesser degrees than tunas. Benthic fish and invertebrates may utilize DPSs as substrate and habitat, but this topic is outside the main focus of this project and report.
Existing scientific information is insufficient for understanding or predicting potential FADs effects of GOM DPSs. However, spatial and temporal relationships of tunas to FADs are well known and may be useful in assessing GOM DPS effects.

In the few instances where studies have been conducted, object (FAD) characteristics (e.g., color, shape, surface area, volume, epibiota, etc.) have shown little or no relationship to aggregated tuna abundance. Object size similarly has shown no relationship to FADs effects, as long as minimum dimension is greater than about one meter.

Based on information on FADs in other places, a number of ramifications of DPS deployment in the GOM are possible. Primary ecological effects could include: a) changes in species distributions, b) changes in species movement and migration patterns, and c) changes in spawning and larval survival/recruitment. Secondary effects of DPSs acting as FADs may include: a) increased fishing mortality, b) changes in population age structure, e) changes in commercial and recreational fisheries, d) changes in fisheries bycatch within FADs-associated fisheries, and f) changes in fishery management and monitoring. Most primary effects would be negative, whereas secondary effects could be either positive or negative. Important recreational fisheries (as well as some commercial fisheries) may spring up in areas of DPS deployment, but existing FADs knowledge indicates that any such enhancement will be due to attraction instead of production.

If FADs effects of GOM DPSs are to be assessed and quantified, direct studies will be needed, rather than extrapolation or inference from existing scientific information. A number of techniques have been successfully used to assess and understand FADs and could be used to study GOM DPS FADs effects; they include acoustic telemetry and tracking, automatic acoustic monitoring, hydroacoustic surveys, combined acoustic tracking and hydroacoustic survey, tagging/recapture studies, fishery-dependent monitoring, fishery-independent monitoring, exploratory fishing, and mathematical modeling. If GOM DPSs are to be directly studied to evaluate their FADs effects, it is important that such studies be done soon, before so many DPSs have been deployed that natural distributions and movements will already have been substantially altered.

Some of the uncertainty about FADs effects of GOM DPSs has to do with uncertainty inherent in the rapidly developing and evolving technology of deepwater petroleum exploitation; scenarios and estimates of future deepwater development are needed. Given this dynamic state of deepwater development, it is likely that DPS FADs effects will have to be studied over time. Early study and assessment, however, could begin to provide managers with reasonable evidence as to whether DPS impacts on GOM pelagic fisheries may or may not be substantial.
INTRODUCTION

Background.—The fact that large pelagic fish are attracted to floating objects in the open ocean has been long known, probably since people first began to build boats and make ocean voyages. Although fishermen have long recognized and utilized the propensity for fish to be attracted to and aggregate near floating objects (177), it was not until the 1970’s that floating objects began to be purposely deployed as fish aggregating devices (FADs) (126). Shortly thereafter, the use of FADs grew explosively, first in the eastern Pacific Ocean, then in the western Pacific and Indian Ocean in the 1980’s, and finally in the Atlantic in the 1990’s (283). FADs were found to be highly effective in attracting and aggregating a large suite of pelagic fish species, especially tunas. In recent years, more than half of the world commercial tuna catch has been caught from around FADs (283), thus demonstrating the strength and significance of the phenomenon of fish aggregation to floating objects. Consequently, scientific interest and research on FADs phenomena and fishery impacts was stimulated and initiated. Recently, scientists have raised a large number of questions about potential important negative effects of FADs on fish and fisheries, including ecological as well as fishery effects. The most important negative ecological effects involve changes in movements and migration arising from the strong attraction to FADs. Some scientists have even proposed that FADs may act as “ecological traps” (252).

Relevance.—Starting in the mid 1990’s the petroleum industry in the northern Gulf of Mexico (GOM) began to rapidly expand into deep waters (depths greater than 1,000 ft or ~300 m) (183). The Minerals Management Service (MMS) convened the Workshop on Environmental Issues Surrounding Deepwater Oil and Gas Development (165) in 1997. In that meeting, MMS raised the issue of the potential for deepwater petroleum structures (DPSs) to impact Gulf of Mexico (GOM) fish and fisheries by acting as FADs. That workshop also identified the need for examination of existing scientific information pertinent to this issue.

Response.—The U.S. Geological Survey (USGS), in its role of addressing information needs of the Minerals Management Service (MMS), developed a project aimed at finding, examining, compiling, and analyzing existing scientific information on FADs and related topics pertinent to the potential FADs effects of GOM DPSs. The purpose of this project was to provide a tool with which MMS and other involved parties could determine the degree to which existing science could be used to assess the potential impacts of deployment of large numbers of petroleum structures in deep waters of the northern Gulf of Mexico.

Product.—This report and included bibliographic documents provide compilation, synthesis, and analysis of scientific information on FADs and fish aggregation from the perspective of potential impacts of deepwater GOM DPSs on pelagic, highly-migratory fish species. The nature of the report and project is mission-oriented, applied (to GOM DPS FADs issues), and practical rather than academic. However, it also provides a detailed compendium of FADs information that should be generally useful to FADs scientists and resource managers.
METHODS

**Bibliographic Data Search and Acquisition.**—Standard bibliographic methods were used to search for existing FADs literature. Online, computer-searchable databases were searched for references that include FAD-related terms in their title, abstract, or key words. Primary emphasis was placed on published, peer-reviewed journal articles. Conference and symposia proceedings were also thoroughly searched. Where possible, gray literature, including reports and non-journal articles were included. Additional information was obtained by searching the Internet and popular literature (e.g., magazines).

Literature identified above was reviewed and examined for FAD-related references. Any such references were in turn examined for further references. Further identified references were added to the bibliographic database. This process was iterated until additional references were not found. References pertinent to GOM DPSs were reviewed, entered into the bibliographic database, keyworded, and abstracts were added (copied if available, written if unavailable). Key word assignment was necessarily subjective and conservative, with key words not assigned unless they were a significant component of the reference. Copies of directly pertinent references were made or ordered through interlibrary loans, or in some cases were available from online sources.

**Bibliographic Data Management.**—References were compiled into a bibliographic database management system program (Papyrus Ver. 7.0, Research Software Design). The system allows full entry and management of reference citations, including abstracts, comments, and key words. It includes facility for searches for terms, key words, titles, dates, authors, journals, etc. Bibliographies can be output into various formats adjusted for style and content.

**Dissemination.**—The bibliographic sections, along with the report text will be made available and disseminated on CD-ROM in hypertext markup language (.html), Adobe Acrobat (.pdf) and rich text (.rtf) formats (on the same CD). The bibliographic database (Papyrus files¹) will be provided as a separate CD. This will allow readers to access and use the information in ways that are most effective and convenient for their individual applications. The first CD will be distributed and made generally available as a USGS Open-File Report, while the latter will be made available upon request.

**Interim Publication/Project Report.**—Early findings and conclusions based on preliminary bibliographic searches and analyses pertinent to the Gulf of Mexico were presented at a MMS sponsored meeting: Gulf of Mexico Fisheries: Bringing Together New and Recent Research (October 24-26, 2000, New Orleans, LA). A paper was prepared and submitted for publication in the meeting proceedings (158).

**FADs Technical Session.**— In order to insure that scientific literature, information and understanding of FADs had been thoroughly researched, information exchange with

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¹ Registered copies of Papyrus or freeware Papyrus Retriever (read only) can be used to search and manipulate the database.
prominent FADs scientists was developed. This was accomplished by convening a technical meeting bringing important FADs scientists together to discuss GOM DPS FADs issues.

A proposal (Appendix A) was developed and submitted to the organizing committee for the American Fisheries Society (AFS), Southern Division (SD) Midyear Meeting, Feb 22-25, 2001, Jacksonville, Florida. Six months prior to submission of the session proposal, the preceding AFS SD Midyear Meeting (Savannah, GA) was attended and preliminary contacts and arrangements for the session were made.

Prominent FADs scientists and pertinent resource managers were identified from important FADs literature, and a select group was contacted and invited to participate as technical presenters or as part of a panel discussion group. An extensive contact database of marine research and management institutions and individuals was developed and used to disseminate a session announcement flier (Appendix B). Selected individuals were contacted, directly by mail, email, or telephone, and were urged to attend. Special emphasis was placed on obtaining participation by a full spectrum of national and international FADs research experts, federal, regional, and state resource management agencies, and representatives of the petroleum industry.

After the session, participants were contacted directly through a series of email messages to solicit their comments about the session, suggestions for future research or management activities, and ideas about need and possible venue for a follow-up meeting/session. Participants were provided with a preliminary copy of the bibliography and were asked to provide citations to important literature not yet included.
RESULTS

**Bibliographic Database Composition.**—The bibliography includes 465 references. Of these, only 140 (30%) are peer-reviewed journal articles; four are published books. The rest are non-peer-reviewed symposia/meeting proceedings, unpublished reports, or other gray literature, references to information available only from the Internet, or popular articles. The earliest reference (Kojima, 1956) was the only reference earlier than the 1960’s, for which period five references were identified. There were 19 references from the 1970’s, 106 from the 1980’s, 250 from the 1990’s and 82 from 2000 or later.

The bibliography is provided (attached) in the following hard-copy formats:
- Alphabetic List of References
- Numeric List of References
- Abstracts – Alphabetic List

The alphabetic (author) list of references includes full citation (AFS format and style, except with full journal names), plus a list of key words for that reference. The numeric list consists of the same references (without key words) ordered by reference number (from computerized data base) and is provided to allow citations be made by reference numbers in this report. Abstracts are provided separately and are listed alphabetically by author (without full citations or key words).

A total of 148 key words were developed by combining key words cited in references with those added from reading and analysis of references. Key words were listed in an alphabetic (all) list with each key word followed by a list of references citing that key word, and the total number of references (ranging from one [11 key words] to 370 [one key word]) to which the key word applies.

To facilitate manual search and perusal of the references by key words, the following cross-indices are provided:
- Geographic
- Taxonomic
- FADs Operational/General
- Aggregation and Attraction (to FADs and Objects) Related Phenomena/Processes
- FADs Research/Study Techniques
- Fisheries Related
- Bibliographic
- Miscellaneous

**FADs Information Availability and Character.**—A large body of information about FADs exists. Although the bibliography includes a total of 465 references, most are focused on specific FADs fisheries or fishery applications, and most of these have little pertinence to scientific understanding of how FADs function or how GOM petroleum structures may function as FADs. Much of the literature derives from early development of moored FADs as a fishing technique (e.g., 7, 8, 11, 12, 16, 59, 289) and programs for further deployment

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2 Depending on how certain publications are categorized (e.g., ICCAT, SCRS).
of FADs and development of artisanal and commercial fisheries of oceanic island nations in the Pacific and Indian oceans \((3, 57, 246, 278, 301, 367, 368, 387, 447)\). Many other publications focus on practical subjects such as FADs design and technology, and associated fishing techniques, and are of little pertinence or value to understanding GOM DPS issues. In compiling the bibliography, all FADs-related references were included if they could be identified and obtained through normal library resources. Publications and reports with content limited to local, artisanal fisheries or catch statistics for FADs fisheries were included if they could be obtained, although generally they are of little value for analysis of DPS FADs issues.

Information on phenomena and processes related to attraction and aggregation of fish to objects was limited, and the bibliography included only 314 such key word entries (keyword index category “Aggregation and Attraction [to FADs and Objects] Related Phenomena/Processes”) out of 2,205 technical key word entries (excluding bibliographic key words). This proportion \((14\%)\) is a measure of the limited degree to which existing FADs literature has value or application with regard to understanding potential impacts of GOM DPSs. Although the information directly useful for understanding GOM DPS FADs issues is limited, there are a few areas that are of clear utility for understanding and predicting DPS FADs impacts.

**Types of FADs.**—The literature separates FADs into two main categories: 1) drifting FADs and 2) moored (anchored) FADs. Drifting FADs includes natural floating objects such as trees, floating algae, and even whale carcasses; as well as man-made objects such as shipping containers, pallets, and floating structures that are specifically designed and constructed to be deployed as devices that attract and aggregate fish. Moored FADs usually are designed and deployed to aggregate fish, although some large moored buoys (e.g., weather buoys) aggregate fish and are exploited by fishermen \((326)\). GOM DPSs include a variety of types of structures and components \((183)\), so it is uncertain as to whether they would function more like drifting FADs or moored FADs. It is unknown whether fish aggregate for the same reasons around drifting and moored FADs \((203)\).

**Species.**—The three species that are most aggregated by FADs and most important to FADs fisheries throughout the world oceans are yellowfin tuna \((Thunnus albacares)\), skipjack tuna \((Katsuwonus pelamis)\), and bigeye tuna \((Thunnus obesus)\). These three species are listed as key words in 63, 47, and 29 references respectively, and are mentioned prominently in many other publications in which they are not listed as a keyword. All three are found in the GOM and commercially harvested, although not as intensively as in most other oceans or seas. These three species, due to their great affinity and attraction to almost all objects in the open sea, can be expected show some attraction and aggregation to GOM DPSs. Yellowfin tuna are already known to concentrate around GOM DPSs, and are caught there by recreational fishermen \((207)\). Skipjack have been taken in commercial quantities from around FADs deployed near Cuba \((131)\).

Information available to predict whether bluefin tuna \((Thunnus thynnus)\) may aggregate around GOM DPSs is sparse. Bluefin tuna are attracted to FADs in the Mediterranean
An important recreational fishery exists off Cape Hatteras, NC, where many large bluefin aggregate near wrecks, further suggesting their propensity to aggregate to objects. The GOM is the only known spawning grounds for the Western Atlantic stock of bluefin tuna (460), and it has been suggested that if they are attracted to and aggregated to DPSs during their spawning season, they may spawn in sub-optimal environments, causing important negative effects on reproduction and recruitment (458) of a species that is already considered to have been reduced to near-extinction population levels (459).

Dolphin (AFS common name, also called dolphinfish, dorado, and mahi-mahi in some places) (*Coryphaena hippurus*) is another species that aggregates around moored and drifting FADs in abundances high enough to support commercial fisheries. Given its well-known tendency to aggregate around floating objects and to be caught around FADs (36, 128, 189, 199, 291, 311, 312, 325, 414, 423, 456, 457), and because the species is abundant in the GOM, dolphin can be expected to be attracted to GOM DPSs.

Other important GOM species known to aggregate and be caught around FADs include: blackfin tuna (*Thunnus atlanticus*) (243, 282, 298, 323), amberjack (*Seriola dumerili*) (128, 191, 192, 199, 291, 410), wahoo (*Acanthocybium solandri*) (84, 282, 290, 312, 368, 410, 412, 415, 423), sharks (161, 164, 198, 199, 203, 290, 410, 412, 415, 423, 427), rainbow runner (*Elagatis bipinnulata*) (36, 84, 443), and marlins (290, 368, 412, 414, 415, 423, 427, 436). Blue marlin (*Makaira nigricans*) are targeted and caught by recreational anglers fishing near GOM DPSs (207).

Coastal pelagic species, such as king mackerel (*Scomberomorus cavalla*) and cobia (*Rachycentron canadum*), also will be attracted and aggregated to DPSs, but their presence would be expected to be less than that reported for shallow rigs (282) that are present in their inshore, primary habitats. Coastal pelagics are outside the main focus of this report and bibliography.

Benthic fish and invertebrates may utilize DPSs as artificial substrate and habitat, as has been well documented for petroleum structures in shallower waters (110, 153, 204). Such structures may provide “islands” of habitat for rare or unusual species (110), particularly by providing habitat for larval settlement and recruitment. Since the focus of this project is aggregation of pelagic species, this project was not designed to research the extensive literature on benthic species relationships to artificial structures.

**Hypotheses.**—A number of hypotheses have been put forward to explain FADs. The hypotheses explaining the association between fish and floating objects (203) include:

- Concentration of food supply hypothesis* (407).
- Schooling companion hypothesis* (178).
- Substitute environment hypothesis* (178).
- Cleaning station hypothesis* (176).
- *Shelter from predator hypothesis* (176).
- *Spatial reference hypothesis* (146).
- Comfortability stipulation hypothesis* (164).
Generic-log hypothesis (and related hypotheses) (424).
Meeting point hypothesis (380).

Review of the hypotheses (308) has eliminated concentration of food as obviously invalid for schooling fish around FADs, and has combined or eliminated several others (*), leaving four major hypotheses (bold).

These remaining hypotheses can be summarized as follows (308): a) the shelter from predator hypothesis proposes that fish aggregate around objects because they can be used by prey as a refuge, b) the spatial reference hypothesis proposes that fish aggregate around objects because objects provide spatial reference points to which fish can orient in the otherwise unstructured pelagic environment, c) the generic or indicator log hypothesis is based on the fact that natural floating objects are often indicators of productive areas (e.g., Langmuir cells), and d) the meeting point hypothesis suggests that objects can be used to increase encounter rate between isolated individuals or small schools and other schools.

The fact that such disparate and possibly interacting hypotheses exist and are as-yet untested, indicates how relatively little is understood about fish attraction and aggregation to objects. It further shows that in-depth understanding of how GOM DPSs may attract and aggregate fish is not possible from present scientific understanding of FADs.

Spatial/Temporal Relationships.— Spatial relationships between tunas and moored FADs is another area in which scientific consensus exists. Tuna remain close, within 1.8 km to FADs during the day and move away from FADs during the night (4, 260). The attractive influence of a FAD for adult yellowfin tuna disappears at around 9 km (4), and the radius of influence of a FAD for juvenile yellowfin tuna and juvenile bigeye tuna is about 5 nautical miles (9.3 km) (260). These conclusions were obtained through acoustic tracking studies. They agree with modeling studies that find that presence of four or five FADs in a 50 km x 50 km area reduces movement of skipjack out of the area by 50% (454). These findings are of direct value in projecting or estimating the effects of GOM DPSs. However, the future spatial distribution of DPSs is itself uncertain, because deepwater petroleum exploitation is evolving and changing.

Object Characteristics and Size.—Little is known about how object characteristics affect the degree to which fish aggregate to it, and only three references (417, 420, 442) addressed this topic directly. No clear relationships were found between aggregation (as measured by catch) and object characteristics including material, shape, color, surface area, volume, and epibiota (417, 420). Only two references addressed the topic of the effect of object size (159, 420). Size of drifting objects was found to be unimportant as long as the minimum dimension was greater than about 1 m (420). Effects of object characteristics and size have not been evaluated for moored FADs.

Interim Publication/Project Report.— Based on initial review of extensive, but not exhaustive, compilation of FADs literature and information (457), we reached a number of
interim conclusions that helped guide the project. These conclusions were all consistent with the final project conclusions.

These conclusions and hypotheses included:

- FADs recently had been deployed and used effectively around the world, but not extensively in the Gulf of Mexico.
- In almost every instance in which they have been used, FADs have been shown to have large effects on fish and fisheries, particularly tunas.
- Many highly migratory pelagic fish species are greatly attracted and aggregated by FADs.
- A number of FADs issues and problems have been identified, including increased catch of smaller/younger fish and potential impacts on distribution and migration.
- Species aggregated by FADs included a number of species present and important in the Gulf of Mexico, including: yellowfin, skipjack, blackfin, and bluefin tuna.
- Therefore, it is likely that GOM deepwater petroleum structures will have measurable impacts on fish and fisheries.
- Processes and factors involved in fish aggregation by floating objects are complex and scientifically not well understood.
- A preliminary review of FADs literature and information suggested that available science would be insufficient for predicting the types and degrees of impacts.
- Directed research and study may be needed to assess and estimate GOM DPS impacts.

Rigs and FADs Technical Session.—The daylong session was held on February 24, 2001 as part of the SD AFS midyear meeting in Jacksonville, FL. It included 13 technical presentations (Appendix C) by U.S. and international experts. Abstracts of presentations are provided in Appendix D. A panel discussion followed and included participation of representatives from regional (Gulf of Mexico Fishery Management Council) and federal (National Marine Fisheries Service, Highly Migratory Species Division) fishery management agencies, the GOM oil and gas industry, recreational fishing interests, invited speakers, and session attendees.

Follow-up responses from FADs experts indicated that the session had been well received, and that the preliminary bibliography had no major omissions or deficiencies. A few, mainly peripheral, citations were offered and added.
Some of the significant follow-up comments included:

- It is critical to determine the potential impact on migrating/spawning adult bluefin tuna.
- It would seem that information on FADs effects of petroleum structures in other parts of the world should be available, but the experts do not know of any.
- More emphasis on fishery management issues particular to GOM DPSs impacts is needed in any subsequent meetings.
- Information on GOM tuna movements is needed, and if not available, tagging studies should be conducted.
- More information on types and distribution of GOM DPSs (present and future) is needed.
- More information on existing GOM commercial and recreational fisheries is needed.
- Directed studies are needed in order to determine FADs effects of DPSs.

Most of the contacted participants were enthusiastically in favor of a follow-up meeting or technical session. Suggestions for a venue for such a meeting included the Annual Tuna Conference (California), somewhere else in California, or Hawaii. The respondents were interested in a follow-up meeting as a way to develop research plans that, in their opinions, were needed and could provide many answers to FADs issues surrounding GOM DPSs. A number of FADs experts expressed opinions that techniques and methodology for direct assessment of GOM DPS FADs effects have been developed and are available from FADs research conducted previously. These approaches could be effectively applied to directly applied to answer many of the important questions and include: acoustic telemetry/tracking (e.g., 1, 78, 104, 259, 364), hydroacoustics (e.g., 201, 235, 379), combined sonic tracking and hydroacoustics (235, 383), remote sonic monitoring stations on or near DPSs (270, 384), tag/recapture studies (28, 238, 265), and modeling (42, 238, 258, 265, 272, 273). A nucleus of interest and support from government agencies, academia, and others could make such a meeting productive and effective. In that light, USGS is continuing to explore the possibility of organizing such a meeting.
CONCLUSIONS

*Projections from Existing Knowledge.*— Existing scientific information, from published studies of FADs elsewhere or from fundamental understanding of fish aggregation and attraction phenomena and processes, is not sufficient for understanding or predicting potential FADs effects of GOM DPSs. However, some valuable conclusions can be made from the existing body of knowledge.

The existing information on FADs indicates that several commercially and recreationally important species will be or are already being attracted to GOM DPSs. The main species are yellowfin tuna, skipjack tuna, and bigeye tuna.

Based on FADs research and experience around the world, it may be subjectively inferred that GOM DPS FADs effects are likely to be significant and possibly could be substantial. However, the existing information is inadequate for scientifically predicting the degree to which such aggregation will occur, let alone for predicting impacts on populations or fisheries. Aggregation of other species such as billfish, wahoo, dolphin, sharks, and coastal pelagics may occur but is unlikely to be substantial relative to overall population levels and distributions.

Similarly, the existing information is insufficient with regard to understanding the phenomena or processes involved in fish attraction to objects. Thus, it is impossible to make scientific projections as to the degree to which different structures or DPS components would attract large pelagic fish. Existing information is completely inadequate for analyzing factors such as size, color, shape, lighting, etc. Therefore, there is little in the available information that can be used to design or manage DPSs with regard to their FADs effects.

There is a strong consensus of scientific opinion that open-ocean fish are not attracted to objects for trophic reasons (254, 260, 453). Thus they are not attracted by the presence of prey species around the object, as has been reported for coastal FADs (109, 146). Instead, pelagic fish (particularly tunas) are attracted to objects for other intrinsic reasons that are yet to be fully understood (113, 164, 308, 424, 457). It is possible, but not conclusively determinable from existing literature, that some less-abundant species like blue marlin and wahoo are attracted by small tunas and other small fish that aggregate around FADs.

Spatial and temporal relationships between yellowfin, bigeye and skipjack tunas and FADs have been reasonably well studied and probably could be applied to GOM DPSs. Similarly, knowledge of tuna movement patterns between and among FADs probably also could be applied to GOM DPSs.

However, it appears that tuna relate to drifting FADs differently than they do to moored FADs. Tuna aggregate under drifting FADs at night (421, 424), whereas they aggregate near moored FADs during daylight hours (50, 78, 235, 260, 261), perhaps utilizing moored FADs as extensions of the reef dropoff zone (78). They move away from moored FADs to
deep waters during the night, perhaps to feed on vertically migrating squid and shrimp (78).

Neither reef dropoffs nor open-ocean depths exist immediately near GOM DPSs. Therefore, it is unknown whether diurnal and spatial distributions around DPSs would be more like those for drifting FADs or those for moored FADs.

The situation may be further complicated due to night-time illumination from DPSs. Lights are often deployed on drifting FADs to attract tuna and other species near drifting FADs at night (114, 120, 437), however the responses of fish to various kinds of light and intensity are complicated (145, 166, 203) and largely unknown for tunas and other FADs species. Thus the effects of DPS lights cannot be evaluated from the literature.

**Potential Ramifications of DPS FADs Effects.**—If, as suggested by existing FADs information, GOM DPSs have FADs effects, there are a number of possible ramifications that should be considered. These may include primary ecological effects including: a) changes in distributional patterns (particularly due to aggregation and concentration in areas with DPSs), b) changes in movement and migration patterns (42, 311, 312, 454), c) changes in spawning and larval survival/recruitment (due to a and b above).

It may be hypothesized that fish respond to floating or moored objects based on evolved behaviors that normally confer selective advantage when evoked by natural objects and processes (257, 412, 415, 422), but such responses may be dysfunctional and confer disadvantage relative to arrays of unnatural objects in an oceanic environment where objects are normally rare (e.g., northern Gulf of Mexico). Under some circumstances, FADs may act as an “ecological trap” that can have serious negative effects by retaining fish in unfavorable environments (252). Locations of primary spawning grounds of yellowfin and bluefin tuna in the GOM are not well understood. FADs effects could have important consequences on bluefin tuna spawning (458). Thus effects of DPS FADs effects on distribution and spawning of GOM tunas cannot be directly estimated.

Secondary, indirect effects of DPS FADs may include: a) increased catchability and fishing mortality due to aggregation around DPSs, b) changes in population age structure (283) due to increased or changed age-specific mortality due to fishing, c) changes in commercial and recreational fisheries due to aggregation, concentration and location predictability, d) changes in fisheries bycatch due to changes in fishing gears and techniques utilized around DPS FADs, and e) changes in fishery management required by new situations due to DPS FADs.

Indirect effects may be either positive or negative. For example, fishing gears and techniques developed to fish near DPS FADs may be more or less optimal relative to harvested age/size. Increased commercial or recreational catches can be considered to be advantageous or disadvantageous, depending on the degree to which they change and the status of the stocks – increased catches can be considered positive if stocks are less than fully exploited but negative if stocks are already fully exploited. Depending on the types of fishing techniques developed for fishing around DPS FADs, undesirable bycatch may be
either decreased or increased. For example, vertical longlines fished around DPSs may result, because of shorter time setting and retrieval, in less bycatch mortality of billfish than conventional, horizontal longlines. It is also possible, however, that due to aggregation of billfish around DPS FADs, more billfish bycatch and mortality would be incurred in such a fishery. Increased fisheries around DPSs may be advantageous to fishery management agencies by virtue of being easier to monitor, or they may cause complications in that conventional (away from DPSs) catch data will no longer be adequate for stock assessment.

Important and valuable recreational fisheries may spring up in areas of DPS deployment. In Hawaii, for example, a network of FADs has been established around the islands to enhance recreational and hook-and-line artisanal fisheries, primarily targeting yellowfin tuna and blue marlin (285). Concentrations of and enhanced fishing for yellowfin tuna and blue marlin have already been reported around certain GOM DPSs, including Exxon “Hoover/Diana” complex and other structures over 185 km offshore (207). Because prey biomass around FADs has been shown to be inadequate for supporting aggregated tuna biomass (308), the impact of DPSs will be primarily due to attraction, as opposed to the alternative explanation of increased production.

**Information Needs.**—If FADs effects of GOM DPSs are to be assessed and quantified, they will have to be done through direct studies, instead of by extrapolation or inference from existing scientific literature. If GOM DPSs are to be directly studied, it is important that such studies be started soon, before so many DPSs have been deployed that natural distributions and movements will already have been substantially altered. Before-and-after studies are an important and powerful tool (156), without which impacts of DPSs may never be fully determined or understood.

There are a number of effective, proven ways that assessment of GOM DPS FADs effects can be made. Much of the existing information about FADs effects on tunas has been obtained through acoustic telemetry and tracking (1, 4, 19, 25, 89, 103, 104, 171, 174, 190, 236, 255, 259, 270, 364, 379, 384, 398, 399, 400, 433, 406). Automatic acoustic monitoring stations have been used to detect return and evaluate site fidelity of tunas to structures (270, 384, 466), and this technique could be very easily applied at DPSs. Hydroacoustic techniques also have been found to be useful in assessing presence and distributional patterns of tunas around FADs (65, 112, 222, 235, 255, 260, 379, 383). Combination of acoustic tracking and hydroacoustic survey has provided important information (255, 383) and with the development of sophisticated new hydroacoustic instruments (65) offers great promise for assessing FADs effects of GOM DPSs.

Other techniques that have been used to assess and understand FADs include tag/recapture studies (28, 163, 238, 258, 265, 272, 273, 433, 436, 442) and fishery-dependent monitoring, as has been done around inshore GOM petroleum structures (197). Both of these approaches are contingent on presence of active large fisheries, which may not yet exist in the deepwater petroleum development areas of the GOM. Fishery-independent techniques (49, 63, 71, 76) and exploratory fishing could be used to preliminarily assess DPSs. Modeling (42, 92, 202, 237, 238, 258, 264, 272, 273, 454, 463) has provided
valuable insights into tuna-FADs relationships, and could be expected to do the same for GOM DPSs. Given the great depths to which FADs-associated tunas are found (171,235, 364), aerial-visual or LIDAR surveys (112) are unlikely to be fully effective, but they may still be useful—especially to determine presence of bluefin tuna or large schools of yellowfin tuna.

Some of the uncertainty about FADs effects of GOM DPSs has to do with uncertainty about DPS development. Due to uncertainties inherent in rapidly developing and evolving deepwater technology, the future numbers, types, and distributions of deepwater structures cannot be accurately predicted or projected. Therefore, it is likely that most future consideration, management, or mitigation of DPS FADs effects on fisheries will have to be tactical rather than strategic. MMS could help efforts to assess these effects by providing scenarios and estimates of future deepwater development.

Part of the uncertainty depends on the degree to which subsurface completion DPSs will be developed and utilized, relative to surface DPS deployment. It is unknown whether tunas and other pelagic fish will aggregate around such subsurface structures. The answer may be conditional on the depth, size and configuration of the subsurface completion units. It is known, however, that tunas aggregate around subsurface structures such as seamounts (28, 238, 268, 431) and possibly even around smaller structures like ship wrecks. Even subsurface completion involves, during their drilling and construction, large moored surface structures that will probably act as FADs. Additionally, DPS support vessels may themselves have temporary FADs effects.

Due to uncertainty about how GOM pelagic fish will be aggregated by DPSs, how DPS technology will develop, and how fisheries will change, it is unlikely that the issue of DPS FADs effects can be immediately resolved. It probably will have to be studied and monitored over time. On the other hand, if direct studies and assessments of DPS FADs were initiated, and if direct aggregation effects on important pelagic fish were to be documented as small or minimal, resource managers could have reasonable confidence that deepwater development would not have major negative impacts on GOM pelagic fisheries.
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Keywords: FADS.


Keywords: FADS, FISHERIES, FISHERY OCEANOGRAPHY, PACIFIC OCEAN.


Keywords: FADS, FISHING, SPORT.


Keywords: ANCHORED FADS, FADS, FISHERIES, TUNA, PACIFIC OCEAN, REVIEW/SUMMARY.


Keywords: CATCH COMPOSITION, FADS, FISHERIES, TUNA, PACIFIC OCEAN, SIZE DISTRIBUTION, YELLOWFIN TUNA.


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ABSTRACTS – Alphabetic List

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58. Ahmed, M.K. 1993. ABSTRACT: Fish Aggregating Devices (FADs) are structures of permanent or temporary nature made of any material to lure or aggregate fish. Importance of such structures also now known as "artificial reefs" is explained. Different structures are described. Illustrations from different sources have been reproduced.

46. Ajayi, T.O., T.G. Tobor, A. Amadi, and R.E.K. Udolisa. 1994. ABSTRACT: A 12-month exploratory pole and line tuna fishing survey implemented in 1982-1983 encountered a mean of 10 schools per day on the fishing grounds within Nigeria's EEZ, and landed an average of 3.0 tons per day out of port. Sub-surface fish aggregating devices installed later within 30 nm of the coast, off Lagos, Nigeria, yielded as much as 10 tons per day. More importantly, the innovation drastically reduced search time, and bunker requirements, thus transforming the economics of operations. Clearly, the entire fishing industry in Nigeria has to devote considerable attention to the emerging science of habitat enhancement and related technologies, in their full ramifications.

23. Anderson, R.C., A. Hafiz, and M.S. Adam. ABSTRACT: The Maldivian tuna fishery has been in existence for centuries, and is still of central importance;

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3 Original abstracts (where available) were edited to correct spelling and some minor grammatical errors that might affect meaning. However, published original abstracts were not changed to conform with American standard style.

4 Abstracts included in references 2 and 234 were in some cases different, while in others were identical. For completeness, both are included.
the great majority of the tuna catch is landed by live-bait pole-and-line vessels. Catch statistics are provided for skipjack, yellowfin, bigeye, frigate tuna and kawakawa, giving also details of the tuna bycatch. Fleet trends, sport fishing, bait fishing and the use of FADs are examined briefly. Although tunas form a major part of the Maldivian diet, they also form a large part of the Maldivian export industry. The EEZ fishery and catch data of foreign vessels are included.

34. **Anibal, O. 1995.** **ABSTRACT:** An account is given of the use of Fish Aggregating Devices (FADs) in Sao Tome and Principe. The FADs have helped the fishermen decrease the amount of time spent looking for fish, thereby reducing the length of fishing trips and thus also saving on fuel. At the same time, the fishermen are also able to spend more time on other fishing techniques or on the maintenance of the craft or fishing gear. Lists are provided of the material necessary for the construction of FADs at depths of 1000 m and 200 m.

107. **Anonymous. 1982.** **ABSTRACT:** This bibliography contains papers on fish aggregating devices (FAD). A list of institutions that have engaged in work on FADs is also included.

105. **Anonymous. 1983.** **ABSTRACT:** The use of anchored buoys as "fish aggregating devices" (FADs) was pioneered in the United States by the Honolulu Laboratory of the Southwest Fisheries Center (SWFC). Off the California coast, bluefin tuna show up regularly in summer and fall, and are caught by purse seiners working out of San Pedro and Port Hueneme. Researchers at the SWFC Laboratory at Tiburon, Calif., believe the FADs deployed at strategic areas may attract and hold the fish, providing greater efficiency to the fishery. A cooperative project to install FADs has been initiated by the Fishermens’ Cooperative Association of San Pedro, the Southwest Region and NMFS, and the SWFC Tiburon Laboratory.

87. **Anonymous. 1989.** **ABSTRACT:** The booklet shows how to make and set Fish Aggregating Devices and is presented in text which is easy to understand with numerous illustrations. Although it is written especially for fishermen, it can also be of use to fishery schools and in the training of practical fishing technologists and extension workers in small-scale fisheries.

66. **Anonymous. 1990.** **ABSTRACT:** The manual discusses the use of FADs as a means of improving fish catches; with the use of simple text and numerous drawings and photographs. Details are given regarding the construction and putting into operation of different types of FADs. Although the manual is aimed in particular for the fisherman, it may be found to be of use in fishery schools and training activities in rural environments.
30. **Anonymous. 1994.** ABSTRACT: The results and conclusions are presented of six case studies conducted in the framework of the project “Bioeconomics of small-scale fisheries in the Bay of Bengal”: 1) Bangladesh – Bio-socioeconomic assessment of the impact of estuarine set bagnet fishery on the marine fisheries; 2) Indonesia – Bio-socioeconomics of the shrimp fisheries in Langkat District, North Sumatra Province; 3) Malaysia – Bio-socioeconomic assessment of the shrimp fisheries in Kuala Sepetang, Perak State; 4) Maldives – Bio-socioeconomic assessment of the impact of Fish Aggregating Devices (FADs) on tuna fisheries; 5) Sri Lanka – Bio-socioeconomic study of the fisheries for small pelagics along the southwest coast of Sri Lanka; and, 6) Thailand – Bio-socioeconomic assessment of the impact of Artificial Reefs (ARs) on the small-scale fisheries in Ranong Province. The findings indicated that many management measures had been introduced by almost all the member countries, but very few of them had been effectively implemented due to incomplete understanding of the problems and insufficient cooperation of the fisherfolk. The recommendations of the project are included.

35. **Anonymous. 1996.** ABSTRACT: This document is the final version of the report of the Fifth Session of the Committee for the Development and Management of Fisheries in the Lesser Antilles, held in Roseau, Dominica, from 14 to 16 November 1995. Major topics discussed were: 1) Specific problems in the small island States of the Lesser Antilles, 2) Experiences in the integration of fisheries into coastal area management, 3) Follow-up to the Fourth Session, 4) Progress in the use of Fish Aggregating Devices (FADs) in some Islands, 5) Role of the CARICOM Fisheries Resource Assessment and Management Programme (CFRAMP) in the Sub-region, 6) Caribbean Aquaculture Development Project proposal, and 7) Future activities of Working Parties. A list of the main recommendations on future actions to be endorsed by the Western Central Atlantic Fishery Commission is included at the end of the document.

2. **Anonymous. 1999.** ABSTRACT: The international symposium "Tuna fishing and Fish Aggregating Devices", October 1999, in Martinique, takes stock of the exploitation of large pelagic fish around FADs, based on regional synthesis for the three oceans and the Mediterranean Sea. Main themes include technology, fishing methods, impact on resources, biology of fish aggregation, anthropology and economic aspects of FAD exploitation. The meeting will gather and disseminate results from recent and ongoing studies on FADs in the different oceans of the world, enhance collaboration between scientists and managers involved in the development of FADS, promote the emergence of scientific and technical research, form a network for cooperation and enhance communications between researchers in the different locations concerned. Original Abstract: Le colloque international "Pêche thonière et dispositifs de concentration de poissons" organisé en Octobre 1999 en Martinique, permet de dresser un bilan, sous forme de
syntheses regionales, de l'exploitation des grands poissons pelagiques a l'aide de DCP dans les trois oceans et en Mediterranee. La technologie, les methodes de pêche, l'impact sur les ressources, le comportement agregatif des poissons et les aspects socio-economiques de l'utilisation des DCP sont les principaux themes developpes. Ces travaux permettront d'assurer une diffusion large des resultats a l'echelle de l'ocean mondial, de favoriser les echanges entre les scientifiques et les gestionnaires impliques dans le developpement des systemes DCP, de promouvoir l'emergence de themes et projets de recherche scientifique et technologique, de mettre en oeuvre un reseau de communication et d'echanges entre les sites et les regions concernees.

95. **Aprieto, V.L. 1987.** ABSTRACT: Tuna production increased phenomenally from less than 10,000 mt in 1971 to 124,000 mt in 1976 when bamboo raft or payao, a FAD was innovated in tuna fishing. Peak production of 261,000 mt was attained in 1985 comprising 20% of the national fish catch that year. Consequently, the Philippines maintained self sufficiency in food fish and became the biggest tuna producer in Southeast Asia, and the fifth in the world.

88. **Aprieto, V.L. 1988.** ABSTRACT: Two types of artificial habitats for fisheries are widely used in the Philippines: the bamboo raft or payao, a deep-water fish aggregating device (FAD) for catching tunas, and the benthic shallow water artificial reefs made of bamboo or concrete which are populated by small pelagic and reef fishes. The use of payao has increased tuna production making the Philippines the biggest producer of tuna in Southeast Asia. However, tuna FADs catch considerable quantities of undersized juveniles and apparently alter migratory and feeding patterns of tuna. The government and the industry have so far deployed over 13,500 artificial reef modules and about 3,000 tuna payaos countrywide. However, there have not been systematic studies on the ecology, biology, fisheries, socio-economics, liability concerns and political consequences needed for the formulation of a rational development programme for artificial habitats for fisheries. Areas of investigation for the proper management of artificial fisheries habitats are indicated.

423. **Arenas, P., M., Hall, and M., Garcia. 1992.** ABSTRACT: Analysis of eastern Pacific Ocean tuna vessel onboard observers' data (presence) was made of species composition of fauna associated with floating objects. A large suite of species was found to be fairly uniformly distributed, with some concentration in the coastal zone. A list of 39 species groups of biota associated with floating object is given. In addition to tunas, species groups found to be frequently associated with floating objects included marlin, dorado, wahoo, rainbow runner/yellowtail, sharks, and sea turtles.
415. Arenas, P., M., Hall, and M., Garcia. 1999. ABSTRACT: Species composition data (presence/absence) for samples associated with floating objects was carried out during 1987-1991. Species composition varies by area, but commonly observed species or groups are found throughout the eastern Pacific Ocean. Main species include dorado, yellowfin, skipjack and several shark species. Marlin were evenly distributed, and many are juveniles. It is suggested that some species use floating objects as links between islands and seamounts along their movement patterns.

433. Ariz, J., A. Delgado, A. Fonteneau, F. Gonzales-Costas and P. Pallares. 1992. ABSTRACT: In the Atlantic, the log fishery contributes to a relatively minor proportion of the purse seine catches (approximately 15% during the period 1988-1990). The dominant species on log schools is skipjack (76%), followed by yellowfin (17%) and bigeye (7%). The skipjack taken under logs have a size distribution identical to the free school ones (average weight 1988-1990 = 2.2 kg), when the yellowfin and bigeye show a majority of small fishes (less than 5 kg) in numbers, but also a significant proportion of the large individuals and subsequent to an average weight of 5.3 kg for yellowfin and 4.5 kg for bigeye. The fishing seasons and locations on logs are limited and stable from year to year during the period under study. As in other oceans, the catch per set under logs is on the average greater than on free schools (41 versus 19 t), and the rate of unsuccessful set is low compared to free swimming school (6% versus 28% on free school). Many logs in the Atlantic seem to be of natural origin and are drifting in the surface currents of the area. The exact origin of the logs is still questionable, especially the proportion from the Amazon and from African rivers (especially) Zaire, both located at similar distances from the fishing zone. The accumulation of logs in the north equatorial convergency has been noticed and allows important tuna catches on logs. More recently, since the end of 1990, artificial logs have been deployed in great numbers in the offshore area by purse seiners, and allow them to catch skipjack in new fishing zones and also yellowfin of larger sizes. Yield per recruit analysis has been conducted and concludes that a further development of the artificial log fishery should increase the yield per recruit of the total fishery, the potential benefit being mainly for skipjack. Research recommendations are developed in order to improve the knowledge upon the tuna and logs association and dynamics, and also to estimate the abundance in a purse seine fishery which develops a log fishing strategy, such as presently in the Atlantic.

434. Ariz, J., A. Delgado, A. Fonteneau, F. Gonzales-Costas and P. Pallares. 1992. ABSTRACT: In the Atlantic, the log fishery contributes to a relatively minor proportion of the purse seine catches (approximately 15% during the period 1988-1990). The dominant species on log schools is skipjack (76%), followed by yellowfin (17%) and bigeye (7%). The skipjack taken under logs have a size distribution identical to the free school ones (average weight 1988-1990 = 2.2 kg), when the yellowfin and bigeye show a majority of
small fishes (less than 5 kg) in numbers, but also a significant proportion of the large individuals and subsequent to an average weight of 5.3 kg for yellowfin and 4.5 kg for bigeye. The fishing seasons and locations on logs are limited and stable from year to year during the period under study. As in other oceans, the catch per set under logs is on the average greater than on free schools (41 versus 19 t), and the rate of unsuccessful set is low compared to free swimming school (6% versus 28% on free school). Many logs in the Atlantic seem to be of natural origin and are drifting in the surface currents of the area. The exact origin of the logs is still questionable, especially the proportion from the Amazon and from African rivers (especially) Zaire, both located at similar distances from the fishing zone. The accumulation of logs in the north equatorial convergency has been noticed and allows important tuna catches on logs. More recently, since the end of 1990, artificial logs have been deployed in great numbers in the offshore area by purse seiners, and allow them to catch skipjack in new fishing zones and also yellowfin of larger sizes. Yield per recruit analysis has been conducted and concludes that a further development of the artificial log fishery should increase the yield per recruit of the total fishery, the potential benefit being mainly for skipjack. Research recommendations are developed in order to improve the knowledge upon the tuna and logs association and dynamics, and also to estimate the abundance in a purse seine fishery which develops a log fishing strategy, such as presently in the Atlantic.

138. **Armstrong, W.A., and C.W. Oliver. 1996.** ABSTRACT: Although the precise mechanisms involved in the attraction of fish to floating objects are unknown, it occurs with sufficient regularity to justify research that explores the use of fish aggregating devices (FADs) to enhance dolphin-safe fishing efforts in the eastern tropical Pacific Ocean (ETP). The focus of NMFS Dolphin-Safe FAD research is to develop methods to build and deploy relatively inexpensive drifting and anchored FADs that will attract mature tuna in sufficient abundance to supplement current harvest levels and to decrease fishing activity associated with dolphins. The purpose of this report is to provide some background on the potential of FADs to aggregate tuna, describe the investigations undertaken by NMFS, and present the results of a cooperative research project.

20. **Atapattu, A.R. 1991.** ABSTRACT: In Sri Lanka, FADs have been used traditionally in coastal areas for a long time, but experimental work with a view to increasing their use was undertaken only in the early eighties. A brief account is given of the fishery industry in Sri Lanka prior to this period. The main objective of establishing FADs in Sri Lanka is to increase catch rates with a reduction in the cost of production; another objective is to harvest fish from lightly exploited stocks, by aggregating them. Site selection and materials, designing and construction of FADs are discussed. The importance of careful monitoring of FADs is stressed and an examination is made of the biological,
economic and social influence of FADs. Management measures and controls are also described.

427. **Au, D.W., R.L. Pitman, and L.T. Ballance. 1992.** ABSTRACT: Data from dolphin surveys and from tuna fleet observers were to analyze species interactions and co-occurrences. Sharks were conspicuously associated with yellowfin tuna, occurring in 40% of the log-associated sets overall, and up to 90% of the sets in some trips. Silky shark (*Carcharhinus falciformis*) was most common, averaging 30 per set, but ranging up to 500 per set. Billfish were associated with tuna in 9% of all sets, but in some trips were associated in up to 43% of the sets.

143. **Auble, G.T., A.K. Andrews, R.A. Ellison, D.B. Hamilton, and R.A. Johnson. 1982.** ABSTRACT: This publication summarizes findings of a workshop held September 14-18, 1981, under a Federal Interagency Energy/Environment Agreement between the U.S. Environmental Protection Agency and the U.S. Fish and Wildlife Service. The U.S. EPA Environmental Research Laboratory, Gulf Breeze, Florida, was host for the sessions held on Pensacola Beach, FL. Discussions focused on information pertaining to fate and effects, identification of general relationships between drilling mud fluids and the marine environment, and identification of site-specific variables likely to determine impacts of drilling muds and cuttings in various marine sites. The workshop was structured around the construction of a model simulating fate and effects of discharges from a single rig into open waters of the Gulf of Mexico.

101. **Bailey, K. 1985.** ABSTRACT: Details are given of the use of fish aggregating devices in New Zealand waters and their success with tuna.

163. **Barut, N.C. 1992.** ABSTRACT: Fishing operations around Philippine payao FADs is described. The number of payaos deployed has increased, and it is suggested that the number of tunas is dispersed among a greater number of payaos. The distance between payaos is about eight nautical miles. The number of days required for a payao to aggregate large numbers of tunas is variable. Tagging studies found that tagged small tunas could move to a different payao in as little as 24 hr, while some remained at the same payao for many days. Recaptures indicate that most of the tuna are retained within the fishing grounds and do not move out of the area.

71. **Beets, J. 1989.** ABSTRACT: Fish aggregating devices (FADs) and benthic artificial reefs have been documented to enhance local fisheries. This study was conducted to investigate experimentally the relative success of combining FADs with benthic artificial reefs and attempt to observe some of the mechanisms by which enhancement occurs. Six replicates (two each of three treatments) were constructed in 26 m of water on a sparsely-colonized algal plain, approximately equals 2 km S. of St. Thomas, U.S. Virgin Islands. The
experimental treatments were (1) two benthic artificial reefs constructed of equivalent volumes of queen conch (*Strombus gigas*) shells; (2) two conch shell reefs surrounded with a cluster of five mid-water FADs; and (3) two clusters of FADs deployed without associated benthic artificial reefs. The replicates were spaced approximately equal 300 m apart along a transect line. The FAD + artificial reef combinations attracted more species and individuals than the other two treatments.

56. **Bertignac, M., and J. Moron. 1994.** ABSTRACT: Landings of small tunas from the Gulf of Thailand increased from 19,000 tonnes in 1980 to 141,000 t in 1989. Thai tuna fleets were responsible for 93% of the 1989 small tuna landings, while Malaysia accounted for the remainder. Purse seines, including luring purse seines which fish on FADs, are the most important gears in the Thai fishery and accounted for 90% of the small tuna catch. In Malaysia, 25% of the catch is made by this gear, the major fishery being by troll boats. In 1989, species composition of the small tuna catch was as follows: 50% longtail tuna (*Thunnus tonggol*) and 25% of kawakawa (*Euthynnus affinis*) and frigate tuna (*Auxis thazard*) respectively. This paper attempts to assess potential interactions between main fleets by estimating fishing mortality coefficients using a length-based pseudo-cohort analysis. A simulation model is then used to evaluate the impact of modifications in fishing mortalities on the production. To avoid overestimating fishing mortalities from the model, an emigration rate was included as from a certain size. Expected gains in production and CPUE predicted by the simulation model are low. The model also predicts that reducing the fishing mortality vector of Thai luring purse seines would increase the catch of the other fleets on kawakawa and frigate. This increase could attain 25% on the total kawakawa catch if the Thai tuna purse seine fishing mortality were increased at the same time.

301. **Bertram, I., and S. Tatuava. 2000.** ABSTRACT: Since 1980 a programme of Fish Aggregation Device (FAD) deployment has been carried out in the Cook Islands. Government has deployed all FADs between 1 to 3 nautical miles from shore at depths ranging from 800 to 1,600 meters. The FADs have undergone various designs with varying degrees of success. The average FAD lifespan during the early 1980s was nine months; however, it increased to 18 months, with some FADs in operation in excess of 30 months. Each FAD cost between NZ$ 7,000 and NZ$ 9,000 to build and deploy. Since their introduction, FAD have been widely accepted as a very effective apparatus in coastal small-scale fishing activities, specifically for pelagic species. Judging by the progressive behaviour of local fishing communities, there is sufficient reason to believe that FADs have created productive fishing zones for Cook Islands fishermen to enable them to supply the ever-increasing local market for fresh fish. FADs are an integral part of local fishing communities and provide a reasonable form of income to the increasing fishing community.
48. Bortone, S.A., J. Van Tassell, A. Brito, J.M. Falcon, J. Mena, and C.M. Bundrick. 1994. ABSTRACT: Point count surveys (5 min, 100 m super(2)) were conducted to gather fish assemblage data on the efficacy of using FADs and/or cinder blocks to increase fishery resources in an area along the southern coast of Gran Canaria. A comparison between the pre- and post-deployment faunal parameters indicates that 16 more species were attracted to the study area. The dependent variables (i.e., number of species, number of individuals and average length) increased after artificial habitat deployment regardless of the configuration type of FAD alone, block alone, or FAD and block together after deployment. The values for these variables were also higher for nearly all variables, the increases were attributable to fishes unimportant to the commercial and recreational fisheries of the Canaries. Lack of available recruits or local perturbations may be responsible for the lack of preferred fishes being attracted to the reef.

1. Brill, R.W., B.A. Block, C.H. Boggs, K.A. Bigelow, E.V. Freund, and D.J. Marcinek. 1999. ABSTRACT: We measured the horizontal and vertical movements of five adult yellowfin tuna (Thunnus albacares, estimated body mass 64 to 93 kg) near the main Hawaiian Islands, while simultaneously gathering data on oceanographic conditions and currents. Fish movements were recorded by means of ultrasonic depth-sensitive transmitters. Depth-temperature and depth-oxygen profiles were measured with vertical conductivity-temperature-depth (CTD) casts, and the current-velocity field was surveyed using an acoustic Doppler current profiler (ADCP). Large adult yellowfin tuna spent similar to 60 to 80% of their time in or immediately below the relatively uniform-temperature surface-layer (i.e., above 100 m), a behavior pattern similar to that previously reported for juvenile yellowfin tuna, blue marlin (Makaira nigricans), and striped marlin (Tetrapturus audax) tracked in the same area. In all three species, maximum swimming depths appear to be limited by water temperatures 8 degree C colder than the surface-layer water temperature. Therefore, neither large body mass, nor the ability to maintain elevated swimming-muscle temperatures due to the presence of vascular counter-current heat exchangers in tunas, appears to permit greater vertical mobility or the ability to remain for extended periods below the thermocline. In those areas where the decrease in oxygen with depth is not limiting, the vertical movements of yellowfin tuna, blue marlin and striped marlin all appear to be restricted by the effects of water temperature on cardiac muscle function. Like juvenile yellowfin tuna, but unlike blue marlin and striped marlin, adult yellowfin tuna remained within 18.5 km of the coast and became associated with floating objects, including anchored fish-aggregating devices (FADs) and the tracking vessel. Like juvenile yellowfin tuna, large adult yellowfin repeatedly re-visit the same FAD, and appear able to navigate precisely between FADs that are up to 18 km apart. The median speed over ground ranged from 72 to 154 cm/s. Neither speed nor direction was strongly influenced by currents.
104. **Brill, R.W., K.N. Holland, and J.S. Ferguson. 1984.** ABSTRACT: Little is known about the optimal placement of fish aggregating devices (FADs) with respect to oceanographic or bathymetric conditions, or to each other. Also, there is little or no direct information available on the true effects of FADs on the behavior of commercially important fish species or the ultimate impact of FADs on fishery resources. It was therefore decided that much could be learned about the optimal placement and effects of FADs by using ultrasonic telemetry techniques to determine the short-term (1-12 days) behavior around FADs of commercially important fish species such as tunas. Yellowfin tuna, *Thunnus albacares*, and skipjack tuna, *Katsuwonus pelamis*, are the primary FAD associated target species in the Pacific. To monitor the fish's swimming depth, as well as their daily movements and residence times around FADs it was decided to employ depth sensitive ultrasonic telemetry systems.

102. **Brouard, F., R. Grandperrin, and E. Cillaurren. 1984.** ABSTRACT: This paper describes the growth of small yellowfin tuna (*Thunnus albacares*) and skipjack (*Katsuwonus pelamis*) trolled in 1983 around fish aggregating devices (FADs) deployed southwest of Efate Island in Vanuatu. The growth parameters have been calculated from length-frequency data using a BASIC program modified from ELEFAN 1 (Pauly and David, 1981). This program allows the calculation of several values of L infinity and k which are represented by several "Explained Sums of Peaks" (ESP). The average growth rate of yellowfin in the size range 30-50 cm was 1.3 cm per month; it might increase with age. The growth rate of skipjack between 30 and 50 cm averaged 1.9 cm per month. Diagrams showing ESP and growth curves are included. The BASIC program as well as an example of data transformation are given as appendices.

86. **Buckley, R.M. 1989.** ABSTRACT: Artificial reefs and fish aggregating devices (FADs) can be used to alter marine habitats to increase fishery productivity. Artificial reefs enhance marine fisheries through both aggregation and production of marine resources. FADs can also enhance resource production. Most artificial reef designs do not completely replicate natural reef habitats. Considerable artificial reef construction has been in response to incentives for solid waste disposal. Recruitment and survival of juveniles is restricted because of the prevalent use of "materials of opportunity" for constructing artificial reefs. FADs are usually lost as a result of inadequate design and engineering. Funding has been haphazard and inadequate for developing artificial reef and FAD technologies. Most applications lack realistic, justified fishery enhancement objectives as the incentive for altering habitat. Solving these major constraints will make it possible to evaluate habitat-alteration technologies as a basis for enhancing marine fisheries.

70. **Buckley, R.M., D.G. Itano, and T.W. Buckley. 1989.** ABSTRACT: Fish Aggregation Devices (FADs) have become an established part of efforts to
enhance catches of offshore fishery resources throughout the Pacific region. Support for FAD programs has usually been based on fishery catch reports providing only sporadic, qualitative, and circumstantial information. Federal funding for a FAD program in American Samoa began in 1979. Troll fishing test fishery analysis of FADs in American Samoa began in 1980. In 1985, test fishery procedures were standardized to use quantitative troll fishing techniques. This enabled assessment of the effectiveness of FADs in enhancing offshore fisheries through comparisons with offshore banks and open-water "control" areas. Analysis of test fishery CPUE's showed a significant difference between open-water areas and offshore banks, but no significant difference between FADs and offshore banks.

38. **Buckley, T.W., and B.S. Miller. 1994.** ABSTRACT: In American Samoa, Fish Aggregation Devices (FADs) provide target fishing locations with high catch rates, but little is known about their ecological impact. The effect on the diet of yellowfin tuna (*Thunnus albacares*) associating with FADs has been examined in the Philippines, French Polynesia and Hawaii, but results differ among the regions. Diel patterns of movement around FADs appear to be consistent among regions. The stomach contents of yellowfin tuna were compared from FADs, offshore banks, areas away from these features and from before FADs were deployed in American Samoa. Differences were minimal among these four groups of yellowfin tuna in the frequency of occurrence of important prey in their diets. Diurnal patterns in the stomach fullness and the frequency of occurrence of some prey in the diet indicate that these yellowfin tuna are not feeding at night and that they may prey on vertically migrating mesopelagic organisms during crepuscular periods. FAD- and bank-associated yellowfin tuna probably follow the diel movement patterns observed in other areas. The regional differences in the apparent effect of FAD association on the diet of yellowfin tuna are discussed and possible explanations are given.

145. **Bullis, H.R., Jr., and C.M. Roithmayr. 1972.** ABSTRACT: The Caribbean sea fauna is relatively rich, both in species and numbers of small clupeoid fishes. These small fishes are potential resource that cannot be exploited by traditional techniques such as seines or trawls.

293. **Buurt, G. van. 2000.** ABSTRACT: In Curacao, deep-water FADs with GRP surface buoys were developed and tested. The first FAD was deployed in 1993. Up to now, a total of five FADs were deployed at the following depths: 730, 685, 700, 754 and 574 metres. Changes were made to the surface buoy, resulting in an improved design, the MKII surface buoy. One FAD lasted three years and one month. The main features of the design used are: the use of a sparbuoy design with constant tension on the moving chain to avoid slamming and jerking of the surface buoy; liberal use of sacrificial anodes, and maintenance to replace these anodes about once a year; the use of a short anchor chain with depth buoys, that does not touch bottom; a one-piece
inverted mushroom anchor. With the GRP surface buoy, a reserve buoyancy of approximately 800 kg is obtained with chain as external ballast about 610 kg of net buoyancy remains (it would seem that the reserve buoyancy needed where strong currents occur, has been underestimated in many designs). Five new GRP MKII buoys are now under construction. Utilizing the experience gained with the deep-water FADs, two new types of FADs made of 500 mm diameter PVC tubes were designed to be used in waters of shallow and medium depth (150-400 m). One design uses a 3-m length of PVC tube, the other a 5-m tube (500 mm diameter). One FAD with 3-m PVC buoy has been tested successfully, two 5-m PVC buoys are under construction. The use of PVC results in a buoy which is substantially less expensive than a GRP buoy. On the other hand, this type of buoy can probably not withstand the same forces as a GRP buoy and we assume that for use in deeper waters the GRP MKII buoy will still be needed.

130. **Buurt, G. van. 1999.** ABSTRACT: In Curacao, deepwater FADs with GRP surface buoys were developed and tested. The first FAD was deployed in 1993. Up to now, a total of five FADs were deployed at the following depths: 730, 685, 700, 754 and 574 m. Changes were made to the surface buoy, resulting in an improved design, the MKII surface buoy. One FAD lasted three years and one month. The main features of the design used are: the use of a sparbuoy design, with constant tension on the moving chain to avoid slamming and jerking of the surface buoy; liberal use of sacrificial anodes, and maintenance to replace these anodes about once a year; the use of a short anchor chain, with depth buoys, that does not touch bottom; a one-piece inverted mushroom anchor. With the MKII surface buoy, a reserve buoyancy of approximately 800 kg is obtained, with chain as external ballast about 610 kg of net buoyancy remains (it would seem that the reserve buoyancy needed where strong currents occur has been under-estimated in many designs). Five new GRP MKII buoys are now under construction. Utilising the experience gained with the deepwater FADs, two new types of FADs made of 500 mm diameter PVC tubes were designed to be used in waters of shallow and medium depth (150-400 m). One design uses a 3-m length of PVC tube, the other a 5-m tube (500 mm dia). One FAD with 3-m PVC buoy has been tested successfully, two 5-m PVC buoys are under construction. The use of PVC results in a buoy which is substantially less expensive than a GRP buoy. On the other hand, this type of buoy can probably not withstand the same forces as a GRP buoy and we assume that for use in deeper waters the GRP MKII buoy will still be needed.

39. **Buurt, G. van. 1995.** ABSTRACT: Three deepwater fish aggregating devices (FADs) were built, two of which have been deployed along the South coast of Curacao. The objective of the program is to develop durable FADs which could be anchored at various sites along the coast of Curacao on a permanent basis. The effectiveness of these FADs and their usefulness to the local fleet
of trolling vessels were evaluated. A Simrad EA300P portable precision echo-sounder with a 49KHz transducer was used. The buoys are made of GRP materials and have a spar buoy design. In this report, design considerations, construction details and deployment methods which may be of use to others are emphasized.

429. **Caddy, J.F., and J. Majkowski. 1992.** ABSTRACT: The sources of floating timber in tuna fishing grounds are usually rivers flowing out of tropical rainforests. Continuing deforestation may have effects on the supply and abundance of logs in major tuna fishing grounds. Man-made "logs" or FADs could be used to offset the decrease in logs.

19. **Cayre, P. 1991.** ABSTRACT: The Regional Tuna Project of the Indian Ocean Commission, includes a Sonic Tagging Programme. The results of the sonic tracking of three yellowfin tuna (*Thunnus albacares*) and five skipjack (*Katsuwonus pelamis*) in Comoros Islands are presented. The vertical swimming behaviour observed within an area with a deep and slightly marked thermocline, are analyzed in terms of percentage of the time spent at different depths or temperatures during the day and night. The results agree well with previous experiences in other oceans. The sonic tagging also indicates a short residence time of tunas concentrated by the DCP moored in the area. An important turnover of fish joined to an important migratory flow through that area, appear to characterise the concentrations of tunas exploited around the FAD. As far as the actual fishing pattern (artisanal fishery) is concerned, it seems that an increase in the number of FADs will be limited by the local market possibilities.

17. **Cayre, P., X. De Reviers, and A. Venkatasami. 1991.** ABSTRACT: The various fields where the effects of exploitation of fish aggregating devices (FADs) can be assessed is illustrated by the results of experiences of anchored FADs recently conducted in four island countries of the Western Indian Ocean (i.e., Comoros, Madagascar, Mauritius and La Reunion). It appears that only a wide programme including studies in the different biological, economic and social fields can lead to appreciation of the real benefits which can be obtained through the mooring and exploitation of FADs. The too frequent straight comparisons of the results obtained in one field only (e.g., fishing efficiency) from area to area is misleading in evaluating the impact of the exploitation of FADs. The authors propose a scheme of steps and questions which should be considered before starting an FAD programme or during its execution. The FAD entity appears as a rich and wide field of integrated research.

452. **Cayre, P., X. De Reviers, and A. Venkatasami. 1996.** ABSTRACT: This is an abstract of a paper (#17) presented in 1990.
18. **Cayre, P., D. Le Touze, D. Norungee, and J. Williams. 1991.** ABSTRACT: The settlement of fish aggregating devices (FADs) around Anjouan Island (Comoros) was undertaken by the Regional Tuna Project of the Indian Ocean Commission. A statistical coverage of the important artisanal canoe fishery was simultaneously set up to assess the FAD efficiency on the CPUE of the yellowfin (*Thunnus albacares*) and skipjack (*Katsuwonus pelamis*) tunas. The detailed data obtained for the last six months of 1989 are analyzed. It appears that FADs significantly enhanced the CPUE of both species for handline fishing gear, and only the CPUE of yellowfin tuna for troll lines. These heterogeneous results are discussed as well as the total FAD efficiency, as measured by the CPUE, on all pelagic species exploited around FADs and in the open sea. Due to the social importance of the artisanal fishery operating with numerous non-motorized canoes and handlines, the continuation of FAD settlement, with a careful monitoring of its economic and social aspect, is desirable.

16. **Chabanne, J. 1991.** ABSTRACT: A review is made of the use of fish aggregating devices (FADs) in French Polynesia, which initiated in the late 1970s. The introduction of FADs was meant as a possible solution to improve fishing yield and solve economic problems. Structures utilized for aggregating fish are of the anchored-buoy type, using various kinds of materials – wood, polyester, iron. Since the start of an FAD project in 1981, some 113 FADs have been deployed; by October 1989, 35 are still in operation. Socio-economic aspects and biological impacts are examined. From the overall economic point of view, FADs have not increased production figures. They have not raised any new problems in the management of existing fisheries, whose main problem remains development.

3. **Chapman, L. 1997.** ABSTRACT: A discussion is presented on the use of fish aggregating devices (FADs) in the waters around Vanuatu to attract and hold schools of tuna for domestic fishermen to exploit. Particular reference is made to trials conducted in May 1997, following the deployment of one FAD with the assistance of the Fishery Department and Mr. Rene Laurant.

300. **Chapman, L. 2000.** ABSTRACT: Over the last 16 years, the Secretariat of the Pacific Community (SPC - formerly the South Pacific Commission) has been developing and providing information on mid-water fishing techniques targeting the larger, deeper-swimming tunas that aggregate around FADs. SPC masterfishermen have conducted in-country fishing trials to test methods, such as vertical longlines, and train local fishermen in their construction and use. Vertical longline catch rates have varied considerably due to a range of reasons with no catches reported in some locations, or just sharks, to highs of over 6.5 kg/10 hooks/hour being reported in other locations. Other methods like drop-stone, palu-ahi, and single-hook drifting lines have been developed within the region, with SPC adopting and transferring this technology to other locations. To further disseminate this
information, SPC has recently published a technical manual outlining a range of mid-water fishing gears and techniques that can be used in association with FADs. An outline of the main gears and techniques with catch data where available is presented, with factors influencing catches discussed based on the findings of SPC masterfishermen over the year.

15. Christy, L. 1991. ABSTRACT: How artificial reefs (ARs) and fish aggregating devices (FADs) work is not well understood, however their main effect seems to be the concentration of fish, making them easier to find and catch. In general, there is a lack of both legal measures explicitly directed at ARs and FADs and also of legal studies analyzing their position under the general law. An examination is made of the legal treatment of ARs and FADs, considering national legislation, the right to place FADs and reefs, and FADs in international waters. Safety of navigation and environmental concerns related to ARs and FADs are discussed briefly. Fisheries legislation and management aspects are also considered.

50. Cillaurren, E. 1994. ABSTRACT: An analysis of the catches and daily observations were carried out on schools of yellowfin tuna, *Thunnus albacares* and skipjack, *Katsuwonus pelamis*, between June 1982 and July 1985 from six small-scale fishing boats around five Fish Aggregating Devices (FAD) anchored off Efate in Vanuatu. One of the aims was to investigate daily fluctuations in surface school occurrence. Regularity of observation and time spent on monitoring enabled us to bring to light the more striking behavioral characteristics of aggregated schools. 91% of the total number of catches were skipjacks (*K. pelamis*) and yellowfins (*T. albacares*). Mixed schools of skipjack and yellowfin tuna were present within a 500 m range around the rafts just before sunrise, the yellowfin being nearer to the FADs than the skipjack. The abundance and extensiveness of surface schools diminished throughout the day. Towards midday, the highest catches of yellowfin tuna were taken in a circle of 100 m radius around the rafts, whereas an increase of skipjack yields was recorded 1 h before sunset. For both species, the proportion of smaller specimens increased from dawn to sunset. *K. pelamis* did not take an obvious position in relation with the direction of the current, while *T. albacares* was mostly found in a downstream position.

76. Clavijo, I.E., J. LaPlace, and W. Tobias. ABSTRACT: The Division of Fish and Wildlife of the U.S. Virgin Islands worked on the development of a small (approximately 20 m) midwater fish aggregation device, or FAD, during 1981 to 1985 primarily for the use of recreational fishermen. The improved design, named the LaPlace FAD, was simple and easily constructed from PVC tubes, polyethylene sheets, polypropylene rope and concrete. The assembled FAD can be deployed readily from a small boat. Longevity studies showed that the improved design lasts up to two years in inshore sites. Minor repairs or replacement of parts can be easily accomplished in the field as needed. Two phases of the study were carried out. One included 50 structures
deployed linearly, the other included 60 structures deployed in clusters of six units. LaPlace FADs were evaluated by trolling on the structures and visually using SCUBA.

321. Coan, A.L., and N.W. Bartoo. 2000. ABSTRACT: US purse seining for tropical tunas in the central-western Pacific started in 1976. The fleet grew quickly from three vessels in 1976 to 62 in 1983, then decreased to 39 in 1998. Catches peaked at 216,000 mt in 1991 and decreased to 177,000 mt in 1998. The majority of the catch is skipjack tuna, with lesser quantities of yellowfin (21%) and bigeye tunas (9%). The fleet concentrated mainly on schools associated with logs (60-80%) until 1984, fished an equal proportion of log sets and free-swimming school sets until 1988, and then fished a majority of school sets (70-80%) until 1995. Since 1996, the fleet fished almost an equal proportion of free-swimming school sets and floating object sets. However, the majority of the floating object sets were on Fish Aggregating Devices (FADs, drifting rafts) instead of logs. Vessels deployed approximately 14 FADs at the beginning of each trip and revisited them as the trip progressed. Each evening, vessels would find a FAD, place lights on them and drift until early morning when they would set on the FAD. As a result, FAD catches increased from 2,000 mt in 1995 to 64,000 mt in 1996, FAD sets increased from 38 mt in 1995 to 1,860 mt in 1996, FAD catch per set remained high, bigeye tuna catches increased almost three-fold, by-catch of non-tuna species increased and catches of small fish increased.

348. Conand, F., and E. Tessier. 1996. ABSTRACT: This article describes the FADs network and related fisheries around Reunion Island. Starting in 1998, 6 - 16 FADs have been deployed per year, and 2 - 17 have been lost per year. In 1994, there were an average of 25.7 FADs deployed on station, and 85% of the large pelagic catch of 635 t were made from around FADs.

85. Crook, M. 1987. ABSTRACT: Details are given of a program conducted in American Samoa in order to investigate the feasibility of static fishing for the pelagic species usually caught by trolling around FADs and offshore banks, e.g., Katsuwonus pelamis, Thunnus albacares, T. obesus, Acanthocybium solandri and Coryphaena hippurus. The fishing gear used, "palu ahi", is described in detail. Findings indicate that this method can be more productive or economic than trolling, but due to the various problems encountered, should not be considered the only way to approach fishing the FADs in the area studied. It is concluded that American Samoa palu ahi fishing around the FADs is a useful but limited alternative to trolling, which can also enhance bottom fish catches while anchored on offshore banks.

84. Cusack, P. 1987. ABSTRACT: An account is given of the fishery existing along a system of deep-water moorings developed for the loading of vessels involved in the phosphate mining industry of Nauru. The mooring system shows a rich ecosystem with schools of mackerel scad (Decapterus puntatus), rainbow
runner (*Elagatis bipinnulata*), tunas (*Thunnus albacares*, *T. obesus* and *Katsuwonus pelamis*) and wahoo (*Acanthocybium solandri*). Techniques used for each of these fisheries are described briefly.

202. **Dagorn, L., and P. Freon. 1999. ABSTRACT:** Among the different assumptions proposed to explain why tropical tuna, *Thunnus* spp. aggregate around floating objects (‘logs’), one of the most recent is that floating objects may represent meeting points for tuna. This “meeting point hypothesis” proposes that tuna can use these floating objects to form larger schools after school fission or dispersion. The influence of meeting points on tuna school sizes is explored through different individual-based models that consider a single fusion rule and a variety of fission rules based on energetic considerations, the role of school size on school cohesion, predator attacks, and dispersion during the night. Results are first analyzed using an averaging approach to study the overall mean school size in habitats having different floating object densities. Second, a dynamic approach is used to compare the temporal dynamics of associated and free-swimming school sizes. The averaging approach indicates that in all the models (except those based on energetics), floating objects increase school size, at least up to a certain object density. The dynamic approach clearly illustrates different dynamics in the school size of associated and free-swimming schools. Most of the authors’ models show that tuna associated with logs resume schooling in larger schools after fission events.

236. **Dagorn, L., E. Josse, and P. Bach. 2000. ABSTRACT:** This article describes tracking experiments conducted on eleven yellowfin tuna using ultrasonic transmitters in French Polynesia between 1985 and 1997. Nine fish were caught near Fish Aggregating Devices (FADs) while the other two were tracked in coastal areas without FADs. The fish showed different patterns of horizontal movements: tight associations with FADs lasting several days, foraging movements confirmed by simultaneous acoustic observations of prey-sized fauna, movements parallel to the shore, and traveling between FADs. This intra- and inter-individual variety of behaviour might depend on the local environment (prey), and on individual biological differences. The influence of FADs, coastlines, and prey on tuna movements is discussed. The lack of information about the surrounding environment, the internal state of the fish and the recent history of the fish usually prevent scientists from adequately interpreting the observed movements. Ideas for future research to studying tuna behaviour near FADs are discussed.

237. **Dagorn, L., E. Josse, and P. Bach. 2000. ABSTRACT:** A fuzzy logic model of tuna behaviour near Fish Aggregating Devices (FADs) was developed to reproduce individual differences in horizontal movements observed from ultrasonic telemetry experiments. In this model, the behaviour of an individual is based on its surrounding environment (FADs and prey) and on its internal state (stomach fullness), which depends on its recent past actions.
Internal sensors are used to determine the motivation of the fish, combined with external sensors, this determines its movements. Sensory information and motivation are modeled using fuzzy sets. A FAD attracts an individual when it is located within the FADs range of influence. The time spent near a FAD depends on the feeding motivation of the fish and on its surrounding environment. If the fish is not hungry, it stays near the FAD. Otherwise, the fish has to forage in order to eat, and might therefore leave the FAD if no prey is available in its vicinity. By varying the environmental conditions near FADs, the model reproduces the different horizontal movement patterns observed for tunas. The model is then extended to allow multiple individuals to co-exist, each individual modeled through the above behavioural model, without any direct or indirect interactions between them. This way, we study the effects of individual behaviour on tuna aggregation near FADs. We find that the model predicts the temporal dynamics of aggregation around FADs exhibited by tunas. By examining the effects of several FAD network models on the aggregation, we also estimate optimal spatial arrangements of FADs.

14. Delmendo, M.N. 1991. ABSTRACT: A review is made of the current state of development of artificial reefs (ARs) in the ASEAN region, describing the experiences gained by the member countries (Malaysia, Philippines, Thailand, Singapore, Indonesia and Brunei) regarding the use of ARs and fish aggregating devices (FADs). The materials used, designs, patterns of installation and cost of construction of ARs are outlined. The effects of ARs on fishery resources and the impacts of FADs on fisheries are examined.

89. Depoutot, C. 1987. ABSTRACT: Anchored fish aggregating devices (FADs) for the catch of high sea pelagic fish have been used ever since 1981. The programme's main purpose is to bring help to artisanal tuna, Katsuwonus pelamis and Thunnus albacares, fishery. The study of the action of FAD is conducted through three ways: 1) by comparing results of tuna fishing on and out of FAD; 2) by studying the induced concentration by the FAD by means of acoustical survey techniques; 3) by studying the fish behaviour through sonic tracking. The proportions of small and big fish in FAD catches are higher than out of FAD ones, however, small fish are not so numerous as under flotsam and big fish are fewer than when there are surface prey fish. The abundance of skipjacks during FAD fishing depends on that of the neighbouring areas, which is not true for yellowfin. The observations of the individual behaviours of a skipjack and a yellowfin confirm the daily variations of the depth of swimming. It is not the case for horizontal moves.

446. Desurmont, A. 1996. ABSTRACT: This article introduces the Bulletin and describes its purposes.

134. Desurmont, A. 1999. ABSTRACT: Since the early 1980's, the Secretariat of the Pacific Community (SPC, formerly the South Pacific Commission) has contributed to the development of FAD programmes for the artisanal fisheries
sector in the Pacific region. In particular, it has put considerable efforts into developing technology that would assure a two-year average FAD lifespan, while maintaining costs under US$ 4,000 per FAD unit. From 1996 to 1998, this work led to the publication of three volumes of the SPC FAD Manual. Volume 2 of this manual, "Rigging Deep-Water FAD Moorings", describes in great detail two FAD models that were developed from the original 1983 SPC-recommended model, and gives precise instructions on the way to construct them. Despite SPC's work, the objectives set, in particular the two-year average lifespan for FADs, have not been consistently met, resulting in many FAD programmes in the region being suspended. An analysis of the reasons why this has occurred is presented, along with a short description of the practical research that could be pursued, using different objectives, to introduce new FAD programmes in the region.

296. Desurmont, A. 2000. ABSTRACT: Since the early 1980's, the Secretariat of the Pacific Community (SPC, formerly the South Pacific Commission) has contributed to the development of FAD programmes for the artisanal fisheries sector in the Pacific region. In particular, it has put considerable efforts into developing technology that would assure a two-year average FAD lifespan, while maintaining costs under US$ 4,000 per FAD unit. From 1996 to 1998, this work led to the publication of three volumes of the SPC FAD Manual. Volume 2 of this manual, "Rigging Deep-Water FAD Moorings", describes in great detail two FAD models that were developed from the original 1983 SPC-recommended model, and gives precise instructions on the way to construct them. Despite SPC's work, the objectives set, in particular the two-year average lifespan for FADs, have not been consistently met, resulting in many FAD programmes in the region being suspended. An analysis of the reasons why this has occurred is presented, along with a short description of the practical research that could be pursued, using different objectives, to introduce new FAD programmes in the region. Original Abstract: Depuis le debut des annees quatre-vingt, le secretariat general de la communauté du Pacifique (SPC, anciennement commission du Pacifique Sud) a soutenu et accompagne le développement de programmes DCP destines au secteur de la pêche artisanale, dans la region Pacifique. Il s'est en particulier efforce de mettre au point des modeles de DCP repondant principalement aux deux criteres suivants: duree de vie superieure a deux ans et cout unitaire moyen inferieur a 4 000 dollars US. Entre 1996 et 1998, ces travaux ont abouti a la publication en trois volumes du manuel de la SPC sur les DCP. Le volume 2 de ce manuel, "La fabrication de DCP pour grandes profondeurs ", presente deux evolutions d'un modele concu en 1983 et en detaille tres precisement les methodes de fabrication. Le present document analyse les raisons pour lesquelles, malgre les efforts deploys, les objectifs fixes, et en particulier la duree de vie minimum de deux ans pour les DCP, n'ont pas ete pleinement atteints et la plupart des programmes DCP de la region ont ete interrompus. Il donne egalemtn une breve description des axes de recherche appliquee qui
Desurmont, A., and L. Chapman. 1999. ABSTRACT: In the area served by the Secretariat of the Pacific Community (SPC), which includes 22 Pacific Island countries and territories, anchored FADs have been used since the late 1970s. First introduced from the Philippines, via Hawaii, they were quickly adopted by both industrial and artisanal fisheries sectors in 1984 more than 600 anchored FADs had been deployed in the region. Since these early days, the development of the technique by the industrial and the artisanal sectors have followed parallel paths with little interaction. In the industrial private sector, companies are funding, deploying and monitoring their own FADs. For some fishing companies, using purse seiners and pole-and-line vessels, from the Solomon Islands or Papua-New-Guinea, these FADs have become a necessity. FAD programmes for small-scale fisheries have been almost exclusively run by the public sector, with technical support from regional and international development agencies and financial assistance from overseas funding agencies. These programmes have had mixed successes becoming an on-going and essential tool in some places like French Polynesia or Guam; or being momentarily suspended, like in Vanuatu or Tonga, because of the lack of funds, partly due to the scarcity of proven economic return to the fishing communities. This document is an attempt to synthesize the current information on these very diverse situations, including technical, economical and social considerations.

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59. **Dickson, J.O. 1993.** ABSTRACT: A discussion is presented on the use of fish aggregating devices in the Philippines fisheries; FADs have substantially increased the catch of tuna, scad and mackerel enabling the country to enter the international tuna market. Details are given of the different types of FADs in use, which include: traditional; deepsea/offshore FADs; 2-layered bamboo raft; rectangular steel-type buoy; steel pontoon-bamboo raft combination; and galvanized drum payaw. Three types of fishing units use FADs to harvest fish - handlines, steel or wooden purse seiners, and wooden ringnetters.

126. **Dickson, J. 1999.** ABSTRACT: Payaw is a traditional concept which has been successfully commercialized to increase the landings of several species valuable to the country's export and local industries. It has become one of the most important developments in pelagic fishing which significantly contributed to increased tuna production and expansion of purse seine and other fishing gears. The introduction of payaw in tuna and coastal fishing in 1975 triggered the rapid development of the tuna and small pelagics fishery. With limited management schemes and strategies, unstable tuna and tuna-like species production, however, had been experienced in the 1980s and 1990s. In this paper, the evolution and development of the payaw with emphasis on the technological aspect are reviewed. The present practices and techniques of payaw in various parts of the country, including its structure, ownership, distribution, and fishing operations are discussed. Monitoring results of purse seine/ringnet operations including handline using payaw in Celebes Sea and Western Luzon are presented to compare their fishing styles/techniques, payaw designs and species caught. The fishing gears in various regions of the country for harvesting payaw are enumerated and discussed. The inshore and offshore payaws in terms of sea depth, location, designs, fishing methods and catch composition are also compared. Fishing companies and fisherfolk associations involved in payaw operation are presented to determine extent of utilization and involvement in the municipal and commercial sectors of the fishing industry. The issues and problems concerning the use of payaw, and its biological, economic impact as well as management aspect are presented. A list of recommendations are presented for future research and action plans.

289. **Dickson, J.O., and A.C. Natividad. 2000.** ABSTRACT: Payao is a traditional concept, which has been successfully commercialized to increase the landings of several species valuable to the country's export and local industries. It has become one of the most important developments in pelagic fishing that significantly contributed to increased tuna production and expansion of purse seine and other fishing gears. The introduction of the payao in tuna fishing in 1975 triggered the rapid development of the tuna and small pelagic fishery. With limited management schemes and strategies, however, unstable tuna and tuna-like species production was experienced in the 1980s and 1990s. In this paper, the evolution and development of the payao with emphasis on the technological aspect are reviewed. The present
practices and techniques of payao in various parts of the country, including its structure, ownership, distribution, and fishing operations are discussed. Monitoring results of purse seine/ringnet operations including handline using payao in Celebes Sea and Western Luzon are presented to compare fishing styles and techniques, payao designs and species caught. The fishing gears in various regions of the country for harvesting payao are enumerated and discussed. The inshore and offshore payaos in terms of sea depth, location, designs, fishing methods and catch composition are also compared. Fishing companies and fisherfolk associations involved in payao operation are presented to determine extent of utilization and involvement in the municipal and commercial sectors of the fishing industry. The issues and problems concerning the use of payao, and its biological, economic impact as well as management aspect are presented. Recommendations are given for future research and actions.

24. **Doumenge, F. 1995.** ABSTRACT: Many integrated coastal resources management include the building of large artificial reefs and the use of Fish Aggregating Devices. The Japanese concept is oriented through the conservation of living resources for the support of traditional fishermen's village life. For the USA policy the rehabilitation and development of fishing grounds are oriented to the maintenance of the sport fisheries. For the Mediterranean Sea, Italy is more in advance owing to the conjunction between public policy planning coastal, fishermen's request and scientific expertise. In reverse, France cannot start large scale programs due to the lack of interest from the scientists and the bureaucrats. Artificial reefs and FADs pave the way for a marine living resources conservation policy and support a sustainable development in accordance with the renewable resources.

43. **Druce, B.E., and M.J. Kingsford. 1995.** ABSTRACT: The association of fish with natural and experimental drifting objects was investigated in the coastal waters near Sydney, Australia (during 1990). Controlled experiments were conducted using small fish attraction devices (FADs) and algae obtained from reefs to test the effects of drift time, size, color and type of object on the fish attracted; “control seines” were done in open water. Total densities of fish were generally higher around the natural drift algae and experimental drift objects than in the adjacent open water. Although well pigmented juvenile fish were most abundant, some larvae and a few adults were also caught around drift objects. Families of fish associated with the drift algae included juvenile mullids, pomacentrids and teraponids as well as larval ambassids and gerreids. Fish were quickly attracted to FADs of different sizes and colors and to experimental algae. Patterns of colonization by fish to drifting objects varied among sampling times, often due to very low numbers of fish captured on some sampling occasions. Families of fish caught around FADs in great numbers that were present in low abundance in open water included pelagic, reef and estuarine-associated fish as follows: juvenile
carangids, sphyraenids, mullids, mugilids and larval ambassids, sillaginids, sparids and gerreids. When large numbers of fish were captured, similar densities and types of fish were attracted to all types of FADs and experimental algae. Many larval fish demonstrated no affinity for algae with high numbers caught in open water and around the drifting objects (e.g., clupeids and atherinids). Drift objects influence the distribution of fish in surface waters. FADs provide a useful method for the collection of small fish and as tools for conducting controlled experiments.

457. **Edwards, R.E., K.J. Sulak, and D. Weaver. 2000.** ABSTRACT: Fish aggregating devices (FADs) recently have been utilized around the world and have been shown to have large effects on fish and fisheries, particularly tunas and tuna fisheries. Other pelagic fish species also are aggregated and impacted by FADs. Fishery problems and potential problems have been identified with FADs, primarily those of increased relative catch of smaller/younger fish and potential changes in distribution and migration. FADs also can have positive effects, primarily by making fishing more effective and efficient. Important and valuable commercial and recreational fisheries have been established by deployment of FADs. The offshore oil and gas industry in the Gulf of Mexico (GOM) recently has been expanding into deep waters of the outer continental shelf and slope where petroleum structures have the potential to act as FADs. A project is being conducted by the US Geological Survey - Biological Resources Division (USGS-BRD) in collaboration with the Minerals Management Service (MMS) in order to assess and anticipate any potential impacts of increased numbers of deepwater petroleum structures on highly migratory fish species in the GOM. Preliminary review of scientific literature on FADs suggests that processes and factors involved in fish aggregation by objects are complex and that the current scientific understanding of FADs is insufficient for prediction of the potential fish aggregating impacts of deepwater petroleum structures in the GOM. Although present understanding of FADs suggests that deepwater structures are likely to have measurable impacts, direct research and study may be needed to fully assess and estimate such impacts.

113. **Edwards, R.E., K.J. Sulak, and D. Weaver. 2001.** ABSTRACT: In view of recently accelerating deployment of petroleum structures in deep waters (>1,000 ft) in the northern Gulf of Mexico (GOM), the Minerals Management Service (MMS) recognized the potential for such structures to act as FADs. In order to allow assessment of this potential, we have researched and organized existing information and literature on FADs and on GOM highly migratory species (HMS) into an annotated, key worded, bibliographic database. This very large body of diffuse information has been reviewed and analyzed. It is being synthesized to provide MMS with a scientific basis for predicting and understanding potential impacts of deepwater structures on HMS. The existing body of information and literature clearly documents the importance and large impacts of FADs on fish and fisheries around the world.
Extrapolation to the GOM from literature on FADs elsewhere indicates that yellowfin tuna (*Thunnus albacares*), bigeye tuna (*Thunnus obesus*) and skipjack (*Euthynnus pelamis*) have high potential to be impacted. However, detailed predictions of FADs effects of GOM deepwater structures cannot be made from existing literature. It is likely that direct studies of fish aggregations around various types of deepwater petroleum structures will be needed.

106. Elst, R. van der, W. Blankley, and S. Chater. 1983. ABSTRACT: The discharge of harmful waste products into the seas around South Africa will increase appreciably in the future, especially with the proposed massive outfall at Richards Bay. Sessile organisms readily encrust submerged and floating objects at sea. Small fish, prawns, crayfish larvae, crabs, etc. are also attracted because of the food and shelter that floating objects provide. It was thus proposed that a series of specially designed rafts (known as Fish Aggregating Devices - FADS) should be suitably anchored in the vicinity of marine outfalls such as the one proposed for Richards Bay. Six of these rafts are now in place and regularly sampled in order to detect any changes that may occur in the abundance, species composition, diversity or growth rates of the associated fauna. Such changes, should they occur, are first evaluated in terms of natural fluctuations, and then assessed in the light of man induced changes.

81. Feigenbaum, D., C. Blair, A. Friedlander, and M. Bushing. 1989. ABSTRACT: Fish Aggregating Devices known as FADs have been employed in a number of places, principally in the tropical Pacific, to attract migratory pelagics for recreational and commercial fishing. The nature of their attractiveness is not fully understood. Within days of their placement, often before significant fouling has taken place, FADs attract large numbers of small fishes. Larger predatory species may come to prey on these using an innate sense to forage around objects in the pelagic realm. For various reasons, including unit failure, their effectiveness has not been well documented. In the present study we set out to fill this void and to evaluate the effectiveness of FADs in a Caribbean tropical island environment.

69. Feigenbaum, D., C. Blair, A. Friedlander, and M. Bushing. 1989. ABSTRACT: Six fish attracting devices (FADs), made with tractor-tire buoys and subsurface attractors, were placed off the northeast coast of Puerto Rico in June 1986 and monitored through December 1986. Three of the units were deployed in 91 m depth, approximately 10 km offshore, and three were placed in 550 m depth, 7 km further offshore. Evaluation of the effectiveness of the FADs was made primarily by quantitative fishing. SCUBA divers examined structural integrity and made qualitative observations on biota. FADs enhanced trolling success. The mean rate of catch and strikes/rod/h was 0.5 near FADs, compared with 0.01 in the control area, and 0.16 and 0.04 in the shelf and offshore transition zones, respectively. There was no
significant difference between trolling catch rates: (a) of inshore vs. offshore FADs; (b) among FADs with different (or no) attractors; (c) of FADs due to their relative position in the array.

Feigenbaum, D.L., and C.H. Blair. 1987. ABSTRACT: The project demonstrated the feasibility of using fish aggregating devices (FADs) to increase harvest of underutilized species in Puerto Rico. A siting plan for FADs and artificial reefs around Puerto Rico was also developed. The report describes and documents the project which evaluated the use of FADs between June and December 1986, by trolling, SCUBA diving, monitoring commercial live bait night fishing, study team night fishing, and experimental longlining.

Fonteneau, A. 2000. ABSTRACT: This poster shows the species composition (tunas and associated species) estimated by scientific observers of Atlantic seiners between 1980 and 1999. Each of the seine sets observed, being almost 3,000 observations, is individually represented by a pie chart with five slices, the surface area of which proportional to each catch (five slices corresponding to four tuna species, and the fifth one for the total of by-catch species). This diagram will be stratified for each period (1) by ecological fishing zone and (2) by fishing mode, free schools and FAD-associated schools. This diagram does show that free schools with mixed species of small tunas (yellowfin, skipjack and bigeye) were often observed before the recent development of FADs. With the massive seeding of FADs, it appears that nowadays these mixed schools of small tunas are always taken under FADs, and are no longer found in free schools. This observation may indicate a strong attraction of small tunas with FADs, at least in the Equatorial area, and a major change introduced by the present massive use of FADs.

Fonteneau, A., J. Ariz, D. Gaertner, V. Nordstrom, and P. Pallares. 2000. ABSTRACT: This paper compares the species composition of free swimming schools and schools associated with fish aggregating devices (or FADs) observed by scientists in the eastern equatorial Atlantic during the early eighties and late nineties. This comparison shows that in free swimming schools, big changes in the species composition have occurred. The main change is a rarefaction of mixed species free schools (skipjack and small yellowfin or bigeye). This change is probably a real biological one, and possibly a consequence of the large numbers of FADs seeded in the area since 1990. Nowadays, most small tuna living in the equatorial area appear to be concentrated under these drifting FADs instead of in free schools. Further study is recommended in order to evaluate the validity and interpretation of this result and to examine its implications.

Fonteneau, A., M. Hall, J. Hampton, P. Pallares, and R. Pianet. 1999. ABSTRACT: This conference will develop a comparative overview of the development of FAD by the tropical purse seine fisheries in the various oceans (Atlantic, Indian, Western and Eastern Pacific oceans). First a
comparative review of fishery statistics will be developed. This comparison will cover geographical patterns, trends over time, seasonality, species composition, size taken, sizes of schools in the various FAD fisheries. Then a comparative review of observer data will be done. Rate of unsuccessful sets on FAD, times of setting, variance of species composition between FAD schools, the observed by-catches by species observed in the various oceans will be compared. The FAD technology used in the various oceans (radio location, underwater nets, numbers, turn over, use of sounders, satellite positioning, use of underwater light, tracking of FAD with satellite and PCs, use of bait, auxiliary boats, etc.) will then be reviewed and compared. The environment and water masses (currents, thermocline, wind, etc.) in which FADs are used more efficiently by purse seiners will be analyzed and discussed. Potential problems introduced by FADs in the tuna stock assessment, primarily because FADs are heavily changing the nature of fishing effort and then most stock assessment, will be discussed. As a last point, the management of FADs presently done or in view by the various tuna bodies will be introduced. It appears that the present massive use of FADs worldwide is probably an unsafe fishing mode which need to be limited to reasonable biological levels.

283. Fonteneau, A., P. Pallares, and R. Pianet. 2000. ABSTRACT: This paper develops a comparative overview of the development of Fish Aggregating Devices (or FADs) by the tropical purse seine fisheries in various ocean areas (Atlantic, Indian, Western and Eastern Pacific Oceans). First, a comparative review of fishery statistics is developed. Recent catches on FADs by purse seiners can be estimated at a level of one million tons yearly. This comparison allows to describe the fishing zones and catch trends over time, the species composition and size taken in the various FAD fisheries. Skipjack tuna is the dominant species in most FAD fisheries, but significant amounts of yellowfin and bigeye are also frequently taken under FADs. The paper also presents an overview of various observer data concerning the by-catches of the various fisheries using FADs. This comparison allows to estimate the total worldwide yearly by-catches at about 100,000 t, and their species composition in each ocean. The FAD technology used in the various oceans by purse seiners is described. The recent use of FADs by purse seiners has introduced major uncertainties in most stock assessments, because analyses are hampered by changes in the fishing effort in a FAD fishery, by changes in fishing zones and in sizes caught. As a last point, the management of FADs presently done or in view by the various tuna bodies are introduced. It appears that the present massive use of FADs worldwide is perhaps an unsafe fishing mode, which could produce serious overfishing of many stocks. There is then a consensus that the use of FADs needs to be controlled and limited to sustainable biological levels.

282. Franks, J.S. 2000. ABSTRACT: Approximately 4,000 petroleum (oil and gas) platforms exist in the northern Gulf of Mexico and form one of the world's
most extensive de facto artificial reef systems. Collectively, these structures may comprise one of the largest FAD (Fish Aggregating Device) arrays in the world, attracting surface and midwater pelagic fishes. The diverse composition of pelagic fish fauna at NGOM platforms is described and includes valued species such as *Thunnus albacares*, *Thunnus atlanticus*, *Coryphaena hippurus*, *Acanthocybium solandri*, *Rachycentron canadum*, *Seriola dumerili*, *Scomberomorus cavalla*, and *Decapterus punctatus*. Petroleum platforms influence pelagic fishery resources and are an important component of the Gulf's commercial and recreational fishing industries. Reviewed literature revealed a sparsely of fundamental knowledge of densities, temporal and spatial occurrence, and fishing effort/catch rates of pelagic fishes at platforms. The role of Gulf petroleum platforms "as FADs" is examined, possible mechanisms for aggregation are reviewed, and a synopsis of the author's preliminary findings on life history aspects of *A. solandri* and *R. canadum* from platforms is presented. It is proposed that platforms provide opportunities for the study of pelagic species to better understand the life history, ecology, behaviour, and habitat requirements of pelagic fishery resources in the Gulf of Mexico.

63. **Friedlander, A., and J. Beets. 1992.** ABSTRACT: Artificial habitats ranging from sunken vessels to designed artificial reefs have been utilized by fishermen for many years in the U.S. Virgin Islands. Continuing experiments have documented appropriate materials and design to enhance fisheries habitat using artificial structures. Extreme habitat degradation and overfishing have necessitated the development of these enhancement measures. Experimental artificial reefs and fish aggregating devices (FADs) have been used as models to determine optimal design and location. Inexpensive, easily deployed FADs have been developed to improve recreational commercial catches of migratory pelagics such as wahoo, kingfish, dolphin, tuna and billfish. Experimental inshore artificial reefs have been used to document the importance of structure, material effectiveness, optimal location and design of artificial reefs used to enhance abundances of important target species.

49. **Friedlander, A., J. Beets, and W. Tobias. 1994.** ABSTRACT: Fish aggregating devices (FADs) of various designs were deployed around the U.S. Virgin Islands to test their relative effectiveness in concentrating pelagic fishes and improving recreational and commercial fishing. Subsurface FADs were deployed along the shelf edge and inshore off St. Thomas. Off St. Croix, surface and subsurface FADs were placed along the shelf edge. Fishing success was evaluated by experimental trolling around FAD and control locations. Over 170 trolling trips comprising 447 fishing hours were conducted between 1986 and 1990. Catch per boat hour ranged from 0.04 to 1.054 on the FADs and 0.07 to 0.305 on the controls. Trolling around FADs yielded a significantly greater number of fish and strikes than control areas except for the St. Croix subsurface FADs. Species diversity of catch also was significantly greater on the FADs compared to controls except for the St.
Croix subsurface units. No significant differences in fishing success were found between the St. Thomas subsurface FADs and the St. Croix surface FADs. The St. Thomas subsurface FADs attracted more coastal pelagic species such as barracuda (*Sphyraena barracuda*), jacks (Carangidae) and king mackerel (*Scomberomorus cavalla*), while the St. Croix surface FADs attracted more oceanic pelagics such as tunas (Scombridae) and dolphin (*Coryphaena hippurus*). The evaluation of various FAD designs and locations can help in the decision of future FAD deployment to meet specific management needs.

93. **Frusher, S.D. 1986.** ABSTRACT: Fish aggregation devices, (FADs) have been one of the most significant introductions to the commercial tuna fishery over the last decade. In this study two FADs were deployed in 160 m and 390 m, respectively, close to the Papua New Guinea coast (< 10 km). The shallower FAD proved unsuccessful both in the amount of fish it aggregated and the consistency with which they were aggregated. In contrast, the FAD in 390 m provided consistent troll catches averaging 12 kg/hr/vessel with several catches exceeding 40 kg/hr/vessel. The deeper water FAD tripled the annual harvest of tunas by artisanal fishermen in Wewak. *Euthynnus affinis* dominated the species composition around the FAD, while *Thunnus albacares, Auxis thazard, A. rochei* and *Coryphaena hippurus* showed seasonal abundance.

426. **Gaertner, D., and M. Medina-Gaertner. 1992.** ABSTRACT: In the southern Caribbean Sea, about half of the catch of tunas comes from free swimming schools and the other half from schools associated with whales and whale sharks. Few are caught from schools associated with floating objects, as there are few floating objects in the prime fishing grounds. Most of the yellowfin caught in this fishery are small.

411. **Gaertner, D., and M. Medina-Gaertner. 1999.** ABSTRACT: In the southern Caribbean Sea, over half of the sets were made on tuna schools associated with whales or whale sharks, while the rest of the sets were made on non-associated schools ("school sets"). An analysis of data collected between 1987 and 1991 showed that sets on tunas associated with whales shifted from November to July from one year to the next, whereas sets on schools associated tunas associated with whale sharks occurred consistently between December and January. Sets on schools of tunas associated with flotsam represented less than 1% of all observations. The low percentage of observations on tunas associated with flotsam may be a result of the location of the fishing grounds with respect to terrestrial sources of flotsam and ocean circulation patterns.

416. **Garcia, M., M.A. Hall, A. Pares-Sierra, and P. Arenas. 1999.** ABSTRACT: A Lagrangian simulation model is used to predict and analyze the trajectories of floating objects entering the eastern Pacific Ocean through five selected
locations near the mouths of major rivers of the region. Most objects are retained relatively close to their source for considerable periods. It is suggested that the association of tunas with floating objects is a retention mechanism, keeping the tunas in the rich coastal areas, and eventually carrying them west through the most productive areas of the eastern Pacific Ocean.

13. Garcia, S. 1991. ABSTRACT: An examination is made of artificial reefs (ARs) and fish aggregating devices (FADs) in Southeast Asian fisheries from a management context. A reef deployment programme raises 2 types of issues related respectively to the administration of the programme (planning, deployment, maintenance, etc.) and to the management of the fisheries on and around the artificial structures. The implementation of such a programme involves various activities related to site selection, delivery of permits for site exploitation, monitoring of structure integrity (safety), maintenance and other interventions of a technical nature. The techniques relevant to the management of fisheries on artificial structures are not very different from the general fisheries management tools, but artificial structures raise particular issues related to the availability of data, the alleged effects on resource concentration and generation, their potential role in conflict resolution, resource allocation, coastal protection and development and their cost effectiveness. Coastal areas represent a domain where natural resources are available that can be used for industrial development, tourism, capture fisheries and aquaculture, recreation, waste dumping, mineral extraction, navigation etc. ARs and FADs are just one additional way of using the coastal zone resources and they interact with others. They can be beneficial for or in conflict with other uses of the coastal space. Their deployment must therefore be considered within the framework of integrated coastal management.

65. Gerlotto, F. 2001. ABSTRACT: A methodology is presented applying multibeam sonar for three-dimensional (3D) observation of fish schools that enhances the conventional use of vertical scientific echo sounders. The sonar employed has 60 beams of 1.5 degree each. Its working frequency is 455 kHz. It is applied on a vertical plan normal to the vessel route, observing from the surface line to the bottom with a range set to 100 m. The sampled volume is 14 times larger than the volume observed with vertical echo sounding. The contribution of this new technology to fisheries acoustics is detailed for school classification, internal school structure, spatial distribution of schools, fish behaviour, and biomass estimates. For each of these points, some preliminary results are presented with the aim of defining the real progress in fisheries acoustics research as a result of 3D acoustics. Finally, a list of technical and methodological improvements is presented that are being developed in order to make multibeam sonar fully adapted to fisheries acoustics.
40. **Gomes, C., R. Mahon, S. Singh-Renton, and W. Hunte. 1994.** ABSTRACT: The role of naturally-occurring drifting objects in fisheries for pelagic species in the southeastern Caribbean was investigated by conducting a questionnaire survey of 253 fishers, 50 from each of St. Lucia, Barbados, Grenada, Tobago and 53 from St. Vincent. The study showed that drifting objects play an important role in large pelagic fisheries in the southeastern Caribbean by attracting fish and thereby increasing their capability. This effect is seasonal, being between January and March in all islands, but having a more extended seasonal duration in Grenada and Tobago. The effect is most marked in water which is green or brown in colour. Fish associate with both natural and anthropogenic drifting objects, with no apparent preference within or between these groups. Fishers actively seek and fish around drifting objects. Fishers from St. Lucia, Barbados, Grenada and Tobago target flyingfish by deploying drifting FADs which they construct of naturally-occurring material. However, no fishers use drifting FADs which they deploy to target large pelagics. The information acquired in this study indicates that the deployment of anchored FADs should succeed in increasing catch rates of large pelagics, and suggests that the potential for developing fisheries for large pelagics by deploying drifting FADs should be explored.

44. **Gorman, T. 1995.** ABSTRACT: Mahi-mahi (dorado, or dolphin fish) is a widely acclaimed table fish, especially in Hawaii, but not well known in Australia; it has the potential as the basis of a lucrative export industry. It is one of the species whose fishery would benefit from the establishment of a national network of fish attracting devices (FADs). FADs have been successfully tried off Western Australia, New South Wales and Queensland. These have however been of a type whose expense could not be justified by their effective life. A simpler design such as is used in Asia could be more cost-effective. Problems of funding and property rights to the advantage of FADs are briefly discussed.

307. **Goujon, M., and C. Labaisse-Bodilis. 2000.** ABSTRACT: In 1998, the French and Spanish tuna-boat owners associations have voluntarily reconducted the Atlantic tuna protection plan (also called moratorium) initiated the previous year. This plan which has become an ICCAT recommendation for 1999, consists mainly in preventing fishing on floating objects (logs) and in having observers on board tuna purse seiners. Data collected by these observers and landing statistics allow to draw preliminary conclusions on some effects of the protection plan, on the fleets and on the Atlantic tuna stocks. Largely respected, the moratorium has led to a spatial redistribution of the fishing effort, an important reduction of the proportion of sets on logs and a decrease of the landings by one third compared to those realized the years before during the same months, particularly for the skipjack and the bigeye tunas. Moreover, data collected allow to calculate catch rates for a number of by-catch species in the purse seine fishery.
Guillou, A., A. Lagin, A. Lebeau, D. Priour, M. Repecaud, L. Reynal, J. Sacchi, and M. Taquet. 2000. ABSTRACT: Since 1983, the research on the optimal conception of FADs in Martinique was particularly focused on the improvement of their resistance to different maritime or human aggressions. Following several experimentations made with different types of FADs, the choice was brought on light devices anchored in 1,500 to 2,000 m depths and an experimental approach was conducted to identify the causes of loss of FADs and to attempt to modelize their hydrodynamic behaviour with relation to the sea conditions. Three mathematical models are used to simulate the FAD behaviour under current action and swell, and to estimate the forces exerted on each part of the device. The results of this study are presented. The FAD design used nowadays for the development of pelagic fishing in Martinique, recommendations for maintenance and preservation of the FADs are also proposed. Original Abstract: De 1983 a 1994, les recherches sur une conception optimale des DCP de la Martinique ont ete plus particulierement orientees sur l'amelioration de leur resistance aux diverses agressions marines ou humaines. Suite aux multiples experimentations menees avec differents types de DCP, le choix de systemes legers ancre par fonds de 1 500 a 2 000 m a conduit a une demarche scientifique comprenant a la fois une analyse des causes de perte des DCP et la modelisation de leur comportement hydrodynamique en foncti on des conditions de mer. Les resultats de ce programme ainsi que le plan du DCP retenu pour le developpement de la pêche des poissons pelagiques en Martinique sont presentes. Des recommandations pour la maintenance et la preservation des dispositifs sont egalement proposees.

Guillou, A., J. Sacchi, A. Lagin, and M. Taquet. 1999. ABSTRACT: From 1983 to 1994, the research on the optimal conception of FADs in Martinique was particularly focused on the improvement of their resistance to different marine or human aggressions that these devices could be incurred and otherwise in the aim of the respect of the international rules of beaconing. Following the several experimentations of different FADs types, the choice was brought on light devices anchored on 1,500 to 2,000 m depths and led to an experimental approach including the identification of the loss reasons and a modeling of the hydrodynamic behaviour in relation with the sea conditions. The results of this study are presented here as the FAD design used at present time for the pelagic fishing development in Martinique. Recommendations for maintenance and preservation of the FADs are also proposed.

Hall, M. 1992. ABSTRACT: Several hypotheses are presented, including: 1) The timing and location of yellowfin spawning are selected to take maximum advantage of coastal production cycles, periods of high input from rivers, and drift patterns. 2) The fishery on logs and schools in an area exploits the same section of the population, which feeds in unassociated schools during the day and drifts with logs at night. 3) The association with a log is adaptive
because it keeps the tunas in rich water masses (Indicator-Log Hypothesis).

4) The floating object is simply an indicator; its characteristics may influence its detection, but not its adaptive value (Generic-Log Hypothesis).

462. Hall, M. 2001. ABSTRACT: Several hypotheses have been offered to explain the association of tunas and other species with floating objects in the world oceans. These are reviewed, in an attempt to assess which ones best explain the association of tunas with floating objects. The emphasis is on experimental approaches that could shed light on the remaining alternatives. Besides the adaptive value of the association, it is also important to address other issues that should help in understanding the ecological and behavioral responses to the floating objects: How are the objects detected/found? Are all objects attractive? What is the residence time under an object? Are there diel changes in the association? Is there fidelity to individual objects? Why do some species or sizes associate with floating objects, while others do not?

418. Hall, M., P. Areans, and F. Miller. 1992. ABSTRACT: Data was collected by observers placed aboard tuna boats and included characteristics of the environment, floating objects, and the tunas and dolphins that form associations. The influence of terrestrial ecosystems was discussed. The characteristics of the pelagic communities around floating objects were defined.

421. Hall, M., and M. Garcia. 1992. ABSTRACT: EPO purse-seine fishery observer data was examined with regard to catch rates in consecutive (next day) sets around floating objects in order to examine hypotheses about fidelity of associated tunas. The hypotheses were that a school of tunas: 1) is associated with a specific floating object, which it leaves by day to forage and to which it returns every night; 2) is associated with a group of objects, which it visits periodically; 3) associates with any floating object it encounters in the evening; and 4) is permanently associated with one floating object, whose vicinity it never leaves, but scatters and perhaps also goes deeper during the day and re-groups in a more compact group under the object at night. Statistical tests showed that there is a significant decline in the average catches in the categories of all tunas, skipjack and tunas other than yellowfin, and skipjack on consecutive nights. Decline of yellowfin catch was marginally statistically significant. Authors conclude that these results are closer to what would be expected under 3) and 4); and that 3) seems more likely, because 4) would not allow the tunas a large enough foraging area.

422. Hall, M., M. Garcia, A. Pares-Sierra, and P. Arenas. ABSTRACT: A Lagrangian simulation model is used to predict and analyze the trajectories of floating objects entering the eastern Pacific Ocean through five selected locations near the mouths of major rivers of the region. For each location, basic characteristics, seasonality, and annual variability are presented and discussed. The main conclusions are that: (1) through either cyclic current
patterns or oscillating north-south movements, most objects are retained relatively close to their source for considerable periods; (2) practically all the transport offshore occurs along 10 deg N, which receives objects from the north and south; (3) El Nino events alter the patterns substantially, increasing the velocity of the offshore movements of the objects, but always along 10 deg N. It is suggested that the associations of tunas with floating objects is a retention mechanism, keeping the tunas in rich coastal areas, and eventually carrying them west through the most productive areas of the Pacific Ocean.

425. **Hall, M., and C. Lennert. 1992.** ABSTRACT: A migratory circuit for yellowfin tuna in the eastern Pacific Ocean (EPO) is proposed. In this circuit, spawning occurs in the coastal zone, newly recruited juveniles are retained in the coastal zone by floating objects, larger yellowfin migrate offshore along 10 deg N in association with dolphins, and adults return to the coastal spawning grounds aided by the subsurface Cromwell Current.

419. **Hall, M., C. Lennert, and P. Arenas. 1992.** ABSTRACT: The EPO purse-seine fishery, where tunas are caught in association with dolphins, in association with floating object and in unassociated schools is described, particularly with respect to sample sizes, number of sets, percentage of successful sets (those with more than 0.5 t caught), and the proportion of catch discarded at sea.

420. **Hall, M., C. Lennert, and P. Arenas. 1992.** ABSTRACT: Data collected by observers in the EPO purse-seine fishery was analyzed with regard to catch per successful set (sets in which catch was at least 0.5 t) relative to characteristics of floating objects on which the set was made. Characteristics examined included: month, location, time of day, sea-surface temperature, water clarity, wind index, current strength, type of object, shape, material, origin, color, percent submerged, estimated time adrift, angle in water, longest dimension, surface of object, estimated volume, epibiota, tree characteristic, and previous sets. The only object characteristic that seemed to affect yellowfin tuna was percentage of object submerged, with catches increasing with percentage. Object characteristic effects were less clear, with color and shape perhaps important.

461. **Hall, M.A. 2001.** ABSTRACT: Since its inception, the purse-seine fishery for tropical tunas in the eastern Pacific Ocean has obtained substantial portions of its catches from sets on flotsam and on fish-aggregating devices (FADs) placed by the fishers. Many other fisheries, both commercial and recreational, also utilize a variety of floating objects to find their target species. This paper describes the tuna fishery with respect to its evolution, the location, the techniques employed, the catches and by-catches, and also the characteristics of the flotsam and FADs. This mode of fishing has increased considerably in recent years, and it is currently being regulated with temporal closures.
Fishing on anchored FADs is not currently practiced in the EPO, but some coastal nations have plans to develop this type of fishery.

412. Hall, M.A., M. Garcia, C. Lennert-Cody, P. Arenas, and F. Miller. 1999. ABSTRACT: In tropical (and some temperate) regions of the eastern Pacific Ocean schools of tropical tunas (mainly yellowfin tuna, Thunnus albacares and skipjack tuna, Katsuwonus pelamis) are known to form associations with floating objects and with dolphins, in addition to forming unassociated schools. These behaviors have given rise to three modes of purse seining for tunas. An analysis of the relative importance of the three fishing modes for the purse seine-fishery between 1980 and 1990 is presented. Spatial and temporal variability in fishing effort, measured in terms of numbers of sets, and average catches of yellowfin and skipjack tuna are described. A brief review of the physical and biological characteristics of the eastern tropical Pacific Ocean is provided, and the effects of the environment on fishing operations and tuna associations are discussed.

417. Hall, M.A., C. Lennert-Cody, M. Garcia, and P. Arenas. 1999. ABSTRACT: Using data collected between 1987 and 1991 by IATTC observers, general linearized model techniques were used to investigate relationships between object characteristics and environmental conditions, and tuna catch. The most important factors affecting catch per set of all tunas caught were the object's location, the time of day when the set was made and the number of sets made previously on the floating object. Season of deployment was important. Generally, the characteristics of the floating object appear to not have had a significant affect on successful catch of tunas. Objects greater than 1 m yielded fewer successful sets. Percentage of object submerged was important, whereas other characteristics, such as color, were not significantly important. Sample sizes were inadequate for fully definitive conclusions.

428. Hallier, J.P., and J.L. Parajua. 1992. ABSTRACT: Data from purse-seine vessel logbooks were analyzed with regard to catches taken from objects fished several times consecutively. Total catch (mt/set) averaged 58.5, 39.5, 33.9, 29.8, 24.6, 22.3 and 11.6 mt in the 1st through 7th consecutive sets. The decline was largely due to decreased skipjack catch, whereas yellowfin catch averaged 6.7, 7.3, 6.6, 8.1, 7.4, 8.3, 7.0 mt in the 1st through 7th sets. Authors hypothesized that this was due to a large body of deep-swimming yellowfin moving toward the surface as the shallow-swimming skipjack were caught and removed.

430. Hallier, J.P., and J.L. Parajua. 1992. ABSTRACT: The tuna fisheries in the Western Indian Ocean are described and the degree to which fishing on floating objects is quantified. For the French, Spanish, and Japanese fleets, the percentage of catch made from schools associated with floating objects is: yellowfin 27%, skipjack 72%, bigeye 69% and albacore 8%. Purse seine depth ranges from 210 to 300 m. Size distributions of skipjack caught on log
and free schools are very similar, while yellowfin and bigeye caught from log schools are smaller than those caught from free schools. Most of the yellowfin caught from log schools are immature. Japanese vessels deploy artificial floating objects to extend the season through periods in which natural logs are scarce.

431. **Hallier, J.P., and J.L. Parajua. 1992.** ABSTRACT: Log book data from French and Spanish purse seiners were analyzed relative to tuna association with objects. Success rates and catch per set are also related to log book data. Analysis of data for catches near a sea-mount ("Gevred sea-mount"), that rises from 4,000 m to 191 m, shows that yellowfin (53%) are more abundant than skipjack (42%) and bigeye (5%). The fact that the distribution is different than that from around floating objects, suggests that the sea-mount does not simply act as a super giant "log."

413. **Hallier, J.P., and J. L.Parajua. 1999.** ABSTRACT: This paper focuses on the tuna fishing on floating objects by the purse-seine fishery. It includes fishing on FADs, as well as logs.

313. **Hallier, J.-P., and A. Delgado de Molina. 2000.** ABSTRACT: The original baitboat fishing technique using a permanent association between the fishing boat and the tuna school has been developed by the baitboat fleet of Dakar, Senegal and is also in use in the Canary Islands. This new fishing technique, the result of 20 years of continuing improvements, has induced a dramatic increase of the catch yields which, in turn, has sustained the survival and even a recent development of the fleet. This technique is based on the aggregating behaviour of tropical tunas. However, it contains a dynamic component which is not found in tuna fishing on drifting or anchored FADs. The specifications of the method, its refinement over the years and its main consequences for the fishery are described together with the school exchanges between baitboats over months even from one year to the next. Based on the analysis of 1228 recoveries from 5500 tagged fish, tuna movements among associated schools, between associated schools and free schools fished by purse seiners and movements in and out of the baitboat fishing grounds help to better understand the dynamics of tunas and schools of this peculiar tuna association. These data show a very high recovery rate, a remarkable tuna fidelity to the original school for all species, a small number of recoveries within the purse seine catch as well as the rare tuna movements outside the baitboat area. The study highlights the complexity and the numerous consequences of tuna and school behaviour.

436. **Hampton, J., and K. Bailey. 1992.** ABSTRACT: The tuna fishery in the western and central Pacific Ocean is the world's largest. The purse seine fleet sets on a variety of floating objects including logs, drifting and anchored FADs, and occasionally whales and whale sharks. Sets on dolphins are not made. Bycatch is more extensive for log and FAD sets than for school or animal
sets. Blue marlin are often caught in log sets. Larger yellowfin are caught most frequently in school sets, but large bigeye are more caught most frequently in log sets. Very small yellowfin and skipjack tuna are often caught beneath logs and FADs and may be discarded by purse seiners. Most sets on logs and FADs are made just before dawn and occasionally at dusk. Tuna aggregations associated with logs may exceed 300 mt, but typically are less than 50 mt. Frequently fished FADs probably support smaller aggregations due to the limited time for recruitment between successive sets.

414. Hampton, J., and K. Bailey. 1999. ABSTRACT: The tuna fishery in the western and central Pacific Ocean is the world's largest. The purse seine fleet sets on a variety of floating objects including logs, drifting and anchored FADs, and occasionally whales and whale sharks. Sets on dolphins are not made. Bycatch is more extensive for log and FAD sets than for school or animal sets. Blue marlin are often caught in log sets. Larger yellowfin are caught most frequently in school sets, but large bigeye are more caught most frequently in log sets. Very small yellowfin and skipjack tuna are often caught beneath logs and FADs and may be discarded by purse seiners. Most sets on logs and FADs are made just before dawn and occasionally at dusk. Tuna aggregations associated with logs may exceed 300 mt, but typically are less than 50 mt. Frequently fished FADs probably support smaller aggregations due to the limited time for recruitment between successive sets.

12. Hardjono. 1991. ABSTRACT: Fish aggregating devices (FADs) in the form of rumpon and payaos have been deployed in Indonesian fisheries for a long time. Three kinds of FADs are recognized to be in specific use, namely: rumpon, which are usually used for small pelagic fishing; payaos, which are usually used for tuna fishing; and, rumpon used for creating artificial reefs. In general, the shape and design of rumpon and payaos operated in Indonesia are the same, comprising float, attractor, rope and sinker/anchor. Proper management measures, control and monitoring of the use of rumpon/payaos need to be developed in order to avoid undesirable effects on the fishing communities such as conflicts and adverse effects on the resources and environment.

53. Hassan, R.B.B.R. 1994. ABSTRACT: A study was conducted in 1988 and 1989 to determine the viability of using steel FAD (payao) as an alternative to the traditional FAD. The commercial capture of fish aggregated at the FADs was done by three local purse-seine boats. The size of the boats was more than 70 GRT. Three designs of aggregating devices were used and the catches for each design at every fishing trip were monitored. Traditional FADs produced higher catch in terms of volume, but comprised a high percentage of low quality fish. The mean fork length of fish caught from the vicinity of the steel-made FAD was found to be larger compared to those caught by traditional FADs. The FAD fitted with plastic strips took a much longer time to aggregate pelagic fish when compared to the traditional FAD. Dominant
species caught from the steel FADs were *Decapterus* sp., *Selar mate*, *Selar crumenophthalmus*, *Rastrelliger kanagurta* and *Euthynnus affinis*. Amongst the three designed FADs, the cylindrical one was found to be the most effective.

52. Hensley, R.A., T.S. Sherwood, and G. Davis. 1994. ABSTRACT: Accurate mooring lengths for fish aggregating devices (FADs) are a critical component of the FAD design. Using the reverse catenary loop, the calculations for lengths of floating and sinking line can be cumbersome, requiring a good deal of training, time and effort. Because all staff deploying FADs do not have a mathematical background and/or the training to do these calculations, a computer program was developed to make this step in FAD construction less troublesome. The computer program was formatted for use with Macintosh computers, because of the ease of operation of these systems. Input into the program, in either English or metric system, consists of all parameters used in construction (i.e., deployment depths, hardware weights) and can be manipulated by the user. Once calculations have been performed, the user can save the calculations for future use. A help section is included for problems that may be encountered during the program. By using this program, the speed for calculating mooring lengths has been greatly reduced. Since the accuracy should also improve, this program could greatly enhance a FAD program by decreasing the amount of FADs lost due to mooring system failure from errors in mooring length calculations.

437. Hiatuka, K. 1992. ABSTRACT: The fishing vessel was aided by a speed boat in attempts to catch unassociated schools of tuna. The speedboat towed a large plastic sheet and was 90% successful in getting free-swimming tuna schools to associate with the sheet and speed boat and to be caught by purse seine vessel. The importance of "shadow" both in the sheet/speed boat association and association with lights at night was hypothesized.

47. Higashi, G.R. 1994. ABSTRACT: Fish aggregating devices (FADs) were introduced in Hawaii in an attempt to increase sportfishing opportunities and revitalize the fishing industry by taking advantage of the "aggregating" behavior of pelagic fishes around floating objects. In 1980, the State of Hawaii's Department of Land and Natural Resources established a FAD system of 26 buoys around the main Hawaiian Islands. Since their introduction, FAD buoy and mooring system designs have undergone considerable technological changes. The Hawaii FAD System evolved from the use of foam-filled tire buoys, using one type of synthetic line to the present sphere buoy design with two types of line. The design changes were developed to create a buoy and mooring line system that would remain on station for a long time and enhance sportfishing opportunities. Today, Hawaii's 78 FADs make up a system, including 56 surface and 22 midwater buoys. The FADs have proven to be very popular among Hawaii's fishermen. Catch statistics show that the FADs have contributed to increased catches and
historical data on FAD survival in the field show that design improvements have produced longer lasting FADs. Future developments in FAD systems point to a combination of surface and midwater FADs around the main Hawaiian Islands.

92. **Hilborn, R., and P. Medley. 1989.** ABSTRACT: A model is proposed for the analysis of fishing tuna from fish-aggregating devices (FAD), and parameters for the model are estimated. Methods are described for determining the optimum number of FADs to be deployed and the optimum number of vessels in a fishery. Field measurement of recruitment and loss of fish associated with FADs is needed for adequate biological or economic analysis of FAD fishing. Results show that if recruitment to FADs is proportional to the biomass not associated with FADs, then increasing the number of FADs beyond some limit will actually decrease total catch.

122. **Holland, K. 1999.** ABSTRACT: Hawaii was one of the first locations to adapt the Philippine payao concept for use in high energy, deep-water environments. In 1980, the State of Hawaii started deploying FADs in a program that has expanded to its current status of 52 approved surface FAD sites. These sites were chosen after consultation with fishermen at public hearings. FAD sites range between 3.5 and 28 nautical miles from shore and mooring depths range between 300 and 3,000 meters. Hawaii's FADs evolved through two previous designs before the current system of a single 1.5-meter diameter sphere was adopted. Today's FADs, have an "inverse catenary" mooring system comprised of sections of floating and sinking rope attached to a "tripod" concrete block anchor system. Initially, funding for the FAD system came from the State of Hawaii. However, the system is currently funded with U.S. federal monies (Dingell-Johnson program) with some matching support from the State of Hawaii and the University of Hawaii. Each FAD costs approximately ~US$ 7,500 to build and deploy. Approximately 20 FADs are replaced each year and the average life span is about 20 months. There are no differences in FAD longevity based on mooring depth, but there does seem to be a difference between windward and leeward locations. Hawaii's FADs are heavily used by artisanal and sport fishermen and by small-scale commercial fishermen. Commercial pole-and-line boats occasionally use the FADs to capture skipjack tuna. Hawaii's FADs continue to be used for various types of pelagic fisheries research. These will be discussed and future research directions will be described.

103. **Holland, K., R. Chang, and S. Ferguson. 1985.** ABSTRACT: A summary is presented of results obtained during tracking research on tuna (*Thunnus obesus* and *T. albacares*). Eight fish were tracked: six fish aggregating devices tracks and two non-FADs tracks.

464. **Holland, K.N. 2001.** ABSTRACT: The state of knowledge of the influence of anchored FADs on the behavior and distribution of pelagic fishes
(predominantly tuna) will be reviewed. Various techniques have been employed to investigate the influence of FADs on fish behavior. These methods include gut analyses, tag-and-recapture experiments and sonic tracking. Tag-and-recapture experiments are demonstrating that FADs can have a very strong influence on the movements of tuna (and on fishing effort) on a regional level. Sonic tracking has taken two forms; active tracking of animals equipped with transmitters and passive monitoring of fish movements by data loggers placed on the FADs. In the former case, tracking vessels are used to follow individual fish and continuously monitor their horizontal and vertical movements - both when they are near a FAD and when they move away. Passive monitoring can elucidate the long-term revisitation patterns of tuna and also possibly give indication of school cohesion and longevity. Current data will be discussed in terms of possible pertinence to Gulf of Mexico fisheries.

78. **Holland, K.N., R.W. Brill, and R.K.C. Chang. 1990. ABSTRACT:** The horizontal and vertical movements of yellowfin tuna *Thunnus albacares* and bigeye tuna *T. obesus* captured near fish-aggregating devices (FADs) were determined using pressure-sensitive ultrasonic transmitters. The movements of these FAD-associated fish were compared with the tracks of yellowfin tuna not associated with FADs. Tracks from 11 yellowfin and 4 bigeye tuna were obtained; these included 23 complete 24-hour periods of observation. Whether associated with FADs or a 40-fathom (75-m) reef dropoff, most yellowfin and bigeye tunas exhibited similar diurnal patterns. The fish tended to remain tightly associated with FADs or the reef dropoff during the day, move away at night, and return the next morning. Swimming strategies possibly associated with energy and thermoconservation were observed.

285. **Holland, K.N., A. Jaffe, and W. Cortez. 2000. ABSTRACT:** Hawaii was one of the first locations to adapt the Philippine payao concept for use in high energy, deep-water environments. Initial experimental FAD deployments were made by the National Marine Fisheries Service in 1977. In 1980, the State of Hawaii started deploying FADs in a programme that has since expanded to its current status of 52 approved surface FAD sites. Funding is primarily derived from federal US programmes and the FADs are primarily focused on the sport fishing community. FAD sites were selected to expedite access by sport fishermen; specific sites were chosen after consultation with fishermen at public hearings. Since 1997, the FAD system has been managed on a collaborative basis between the State of Hawaii and the University of Hawaii. Hawaiian FADs evolved through two previous designs before the current system of single-sphere spar-buoy was adopted. Today's FADs have an "inverse catenary" mooring system comprised of sections of floating and sinking rope attached to a "tripod" concrete block anchor system. FAD sites range between 3.2 km and 46 km from shore. Mooring depths range between 200 and 3,000 meters. Average on-site longevity is 31 months; there is no correlation between longevity and depth of mooring. Windward locations
have significantly shorter lifespans than leeward locations. Ten to twenty FADs are replaced each year. Each FAD costs approximately US$ 7,500 to build and deploy. Hawaiian FADs are heavily used by private and commercial sport fishermen and by small-scale artisanal and commercial fishermen. Commercial pole-and-line boats occasionally use the FADs to capture skipjack tuna. Hawaiian FADs will continue to be used for various types of pelagic fisheries research.

194. Hueter, R., and J. Childs. 2001. ABSTRACT: Offshore petroleum and gas structures can function as attracting devices for a variety of marine species, including elasmobranchs (sharks, skates and rays). Sharks and rays may use these structures as refuges, as core areas for daily activities, and as sources of food, both natural and anthropogenic (bait, offal). In the shallow depths surrounding these structures in the Gulf of Mexico, sharks such as the silky shark (*Carcharhinus falciformis*), scalloped hammerhead (*Sphyrna lewini*) and whale shark (*Rhincodon typus*) and rays such as the spotted eagle ray (*Aetobatus narinari*) and the Atlantic manta (*Manta birostris*) are often observed. Some pelagic elasmobranch species, such as the silky shark, appear to use these structures as core areas for juvenile stages. In the deep waters surrounding the structures (>1000 ft), species of deepwater sharks such as sixgill sharks (*Hexanchus* spp.) and large deepwater dogfishes (*Centrophorus* spp.) have been observed by ROV-mounted video cameras deployed from the rigs. The implications of these various observations will be discussed in reference to the emerging trend of deeper petroleum and gas rigs in the Gulf of Mexico.

31. Ibrahim, S., M.A. Ambak, L. Shamsudin, and M.Z. Samsudin. 1996. ABSTRACT: Various hypothesis have been proposed to explain why floating artificial habitats are successful in attracting fishes. Food may be a stimulus for aggregating some species around Fish Aggregating Devices (FADs). This study attempts to discover if sessile marine organisms which readily encrust traditional FADs, are important food organisms for fish. A new group of FADs was installed in a rich fishing ground. Different parts of the FADs were sampled every two weeks for identification of encrusted organisms, and 10 species were identified. the density of the organisms fluctuated with time of immersion. Plankton collected from the water at the FAD sites was also identified. Stomach contents of 90 fishes caught around these FADs were analysed and the organisms found in the stomachs were compared with those on the FADs. This study suggests that the attraction of fishes to FADs is due to mechanisms other than feeding on organisms encrusting the FADs.

57. Ibrahim, S.M., I. Mohamad, and M.A. Ambak. 1994. ABSTRACT: Several forms of fishing gear are operated together with fish aggregating devices (FADs) in Malaysia. In terms of catch volumes, purse seines are the most important. The devices are normally deployed in fishing grounds at depths of 10-30 m. Such
aggregating of fish prior to harvesting has improved the economics of fishing operations by reducing the time and fuel spent in searching for the fish.

113. **Itano, D.G. 1996.** ABSTRACT: The Pelagic Fisheries Research Program (PFRP) of the University of Hawaii funds several projects on the pelagic fishery resources of the central and western Pacific. Dr. Kim Holland is the active principal investigator to a small-scale mark and recapture study for bigeye and yellowfin tuna in Hawaiian waters funded by the PFRP. The Hawaii Tuna Tagging Project (HTTP) was originally requested by a small group of fishermen who exploit tuna on a highly-productive seamount and near offshore anchored fish-aggregation devices (FADs). The project is restricted in release sites to the Cross Seamount, located 160 nautical miles south of Honolulu, Hawaii, and the offshore FADs located between 150 and 180 miles from shore. The PFRP has also funded a modeling study to optimize the design of a larger-scale tuna tagging project for the entire Hawaii EEZ. The participants in the fishery target juvenile bigeye and yellowfin tuna that aggregate to the Cross Seamount and offshore FADs. The fishery consists of small vessels of 10 to 30 meters in length that use simple handline or troll gear to take bigeye and yellowfin in the 6- to 25-kg range. The area near the seamount has also been historically exploited by Hawaii-based longline vessels targeting larger bigeye and yellowfin tuna. Initial concern by the handline fishermen regarding gear interaction and sustainability issues drove the initial funding of this project.

28. **Itano, D.G. 1998.** ABSTRACT: The Pelagic Fisheries Research Program (PFRP) of the University of Hawaii funds several projects on the pelagic fishery resources of the central and western Pacific. Dr. Kim Holland is the active principal investigator to a small-scale mark and recapture study for bigeye and yellowfin tuna in Hawaiian waters funded by the PFRP. The Hawaii Tuna Tagging Project (HTTP) was originally requested by a small group of fishermen who exploit tuna on a highly-productive seamount and near offshore anchored fish-aggregation devices (FADs). The project is restricted in release sites to the Cross Seamount, located 160 nautical miles south of Honolulu, Hawaii, and the offshore FADs located between 150 and 180 miles from shore. The PFRP has also funded a modeling study to optimize the design of a larger-scale tuna tagging project for the entire Hawaii EEZ. The participants in the fishery target juvenile bigeye and yellowfin tuna that aggregate to the Cross Seamount and offshore FADs. The fishery consists of small vessels of 10 to 30 meters in length that use simple handline or troll gear to take bigeye and yellowfin in the 6- to 25-kg range. The area near the seamount has also been historically exploited by Hawaii-based longline vessels targeting larger bigeye and yellowfin tuna. Initial concern by the handline fishermen regarding gear interaction and sustainability issues drove the initial funding of this project.
Itano, D.G., and K.N. Holland. 2000. ABSTRACT: In Hawaii, a variety of small- and medium-scale pelagic fisheries target fishing effort on a network of coastal moored FADs, natural inshore tuna aggregation points, offshore seamounts and offshore weather monitoring buoys. Large-scale longline vessels also operate in the Hawaii exclusive economic zone (EEZ) and beyond. These circumstances provide an ideal setting for tag-and-release experiments designed to elucidate the movement patterns, residence times, exchange rates and vulnerability of bigeye tuna (*Thunnus obesus*) and yellowfin tuna (*Thunnus albacares*) within the Hawaiian EEZ. Preliminary recapture data indicate that FADs, island reef ledges and seamounts exert an overwhelming influence on the catchability of tuna. Recapture rates from these locations vastly outweigh tag returns from open water areas. As of August 31, 1999, a total of 15387 bigeye and yellowfin tuna ranging in size from 29 to 133 cm fork length (FL) and from 26 to 143 cm FL respectively (mean 59.8 ± 14.1 cm; 58.4 ± 17.3 cm) have been tagged and released throughout the Hawaii EEZ. Recapture rates for both species have been similar with an overall recapture rate of 10.3%. The location of tag releases reflects the importance of associative behavior and schooling to the vulnerability of tuna; seamounts and FADs accounted for 72.4% and 23.5% of all tag releases. Within the main Hawaiian Island group (excluding the offshore seamounts and buoys), 83.1% of all recaptures have been made on anchored FADs and 11.9% of recaptures have come from ledges or tuna aggregation areas close to the islands where bigeye and yellowfin tuna become vulnerable to hook and line gear. As these studies continue, additional and longer-term recaptures will provide increasingly detailed information on the movement patterns and vulnerability of bigeye and yellowfin tuna as they grow, move and recruit to different fisheries.

Jayakody, D.S., and S.S.C. Pieris. 1994. ABSTRACT: Three fish aggregation devices (FADs), made from bamboo and other locally available materials, were deployed on the continental slope off Lunawa, Panadura (West coast of Sri Lanka) and Ambalangoda (Southwest coast of Sri Lanka). Information on fishing effort associated with the FADs, catch and species composition were collected during weekly visits. When compared to other non-FAD associated fisheries conducted by the same gear, handline fishing with live bait using non-mechanized traditional canoes was shown as the ideal fishing craft/gear combination to fish around FADs. *Coryphaena hippurus* and *Elagatis bipinnulata* contributed 42.4% and 21.7% respectively to the total catch. As these two species are not caught in large quantities in other fisheries, FADs proved to be useful in exploiting this underutilized resource.

Josse, E., L. Dagorn, and A. Bertrand. 2000. ABSTRACT: Eighty-seven two-hour acoustic surveys (radius 0.8 nautical mile, vertical range 0-500 m) around 17 fish aggregating devices (FADs) were conducted in French Polynesia between December 1995 and February 1997. Associated tuna densities were calculated using two different techniques: echo counting when the fish had
sufficient distances from each other and echo integration when the fish swam close together (in schools). No acoustic detection of tuna was observed during 27 of the 87 surveys, representing 81% of all the nocturnal surveys and 15% of the diurnal ones. The 60 other surveys showed three different classes of aggregations: (1) “deep scattered fish”, observed 45 times, (2) “intermediate scattered fish”, observed 16 times, and (3) “shallow schooling fish”, observed 16 times. Sometimes aggregations of different classes were observed beneath the same FAD. The size of the fish inside the aggregations (determined from target strength values), the distance between the individuals, and the depth of the fish all decreased from “deep scattered fish” to “shallow schooling fish” (100-300 m for “deep scattered fish”, 50-150 m for “intermediate scattered fish”, and above the depth of 50 m for “shallow schooling fish”). Fish densities also varied according to the class of aggregations: 7.3, 26, and 801 fish per km$^3$ on average for “deep scattered fish”, “intermediate scattered fish”, and “shallow schooling fish”, respectively. The highest densities were observed during daytime, while night-time observations indicated a variety of situations, from the absence of individuals to large amounts of fish.

37. Kailola, P.J. 1995. ABSTRACT: The results are presented of a consultancy conducted between November 1995 and January 1996 in order to review policies and initiatives to enhance fisheries management and development in Fiji. The following areas were covered: 1) Review of inshore fisheries for subsistence and small-scale fisheries, export, aquaculture; 2) Review of offshore fisheries – tuna fishery, deepslope fishery, recreational gamefish fishery, trollfish fishery, broadbill swordfish fishery, sharkfin fishery; 3) Fishing effort and fish supply – inshore fishing effort, fish for domestic markets, fish for export markets; 4) Infrastructure needs – FADs, information services, improved fisheries legislation, enforcement, improved in-house management of the FD, fish quality management program, value-adding, ice availability, berthing facilities, marketing services, extension services, training opportunities, stock assessments, marine reserves; 5) Increasing private sector participation in fisheries – ice, freshwater aquaculture, mariculture, Fiji Development Bank, provision of FD services, FADs, value-adding and new fisheries. A list is included of the main recommendations made.

286. Kakuma, S. 2000. ABSTRACT: In early 1980s, FAD fisheries were introduced from the Philippines to Japan, mainly to Okinawa. The fisheries have well developed becoming one of the main fisheries in Okinawa where 210 FADs are approved to deploy in 1999. The annual catch by roughly 1,000 boats (most of them are small) is 2500-4000 mt; average catch from one FAD is about 20 mt; average catch by one boat on one day is 73 kilogrammes. FADs are also important for easing the fishing pressures on bottom fish stocks. Most of the FADs were deployed and managed by local fishermen's groups that have improved the structures of the system to withstand typhoons.
catches are strongly depending on the sites, usually the farther offshore, the better the catches. A variety of fishing methods are devised targeting each species and the size of the fish. Being most abundant and having relatively higher prices, yellowfin tuna is the most important and consists 68% of the total production. There have been conflicts among fishermen on the use of FADs since the early stage of the fisheries development. Now, the number of FADs is regulated by a management committee. Conflicts between fishermen and sport fishermen have become problems; on the other hand, the sport fishing could lead to further development of the fisheries. Degraded fish meat caused by high meat temperature and occasional oversupply have been major marketing problems since prices are strongly related to the meat quality and the fish supply.

367. **Kakuma, S. 1996.** ABSTRACT: Yellowfin tuna (*Thunnus albacares*) is a main target for the fisheries at Fish Aggregating Devices (FADs) off the south of Okinawa island. Catch and weight composition of the tuna were monitored at a fisheries cooperative market from 1989 to 1998. Some distinct weight groups (considered to represent cohorts) appeared in the catch and the weight of these groups increased monthly - presumably as individual tuna grew. Although small, light weight fish were caught year-round, the 2 kg weight group that was recruited in May grew to about 15 kg by May of the next year. There was a significant seasonal cycle in the monthly catches. The catch of heavier weight groups decreased in winter indicating the tuna moved out of this FAD area. At one of huge FADs (Nirai), fifteen nautical miles southeast of Okinawa island (depth about 1,300 m), a current meter (Aanderaa RCM-7) recorded current and water temperature from June 1995 to March 1996. The current meter was attached to the FAD at 4 m depth. When typhoons attacked Okinawa, the water temperature drastically dropped. Typically, average current speed was 29 cm/s and eastward current was most frequent. Being affected by tide, the current was averaged over twenty-five hours. Current speed was correlated with the yellowfin catch in 120 daily sets at the FAD; the weaker the current speed, the greater the catch. Although not significant, the catch was greater with northeastward current than with southwestward current.

123. **Kakuma, S. 1999.** ABSTRACT: In early 1980s, FAD fisheries were introduced from the Philippines to Japan, mainly to Okinawa. The fisheries have well developed becoming one of the main fisheries in Okinawa where 210 FADs are approved to deploy in 1990. The annual catch by roughly 1,000 boats (most of them are small) is 2,500-4,000 mt; average catch from one FAD is about 20 mt; average catch by one boat on one day is 80 kg. FADs are also important for easing the fishing pressures on bottom fish stocks. Most of the FADs were deployed and managed by local fishermen's groups who have improved the structures of the system to withstand typhoons. The catches are strongly depending on the sites; usually the farther offshore, the better the catches. Variety of fishing methods are devised targeting each species and the
size of the fish. Being most abundant and having relatively higher prices, yellowfin tuna is the most important and consists 70% of the total production. There have been conflicts among fishermen on the use of FADs since the early stage of the fisheries development. Now, the number of FADs is regulated by a management committee. The conflicts between fishermen and sport fishermen have become problems, on the other hand, the sport fishing could lead to further development of the fisheries. Degraded fish meat caused by high temperature and occasional over supply have been major marketing problems since prices are strongly related to the meat quality and the fish supply.

309. Kakuma, S. 2000. ABSTRACT: Yellowfin tuna (Thunnus albacares) is a main target for the fisheries at Fish Aggregating Devices (FADs) off the south of Okinaw Island. Catch and weight composition of the tuna were monitored at a fisheries cooperative market from 1989 to 1998. Some distinct weight groups (considered to represent cohorts) appeared in the catch, and the weight of these groups increased monthly, presumably as individual tuna grew. Although small, light-weight fish were caught year round, the 2 kg-weight group that was recruited in May grew to about 15 kg by May of the next year. There was a significant seasonal cycle in the monthly catch. The catch of heavier weight groups decreased in winter, indicating the tuna moved out of this FAD area. There was also a large fluctuation in the annual catch. The number of 15 kg-weight group in May and the annual catch of that year were significantly correlated.

At one of the huge FADs (nirai), fifteen nautical miles southeast of Okinawa Island (depth about 1,300 m), a current meter (Aanderaa RCM-7) recorded current and water temperature from June 1995 to March 1999. The current meter was attached to the FAD at 4 m depth. When typhoons attacked Okinawa, the water temperature drastically dropped. Typically, average current speed was 29 cm/s and eastward current was most frequent. Being affected by tide, the current was averaged over twenty-five hours. Current speed was correlated with the yellowfin catch in 120 daily sets at the FAD; the weaker the current speed, the greater the catch. Although not significant, the catch was greater with northeastward current than with southwestward current.

21. Kellison, G.T., and G.R. Sedberry. 1998. ABSTRACT: Attraction of demersal finfish to six artificial reef designs off Charleston, South Carolina, was studied using a SCUBA visual census technique. The experiment was designed to examine the effect of (1) increased vertical profile and (2) hole diameter on the recruitment and retention of demersal finfish to each of the six artificial reef designs. Increased vertical profile was accomplished through the addition of fish aggregation devices (FADs) to half of the benthic artificial reef units, which were concurrently equipped with large diameter holes (25.4 cm diameter), small diameter holes (12.7 cm diameter), or no holes. Mean abundances of demersal finfish individuals were significantly
greater on FAD units than on units lacking FADs. Hole diameter was only occasionally a significant factor affecting mean total number of demersal individuals and species and did not significantly affect estimated average total lengths of species present. Hole presence (both hole diameters) had a positive significant affect on mean numbers of demersal individuals and species. The dominant species observed on the reefs included Decapterus punctatus, Stenotomus chrysops, Centropristis striata, Monacanthus hispidus, and Haemulon aurolineatum. Early observations of the unit designs have already prompted the South Carolina Marine Artificial Reef Program to deploy artificial reef units of the same design in a permitted reef site.

368. Kikutani, K., T. Toyoshima, and I. Tokuda. 1996. ABSTRACT: The fisher cooperative had 144 members with landings income of US$ 1.5 to 2.0 million per year. Ten FADs were moored on the eastern side of the island and accounted for 15.6% of the fish landed. Species fished included wahoo, skipjack, yellowfin tuna, bigeye tuna, mahi mahi, and blue marlin.

156. Kingsford, M.J. 1999. ABSTRACT: There is widespread use of fish attraction devices (FADs) in commercial fisheries and research. Investigations on the utility of FADs to catch fishes, and factors influencing fishes associated with FADs, require careful consideration of experimental designs. The development of appropriate models, from observations and the literature, should be developed before hypotheses can be tested with robust sampling designs. Robust sampling designs may only be possible if investigators have some role in the planning stage of deploying FADs. If the objective of the study is to determine the influence of FADs on assemblages of fishes, then experimenters need to consider that a “FAD-effect” (= impact) cannot be demonstrated without controls. Some preliminary studies may be required to determine the spatial extent of a FAD-effect before suitable sites can be chosen for controls. Other controls may also be necessary, depending on the method used to estimate numbers of fishes (e.g., controls for disturbance). Recent advances in sampling designs that are applicable to impact studies are discussed. Beyond-BACI (Before After Control Impact) and MBACI (Multiple BACI) designs are recommended because they cater for temporal and spatial variation in the abundance of organisms, which is generally great for pelagic fishes. The utility of orthogonal sampling designs is emphasized as a means of elucidating the influence of multiple factors and, importantly, interactions between them. Further, nested analyses are suggested to deal with multiple temporal and/or spatial time scales in sampling designs. The independence of replicate FADs should also be considered. Problems of independence include: FADs that are connected, thus providing potential routes of movement of associated fishes; temporal dependence where the number of fish at a time influences the number at the next time due to fish becoming residents; and the fact that the proximity of other FADs may influence numbers of fishes. Solutions to these problems are suggested. The
recommendations in this paper are relevant to investigations on pelagic fish of all sizes, with and without FADs.

42. Kleiber, P., and J. Hampton. 1994. ABSTRACT: From an experiment with ordinary dart tags, the authors found evidence of the effect of fish-aggregating devices (FADs) and of islands on the movements of skipjack tuna (*Katsuwonus pelamis*) around the Solomon Islands. By fitting a fish movement model to the tag data, we were able to estimate mortality and movement parameters (including diffusivity), parameters of a function that models FAD attraction, and a separate parameter of island attraction. Diffusivity was high enough to effectively distribute fish throughout the island archipelago (approximately 150,000 km$^2$) within a few months. Estimates of FAD parameters indicate that the presence of up to four or five FADs in an area approximately 50 x 50 km can reduce the propensity for skipjack to leave that area by approximately 50%, but that deploying additional FADs in such an area does not significantly increase their effectiveness in holding skipjack. Estimates of the island attraction parameter imply that the propensity of skipjack for movement away from the archipelago is less than half the propensity for movement within it.


146. Klima, E.F., and D.A. Wickham. 1971. ABSTRACT: Artificial structures positioned off Panama City, Florida During July 1969 proved effective in attracting commercial quantities of round scad, Spanish sardines, and scaled sardines. The structures' positions in the water column and their design were important in attracting fish. Midwater structures which resembled a small pup tent were effective in attracting up to 25 metric tons of fish and consistently attracted from 1/2 to 5 metric tons daily. SCUBA divers made visual estimates of the number of each species present at the structures. This paper discusses the behavior of the fish and presents a possible explanation of why fish are associated with submerged structures.

458. Lamkin, J.T., J.J. Govoni, and T.D. Leming. 2001. ABSTRACT: Bluefin tuna, *Thunnus thynnus* and other scombrids spawn in the Gulf of Mexico in late April, May, and into early June. The relationship between larval bluefin tuna and thermal fronts has been established through previous studies, while an assessment of eddies and their associated fronts as spawning and nursery habitat has not been undertaken. In 1995 we began a three year effort in the eastern Gulf of Mexico to examine the influence of these eddies and the Loop Current on the distribution of scombrid larvae. Preliminary results indicate that scombrid larvae were located in the upper 25 meters, and were most abundant near the cold-core ring - Loop Current interface. Understanding the dynamics of scombrid spawning habitat is difficult in view of the scale and variance in inter-annual and decadal circulation patterns in the Gulf of
Mexico, and our efforts are far from complete. However, we are concerned that offshore oil structures acting as FADS could disrupt this spawning behavior by concentrating bluefin in non-traditional spawning sites. This would not only increase their vulnerability to longline and recreational fishing gear, but could lead to greatly increased larval mortality as well.

310. **Laurans, M., M. Taquet, L. Reynal, and A. Lagin. 2000.** ABSTRACT: Fishing with a beach seine for catching small pelagic fishes is a traditional activity in Martinique. Since the early eighties, an important decrease in the number of fishermen practicing this activity has been recorded. In the context of high exploitation of reef resources, the beach seine presents a low selectivity, catching too many juveniles of demersal fish. The FADs established in coastal areas, have been successfully used in others regions of the world for exploiting small pelagics. Thus, it could allow to favour a change of exploitation style of these resources in Martinique. In partnership, IFREMER, the Regional Council and the Fishing Committee have began an evaluation of the potentialities for this type of structures around the island. To achieve this study, several experimental coastal FADs have been established in different places. Surveys by subaquatic observations are periodically carried out to compare the attractive power of different aggregation devices (colour, shape, volume) and understand the factors influencing the determinism of the aggregation (biotic and abiotic). The results presented and discussed correspond to the initial stage of this study which should be pursued in the next month. Original Abstract: La pêche a la senne de plage pour la capture des petits poissons pelagiques est une activité halieutique traditionnelle et ancienne en Martinique. Depuis le début des années quatre-vingt, une diminution importante du nombre de pêcheurs pratiquant cette activité est enregistrée. Les dispositifs de concentration de poissons (DCP) implantés en zone côtière sont abondamment utilisés dans d'autres régions du monde avec succès. Ils pourraient donc permettre de redynamiser ce secteur en Martinique. L'IFREMER, le conseil régional et le comité des pêches ont entrepris, en partenariat, une étude permettant d'évaluer les potentialités du développement de ce type d'aménagement autour de l'île. Pour réaliser cette étude, plusieurs DCP coteïens expérimentaux ont été implantés dans différents sites. Ils font l'objet d'un suivi halieutique base sur les comparaisons des captures réalisées par les professionnels sur et hors DCP. En parallèle, des campagnes d'observations sous-marines sont effectuées de façon périodique. Elles permettent d'une part de comparer les pouvoirs attractifs de différents dispositifs d'agregation (forme, volume, couleur) et, d'autre part, de mieux comprendre les facteurs biotiques et abiotiques influençant le determinisme de l'agregation. Les résultats presentes et discutes correspondent a la phase initiale de l'étude qui doit se poursuivre dans les prochains mois afin de couvrir toute la saison de pêche.

245. **Laurans, M., M. Taquet, M. Reynal, and A. Lagin. 2000.** ABSTRACT: In recent years, the use of FADs in Martinique has evolved from an experimental stage
to a productive one. This transformation results in the pitching up of operational device park by the regional fishery committee. Nevertheless, this technical change in fishing practices is not implemented in a homogeneous way all around the island; some differences exist especially between the Atlantic and the Caribbean coasts. From surveys carried out during an annual cycle on two main landing sites, this study describes the pelagic fishing activity around FADs and in the open sea. A comparison of fishing strategies adopted in different places as well as an analysis of the results obtained by the fishing units in terms of species (size of catches and daily yields) allow to describe the progress made in the implementation adoption of this new fishing practice. For several fishermen, fishing around FADs has become an exclusive job, practiced all year round. For others, FADs is used in addition to traditional fishing activity on flotsam, "Miquelon" fishing and keeps a seasonal character.

Original Abstract: Au cours des recentes annees, l'utilisation des DCP en Martinique est passee du stade experimental au stade operationnel. Cette mutation se traduit par la prise en charge du parc de dispositifs operationnels par le comite regional des pêches. Toutefois, l'adoption de cette nouvelle technique d'exploitation ne s'effectue pas de façon homogene dans toutes les communes de l'ile, des differences existent notamment entre les cotes Atlantique et Caraibe. A partir d'enquetes effectuees pendant un cycle annuel, sur deux principaux points de debarquement, cette etude decrit l'activite de pêche des poissons pelagiques avec ou sans DCP. Une comparaison des strategies de pêche developpees dans les differentes sites ainsi qu'une analyse des resultats obtenus par les unites de pêche en termes d'especes, de taille des captures, de rendement journalier permettent de decrire la progression differenciee de l'adoption de cette nouvelle activite halieutique. Pour certains pêcheurs, la pêche sous DCP est devenue un metier exclusif, pratique tout au long de l'annee. Pour d'autres, le DCP est utilise en complement de l'activite traditionnelle de pêche sous bois derivants, "pêche a Miquelon", et conserve un caracteres saisonnier.

303. Le Gall, J.-Y. 2000. ABSTRACT: Tuna world fisheries yield 3 million tons per year; the increase rate of whole production is constant and sustained since 30 years. This original figure for marine fisheries is due to enlargement of tuna fleets and fishing grounds over all the world ocean, the continuous increase of tuna fishing power by in board equipment and remote sensing equipment for searching and scouting (on board, aircraft, satellite, telecommunication). During the last 20 years, the log-associated tuna fishing has contributed to the local individual and tuna fleets efficiency and fishing power either for large industrial tuna seiners by radio-equipped buoys on natural (debris) or artificial man-made logs. The same trend is noted for numerous artisanal tuna and large pelagic coastal fisheries on moored fishing aggregating devices and networks. The first part of the paper is a review of data and results to assess and rank the "Surfaces prospected by in board tuna seiners and associated aircraft and satellite techniques" (visual, radar, sar-radar and satellite altimetry sensors). The final objective is the comparison with the surfaces and
volumes associated to FADs. Since 20 years, tuna ecology and behaviour data from ultrasonic tagging (short-term depth/distance/time migration around logs and FADs) are used for fishing of tuna associated with floating objects, namely FADs. The second part of this paper is an "Assessment of FADs aggregating associated surface and volume" linked with oceanographic data: large oceanic geostrophic current and observed drift speed of radio-equipped FADs in the Indian Ocean. Using the available data on FADs, tuna fishing technology linked with oceanographic and biological data results from ultrasonic tuna tracking experiments, the paper is an attempt to identify and place the FADs technology in the scale of tuna fishing devices as a contribution to the increase of tuna fishing power either individual tuna boat or tuna fleets. Original Abstract: La production mondiale des pêcheries thonières est actuellement de l'ordre de 3 millions de tonnes par an et conserve depuis pres de 50 ans un taux de croissance annuel soutenu. Cette croissance, exceptionnelle pour un secteur des pêches maritimes, est due a plusieurs causes: accroissement des effectifs et des puissances de pêche des grandes flottes thonières industrielles oceaniques qui exploitent les ressources thonières de l'oceean mondial et le developpement conjoint de nouvelles techniques de pêche et de nouvelles technologies d'aide a la pêche, telles que les dispositifs de concentration de poissons (DCP). L'accroissement de la puissance individuelle des navires est du au developpement de la construction navale (mechanisation, propulsion, hydraulique, conservation et traitement a borda) et a l'utilisation d'une gamme diversifiee d'aides a la pêche : navigation, telecommunication, localisation des zones favorab les, detection visuelle ou radiometrique assistee par equipement a bord, en helicoptere et avion, detection acoustique, detection par radar de bord, radar-avion ou, a terme, antenne SAR sur satellite. Plus recemment, soit depuis 20 ans, les caracteristiques du comportement, migration de court terme, agregation et concentration des poissons pelagiques, fixation et retention des bancs de thons, sont utilisees, par les dispositifs de concentration de poissons (DCP) ancrs ou derivants. Cette contribution a pour objectif de situer et placer les DCP fixes ou derivants sur cet ensemble de techniques d'aide a la pêche thoniere. Les donnees pour cet essai de classement sont d'ordres biologique, ethologique et comportementaux (amplitude de deplacement des thons et dimension de la sphere d'attraction d'un DCP) et d'ordres environnemental et oceanographique : masse d'eau concernee par un DCP dans une large veine de courant oceanique ou cotier. On tente de quantifier et d'ordonner les surfaces et les volumes prospectes par les thoniers et particulierement les volumes et masses d'eau exploites par les thoniers utilisant des DCP. Ce classement des DCP dans la serie des dispositifs d'aide a la pêche thonière facilitera l'appréciation de leur contribution a l'augmentation des puissances de pêche des thoniers.

2. Le Gall, J.Y., P. Cayre, and M. Taquet. 1999. ABSTRACT: The international symposium "Tuna fishing and Fish Aggregating Devices", October 1999, in Martinique, takes stock of the exploitation of large pelagic fish around FADs,
based on regional synthesis for the three oceans and the Mediterranean Sea. Main themes include technology, fishing methods, impact on resources, biology of fish aggregation, anthropology and economic aspects of FAD exploitation. The meeting will gather and disseminate results from recent and ongoing studies on FADs in the different oceans of the world, enhance collaboration between scientists and managers involved in the development of FADs, promote the emergence of scientific and technical research, form a network for cooperation and enhance communications between researchers in the different locations concerned. Original Abstract: Le colloque international "Pêche thonière et dispositifs de concentration de poissons" organisé en octobre 1999 en Martinique, permet de dresser un bilan, sous forme de synthèses régionales, de l'exploitation des grands poissons pelagiques à l'aide de DCP dans les trois océans et en Méditerranée. La technologie, les méthodes de pêche, l'impact sur les ressources, le comportement aggregatif des poissons et les aspects socio-économiques de l'utilisation des DCP sont les principaux thèmes développés. Ces travaux permettront d'assurer une diffusion large des résultats à l'échelle de l'océan mondial, de favoriser les échanges entre les scientifiques et les gestionnaires impliqués dans le développement des systèmes DCP, de promouvoir l'émergence de thèmes et projets de recherche scientifique et technologique, de mettre en œuvre un réseau de communication et d'échanges entre les sites et les régions concernées.

234. Le Gall, J.-Y., P. Cayre, and M. Taquet. 2000. ABSTRACT: The associative behaviour of large pelagic fish, tuna and related species, is strongly influenced by the presence of fixed or drifting, natural or artificial floating objects such as FADs. The number of FAD for the development or maintenance of tuna fisheries, both oceanic industrial and small coastal fisheries, is increasing in such a way that at present one quarter of the worldwide production of tuna (one out of four million tons produced annually) is dependent upon the use of FAD. This evolution is, in some respects, worrying and has justified holding an international meeting on the theme "Tuna fishing and FAD". This symposium took place in October 1999 at La Martinique (French West Indies). It follows an international working group organized by the IATTC in Jolla (California) in 1996 (Scott et al., 1999). The papers presented during the symposium are published in two different publications: Proceedings "Les Actes de Colloques" (Le Gall et al., 2000) bring together regional summaries (Pacific, Atlantic and Indian oceans and Mediterranean sea), questions relating to the technology of FAD and associated fishing techniques, the behaviour of tuna towards fishing detection equipment, the impact of FAD on the behaviour of fishermen; This special issue of the journal Aquatic Living Resources: Mechanisms and effects of the aggregation of tuna by Fish Aggregating Devices (FADs), attempts to provide some understanding of the determinism of the association between attracting objects and large pelagic fish, to propose a model of tuna movement, to describe the preferential distribution of species and size of
aggregated fish, to compare the specific duration of residence in the different types of aggregation (FAD, sea mounts, etc.). The need to conduct research programs on an international level in order to progress in the understanding of this phenomenon has been emphasized. What is the role of FAD in the oceanic environment: refuge from predators, concentration of food, signs of rich environment, points of spatial reference and orientation support, meeting point (Fréon and Dagorn, 2000)? Amongst the hypotheses developed to explain the aggregation of pelagic fish on FAD, some have been the subject of presentations and discussions concerning the experimental designs already implemented or which will serve as the basis for future scientific investigations. The main research presented in this special issue deals with: the changes in associative behaviour of tuna in relation to FAD through the joint use of underwater acoustic prospecting (echo sounders, sonar) and detecting by ultrasonic devices; the analysis and model building of movement and migration surrounding FAD networks and of exchanges between offshore areas and coastal fisheries; the effects of FADs on the ecology of tuna, and in particular the alteration of their place in the food chain system caused by FADs; the impact of changes in the means of operation on production in specific tuna fisheries in terms of size levels and species diversity; the organization and emergence of industrial and local networks, and their effect on the marketing of fish products.

453. Lehodey, P. 1996. ABSTRACT: The article summarizes a student thesis (DEA) on the subject. Stomach contents of yellowfin, skipjack and albacore caught around FADs in French Polynesia were analyzed relative to their capture locations. Fish dominated the prey composition. Many of the stomach contents were reef species, suggesting that the tuna migrated to reefs to feed.

124. Lennert-Cody, C., M. Garcia, and M. Hall. 1999. ABSTRACT: In the early 1990's, the adoption of the “dolphin-safe” label by a sector of the canning industry closed markets to vessels that set their nets on schools of tunas associated with dolphins. As a result, fishing on drifting FADs developed as an alternative method for catching tunas. The vessels typically deploy bamboo rafts, often equipped with radio transmitters that allow for semi-continuous tracking of the FADs. Beginning in 1992, more and more vessels began to use this fishing strategy, and added a large area to the already extensive tuna fishing grounds in the Eastern Pacific Ocean. This paper is based on data collected by observers of the Inter-American Tropical Tuna Commission which covers practically all of the fishing effort on floating objects by vessels of more than 363 mt of fish-carrying capacity. In this paper, we describe in quantitative terms the way the FAD fishery operates, including target species, catches, discards, bycatches, fishing grounds, seasonality, size distribution of the catches, and the physical characteristics of the FADs. Many patterns are not yet clearly established because the fishery on drifting FADs in the Eastern Pacific Ocean is a relatively new fishery.
287. **Lennert-Cody, C.E., and M.A. Hall. 2000.** ABSTRACT: The development of this fishery for larger vessels is described using data collected by observers aboard vessels of more than 363 metric tons fish-carrying capacity. Bamboo rafts, equipped with radio-transmitters that allow for semi-continuous monitoring, are typically used as FADs. Old purse seine netting is often suspended below the bamboo raft to give the FAD an enhanced underwater profile. Similar to the fishery on flotsam between 1992-1998, most sets on FADs were made before 8 AM, with skipjack and bigeye being the dominant tuna species caught, and yellowfin tuna captured in lesser amounts. Discard ratios of skipjack and bigeye were comparable for the two modes of fishing; however, the success rate on FADs for bigeye was more than twice that on non-FAD floating objects ("logs"). In addition, the fishery on logs was largely a coastal fishery, while the fishery on FADs extended west to 150° W, into areas that had not been significantly utilized by the purse seine fleet. The capture of tunas per set varied most with area, season and year. Nonetheless, capture per set for at least one of the three tuna species was also found to vary with the depth of the purse seine net and the amount of the netting hanging below the FAD. The effect of net depth and FAD depth on tuna capture varied by area, season and FAD color.

135. **Leproux, F. 1999.** ABSTRACT: French Polynesia started it's Fish Aggregating Device programme in June 1981 with the positioning of the first buoy offshore of the main island of Tahiti. Since then, 251 structures have been installed throughout the five archipelagoes of this French overseas territory. The shape and size of the devices have evolved eight times over this period, however, a single model has not yet been adopted. Trials are currently underway using lighter structures similar to those found in the Indian Ocean. The anchoring lines have progressively been modified through better knowledge of material and product availability, as well as better understanding of environmental constraints. The programme is entirely financed by the territorial government and managed by the public sector. This ongoing technical assistance, aimed towards the local small-scale coastal fishery, is considered an important factor to maintaining this activity alive. Up until 1997, this economical support policy of outer island populations far from the metropolis central town, along with incidental fishing methods around FADs, have given mitigated results without nevertheless putting into cause this programme. The use of “drifting handlines” retained at the surface by small indicator floats are one of the contributing factors to the degradation of the anchor lines. It is now commonly accepted that a new fishing strategy must be adopted so that professional coastal fishermen become more aware with regards to an expensive work tool due to local bathymetric conditions, so that fishing effort is increased through the development of better adapted fishing techniques, and finally so that community spirit rules over individualism.
Love, M. 2001. **ABSTRACT:** Beginning in 1995, we have been conducting surveys, using an untethered research submersible, of the fish assemblages of seven oil and gas production platforms and numerous natural reefs in southern California. Thirty-five species of rockfishes (*Sebastes* spp.) form the dominant taxa over both artificial and natural structures; they comprise over 90% of all fishes by both number and biomass. There are three distinct fish assemblages around platforms: 1) midwater, 2) near-platform benthic and 3) the shell mound surrounding the platform. Young-of-the-year (YOY) rockfishes predominate in the midwater, subadult and adult rockfishes are found near the bottom and a separate suite of YOY rockfishes live on the shell mound. Because the midwater assemblage depends on YOY rockfish recruitment strength, it exhibits strong annual variability, depending on ocean conditions. The near-platform benthic assemblage appears to be more stable. There is some evidence that platforms both produce and aggregate fishes, depending on species.

Love, M.S., J.E. Caselle, and L. Snook. ABSTRACT: In 1996 we surveyed the fishes living on and around seven offshore oil platforms in the Santa Barbara Channel area. We conducted belt transects at various depths in the midwater and around the bottoms of each platform using the research submersible Delta. The bottom depths of these platforms ranged from 49 to 22 m and the midwater beams ranged from 21 to 196 m. We found that there were several distinct differences in the fish assemblages living in the midwater and bottom habitats around all of the platforms. Both midwater and bottom assemblages were dominated by rockfishes. Platform midwaters were dominated by young-of-the-year (YOY) or juveniles up to two years old. Rockfishes larger than about 18 cm total length were rarely seen in the midwater. The fish assemblages around the bottoms of the platforms were dominated by larger individuals, primarily subadults or adults. Density of all fishes was similar between the bottoms and midwater of any given platform. However, the total biomass was much greater on the bottoms, owing to larger fish living there. There was a consistently greater number of species on the bottom than in the midwater of each platform, likely because of a larger variety of habitat types on the bottom. The fish assemblages also differed among platforms. We found significantly higher densities of young-of-the-year rockfishes around platforms north of Pt. Conception compared with those in the Santa Barbara Channel, probably because the more northerly platforms are located in the more productive waters of the California Current.

Malig, J.B., A.S. De Jesus, and J.O. Dickson. 1991. **ABSTRACT:** Fish aggregating devices (FADs) have been associated with Filipino fishermen. Recognizing their importance and potential, the fishermen have adopted the device with modifications to suit the different types of fish caught, fishing methods and techniques. At present, it is estimated that there are 3000 FADs, or “payaws” in the country. A description is given of the payaw, which consists of four functional parts, namely: floating section; anchoring section, mooring section
and attractant section. There are currently four types of payaw in use, according to the float section material: 2-layered bamboo raft; rectangular steel buoy-type; steel pontoon-bamboo raft combination; and, galvanized-drum payaw. The types of payaw users include municipal tuna handliners, municipal ringnetters, commercial ringnetters, and commercial tuna purse seiners. The impact of FADs on marine resources is examined briefly and various conflicts and solutions among the payaw users are outlined.

4. Marsac, F., and P. Cayre. 1998. ABSTRACT: This paper analyses acoustic tagging of eight yellowfin tunas undertaken around Fish Aggregating Devices (FADs) in La Reunion island (Indian Ocean). Emphasis is laid on the horizontal movements and thus complete previous studies on vertical movements around the same FADs. The first result of the present study deals with the relative dwelling time of yellowfin over the distance to FAD where tagged, in 0.9 km intervals. Distributions of dwelling time are different between day and night. During daytime, the fishes remain in the close vicinity of the FAD (mostly within a 1.8 km radius), whilst a drastic disassociation to the FAD occurs at night. During the day, the attractive influence of the FAD disappears 9.3 km away; this finding leads to the suggestion that a minimum distance of 18 km between neighbouring FADs should be applied in La Reunion to avoid overlapping radii of influence. The second group of results points out the potential use of the vertical and total swimming speeds as indicators of the foraging activity of the fish and of the type of movements (behaviour of tight association to FAD, transit among FADs or offshore migration, away from the area of FADs). The day/night change affects the vertical activity, with large magnitude of vertical movements exhibited at night. The total speed during the offshore movements is estimated about 1.2 m s⁻¹: the shift from a phase of tight association to FAD toward a phase of transit movement is characterized by an increase of the total speed. A typology of the relationships between swimming speed and feeding activity is proposed and discussed.

25. Marsac, F., P. Cayre, and F. Conand. 1996. ABSTRACT: The ongoing ultrasonic experiments of phase 2 of the Regional Tuna Project (Commission de l'Ocean Indien) are reported and analysed in relation to the local environmental parameters. Although seven yellowfin tuna (Thunnus albacares) were tagged during the first three cruises of the project, only five of them are considered in this paper, as they were tracked around FADs. Seasonal trends affect the horizontal movements associated with FADs: strong association and homing behaviour during the fishing season vs. weaker association when the fishing season comes to an end and the fish start migrating from the area. The vertical movements are analysed in order to provide a typology of the distribution of tuna in relation to different features (FAD association by day and at night, transits between FADs by day and by night) from which other variables are considered: life stage juvenile or adult), moon phase and thermal structure.
ABSTRACT: This paper discusses the hypothesis that small tunas and the various species found in association with drifting FADs (such as "mahi-mahi", rainbow runner, wahoo, etc.) may be biologically trapped by such a strong association. Massive seeding of drifting artificial FADs was observed worldwide during recent years. In this hypothesis, we suggest that FADs may alter some biological characteristics of epipelagic populations associated with them: migration, growth, condition factors, predation and natural mortality. As FADs are most often used in the equatorial currents, they tend to exhibit zonal drift. Therefore, the associated populations would be artificially transferred from one part of the ocean to another, when they would show different movement patterns in the absence of FADs. Natural logs were probably beneficial in terms of ecology and evolution, because they tend to accumulate in convergence areas, most often considered as rich forage areas. Now, FADs are seeded in offshore areas, which are not necessarily favourable for tuna feeding. This apparently strong association between fishes and drifting FADs may then produce an unexpected biological impact on tuna populations and their associated fauna. The plan is to test this hypothesis in the Atlantic, developing an ad hoc research programme based on tagging, biological and physiological studies, in association to an analysis of high resolution fishery data before and after the development of the FAD fishery.

Original Abstract: Cet article discute l’hypothèse selon laquelle les petits thons et les différentes espèces associées à des DCP derivants (comme...
les coryphenes, elagatis, thazards, etc.) pourraient être pris dans un piège biologique resultant de cette forte association. Le déploiement massif de DCP artificiels derivants a été constaté à l'échelle mondiale au cours des dernières années. Dans cette hypothèse, ces DCP, colonisés en permanence par de grandes fractions de populations epipelagiques, pourraient modifier les caractéristiques biologiques des espèces concernées: leur migration, leur croissance, leurs facteurs de condition, la predation et la mortalité naturelle. Les DCP étant plus fréquemment utilisés dans les courants équatoriaux, ils tendent à deriver zonalement. Ainsi, les populations associées seraient artificiellement transférées d'un bord à l'autre de l'océan, alors qu'elles manifesteraient d'autres types de déplacements en l'absence de DCP. Les débris naturels étaient probablement bénéfiques sur le plan de l'écologie et de l'évolution car ils s'accumulent dans des zones de convergence le plus souvent considérées comme des zones riches en nourriture. Maintenant, les DCP sont mouillés au large, dans des zones qui peuvent ou non être favorables à l'alimentation des thons. Cette association apparemment forte entre poissons et DCP derivants pourrait alors causer un impact biologique inattendu sur les populations pelagiques (thons et faune accompagnante). L'objectif est de tester cette hypothèse dans l'Atlantique au moyen d'un programme de recherche s'appuyant sur du marquage et des études biologiques et physiologiques, parallèlement à une analyse des données de pêche (tailles et CPUE, avant et après le déploiement des DCP derivants).

131. Martin, C.C. 1999. ABSTRACT: From 1981 to 1994, several tests were carrying out with different types of FAD. The best result was obtained with a floating part made with three oil drums in a steel cage. The anchor line was made considering the instructions of Matsumoto (1981), Murdy (1980), DeJesus (1982) and Boy and Smith (1984), overdimensioned the relation weight/depth. The main goal of the test was to investigate the possibilities of FAD in the rehabilitation of "pesqueros" places in which the skipjack concentrates or "resident schools" used to be fished. Knowledge of the resistance of the anchor line test, under bad whether conditions and current strength over 5 km, and the behaviour of the fishes concentrated was also an objective of this study. Overall satisfactory results was obtained in the 4.8 month the FAD exists; the total catch of 5.6 ton, a yield of 852 kg/boat/day during winter season and its resistance on a total of 15 days North wind colds and one low intensity hurricane (80 km/h). The FAD disappeared at April when in the area of deployment mostly has a calm sea. Vandalism may be the cause of the lost of the FAD.

60. Matsumura, Y. 1992. ABSTRACT: The catch of young flying fish, Cypselurus hiraii and Cypselurus heterurus doederleini, by boat seine fishery in the northern coastal waters of Nagasaki Prefecture, Japan shows wide yearly fluctuations. The effects of five factors on the fluctuations were recognized by multiple regression analysis using data from 1976 to 1987. The factors are as follows: annual catch of adult flying fish by nine set-nets in the coastal
region of Yamaguchi Prefecture ($X_1$); average surface water temperature in July ($X_2$) and catch by FADs of dolphin fish as predators in August ($X_3$) in the offshore region of Yamaguchi Prefecture; days of northeast wind at Hirado Meteorological Station, Nagasaki Prefecture ($X_6$); and number of boat seine belonging to Ikitsuki Fisheries Cooperative Association, Nagasaki Prefecture ($X_7$).

62. **McElroy, J.K., and J.C.B. Uktolseja. 1992.** **ABSTRACT:** There is a wide geographical spread of skipjack pole-and-line fishing bases in East Indonesia. The article identifies and analyses the relative importance of several interactive factors on pole-and-line vessel catch performance, including the effects of the vessel (e.g., its size, horsepower and age), baitfish (its availability and abundance), the crew (number and skill), season, weather, use of Fish Aggregating Devices (FADs), geographical location of the fishing ground, and "fleet congestion." The importance of FADs in improving catch performance is particularly highlighted. Partly from this comparative analysis, it is postulated that the resident stock of skipjack in this area is supplemented by large seasonal migrations from the western tropical Pacific stock. As the bulk of this migration passes through the waters north of Irian Jaya, this region must offer some of the best fishing opportunities, and hence will have the highest priority for the future development of skipjack pole-and-line and purse seine bases in Indonesia.

41. **McElroy, J.K., and J.C.B. Uktolseja. 1994.** **ABSTRACT:** Given the geographical spread of existing skipjack pole-and-line fishing bases in east Indonesia, the paper analyses the relative importance of several interactive factors on pole-and-line vessel catch performance, including the effects of vessel size, horsepower and age; crew size and skill; availability and abundance of bait; season; weather; use of Fish Aggregating Devices (FADs); location of the fishing ground, and "fleet congestion." Partly from this comparative analysis, it is postulated that the resident stock of skipjack in this area is supplemented by large seasonal migrations from the western Pacific stock. As the bulk of this immigration must pass through the waters north of Irian Jaya, this region must offer some of the best fishing opportunities, and hence will have the highest priority for the future development of skipjack pole-and-line bases in Indonesia.

116. **McElroy, J.K., and Wijopriono. 1994.** **ABSTRACT:** Given the significance of the purse seine fleet to fish supplies in Java, an island in Indonesia with a population approaching 100 million, the paper analyses the relative importance of several interactive factors on Javanese purse seine vessel catch and economic performance, including the effects of vessel size, age, speed, net size, use of fish aggregating devices (FADs) and fishing lights, lunar period, season, oceanographic and weather characteristics, distance to and location of the fishing ground, the impact of navigation, fish location and communication aids, “fleet cooperation” and “fleet congestion”, time/distance...
to port auction. The importance of vessel size, on fishing pattern and preservation method(s) used is highlighted, as is the importance of lunar period and brightness of artificial fishing lights.

139. McIntosh, G.S. 1985. ABSTRACT: The project was undertaken to improve existing fish aggregating device (FAD) technology and to enhance pelagic finfish capture by recreational fishermen off Southeast Florida. Previous FAD experience by other workers in the Pacific Basin indicated that, although FADs were effective devices to manage wild stocks of fish, they suffered a distinct disadvantage by being short lived. A literature search was performed, data were reduced and analyzed and a computer program developed to assist future workers in FAD component selection, mooring design and configuration. A new design was developed and deployed off Fort Lauderdale, Florida. These FAD installations were monitored for a period of 18 months by diver observations, color fathometer readings and land based interviews. Catch per unit effort was determined and cost estimates associated with fishing "on" or "off" the FADs were developed.

83. McIntosh, G.S. 1986. ABSTRACT: As a direct result of the 1979 conference, the author submitted a proposal to the Caribbean Conservation Association for the introduction of artificial reef construction techniques to the region. Although the construction of FADs was not a priority element in the body of the proposal, reference was made to the design, construction and installation of specific reefs for specific marine species. This might be considered the first attempt to introduce FADs and fishery enhancement technology into the region.

326. McPhaden, M.J., P. Freitag, J. Servain, and E. Josse. 2000. ABSTRACT: Moored buoy arrays in the tropical Pacific and Atlantic Oceans are essential components of present day climate observing systems. The Tropical Atmosphere Ocean (TAO) array in the Pacific, supported by the US, Japan, France, and Taiwan, consists of approximately 70 deep ocean moorings spanning the width of the basin between 8°N and 8°S. The Pilot Research Moored Array in the Tropical Atlantic (PIRATA), supported by Brazil, France and the US, extends across 0-35°W, 10°S-15°N. The purpose of these arrays is to provide high quality, in situ, real-time data for climate research and forecasting. Array measurements consist of surface winds, sea surface temperature, upper ocean temperature, and a wide variety of other meteorological and oceanographic parameters. Data are telemetered in real-time via Service Argos, and a subset of these data is placed on the Global Telecommunications System (GTS) for distribution to operational centers for assimilation into weather and climate forecast models. In this presentation, we show examples of data from the 1997-1999 El Nino/La Nina cycle in the Pacific, and from a major Atlantic warm event in 1998-1999. We also discuss the impact of the fishing activity around the moored buoys, which by their nature act as fish aggregation devices (FADs). Fishing in the vicinity of TAO
and PIRATA buoys often leads to gear conflict with resultant losses of mooring equipment and fishing equipment. Moreover, fishing related activity is the primary cause of data loss in these arrays in the western and eastern Pacific, and in the eastern Atlantic. Attempts to reduce these losses through informational outreach programs have been attempted, without much apparent success. Efforts to increase awareness in the fishing community about the highly detrimental effects of fishing activity around deep ocean moored buoys continue.

240. Menard, F., B. Stequert, A. Rubin, and E. Marchal. 2000. ABSTRACT: Since 1991, fishing operations on tuna schools associated with drifting Fish Aggregating Devices (FADs) have become widespread in the purse seine fishery in the Gulf of Guinea. In the offshore South Sherbro area (05° N, 10-20° W), FAD-associated catches represent about 75% of the total catch. This FAD fishery exploits concentrations of skipjack mixed with a smaller amount of bigeye and yellowfin tuna of similar size (46 cm), and some large yellowfin. Catches on unassociated tuna schools are mainly composed of large yellowfin in breeding phase and skipjack. Here we studied tuna diet in relation with the aggregation mode (FAD-associated or unassociated tuna schools), species, and size. The stomach contents of around 800 fish were analysed. Numerous empty stomachs were found, especially in fish caught under FADs. Diets were similar for all small-size tuna sharing the same aggregation type. Small tuna mainly feed on Vinciguerria nimbaria (Photichthyidae), a mesopelagic fish of the micronekton, whereas large tuna mainly feed on Scombridae, mixed with Cubiceps pauciradiatus (Nomeidae) when they were caught in unassociated schools. The feeding habits of tuna are discussed with emphasis on the behavior of V. nimbaria. Estimations of the daily ration of similarly sized tuna with the same aggregation mode were very close. The low estimated rations for small, FAD-associated tuna show that logs do not have a trophic function, but rather are a refuge. In contrast, FADs seem to influence the diet of large tuna because of the Scombridae prey that probably is associated to the FAD.

386. Moarri, G., and F. Leproux. 1996. ABSTRACT: Artisanal fishermen fish a 400 m long mainline (250 lb-test) attached to a 2 m leader of 180-220 lb-test monofilament with a 12/0 or larger circle hook. The bait is lowered by wrapping line around a rock and the rock falls away allowing the bait and small pieces of chum (also wrapped up by line around the rock) to drift freely. The main line is attached to a float and allowed to drift near the FAD.

305. Monintja, D.R., and C.P. Mathews. 2000. ABSTRACT: Rumpons, (FADs) were widely deployed in Indonesia in the eighties. In the Halmahera area, rumpons increased CPUE by 41%, landings of fish per ton of live bait increased by 24%, the consumption of diesel oil for tuna catches reduced by 46%, and profits increased from Rp 10 to 60 million by boat per year. Tuna aggregation around rumpon increased catchability by more than 40% compared to free
swimming tuna. The Halmahera skipjack fishery was assessed by combining catch and effort data from rumpon and pre-rumpon areas of the fishery, and showed that controlled effort could increase landings of approximately 15,000 t per year. Tagging data show that the Halmahera skipjack fishery is probably supported by a local unit stock. Philippine rumpons (payaos) were fished with small mesh purse seine and ring nets fishing small sized tunas 12-35 cm FL (40-50% of landings) and caused recruitment overfishing. Indonesian rumpons were fished with pole-and-line causing neither recruitment nor growth overfishing.

128. Morales-Nin, B., L. Canizzaro, E. Massuti, A. Potoschi, and F. Andaloro. 1999. ABSTRACT: The Mediterranean small-scale fleet is highly adaptive, showing a dynamic fishing intensity and strategy, and exploiting seasonal abundant resources. In this area, the aggregatory behaviour of juvenile fish under floats has been used since ancient times to exploit oceanic migratory species such as dolphinfish (*Coryphaena hippurus*), using anchored Fish Aggregation Devices (FADs). In the last ten years, the critical fishery situation caused by traditional resources overexploitation increases strongly the dolphinfish fishery in Italian, Spain, Tunisian, Libyan and Maltese seas. A total of 2,300 boats are engaged in this fishery from August to December, being Malta, Tunisia, Sicily and Majorca the main fishing areas. An annual yield of around 1,000 tonnes is obtained, with most catches on September-October. The FADs (~1 m²) are made by different cheap floating materials, and are moored in fixed places, ranging from shore waters to areas 60 miles off the coast (1,500 m depth). Between 20 and 100 FADs are deployed by each boat. The gears used are special surrounding nets without purse line, and conventional purse seine nets. The fishery exploits young-of-the-year dolphinfish (<6 months old), originated by a pre-spawning migration of adults from Atlantic waters. Their catches show high annual and monthly variability, depending on the recruitment and the accessibility of recruits to the fishery. Pilotfish (*Naucrates ductor*) and greater amberjack (*Seriola dumerili*) are also exploited in this fishery as by-catch. In total about 1,000 metric tons of dolphinfish are yearly captured. The FADs are historically placed in the sea in August. Recently, the FADs fishing period has become longer in Sicily, and the FADs are placed in July to catch pilotfish and greater amberjack juveniles. In recent years, the interest for this fishing method and the study of these fisheries have increased in the Mediterranean. Although it can be considered as an under-exploited resource in the area, and the fishery is economically profitable with good revenue, the market and its seasonality limit this exploitation.

291. Morales-Nin, B., L. Cannizaro, E. Massuti, A. Potoschi, and F. Andaloro. 2000. ABSTRACT: The Mediterranean small-scale fleet is highly adaptive, showing a dynamic fishing intensity and strategy, and exploiting seasonal abundant resources. In this area, the aggregatory behaviour under floats of juvenile fish has been used since ancient times to exploit oceanic migratory
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82. **Mueller, E.L. 1988.** ABSTRACT: Extensive mariculture methods in inter-reef areas and in areas of dead coral reefs were tested. Local fishermen constructed artificial tire reefs and fish aggregation devices (FADs). The process of building artificial shelter or substrate for fish, maintenance and harvest as part of development work of a church agency is an example which could be used more extensively. Improved traditional coastal resource management for tropical mariculture in developing countries like Papua-New Guinea needs more knowledge and experience at grass root level. Experience gained, both in marine and social knowledge, are presented as a result of trials.

450. **Munprasit, A., and I. Chanrachij. 1996.** ABSTRACT: Article describes FADs deployed and purse-seine fishing techniques. FADs were 3-5 m long x 2-4 m wide x 6-8 m deep and made of bamboo, wood, iron, netting and plastic sheets.

94. **Murray, J.D., J.C. Howe, D.G. Lindquist, and D.C. Griffith. 1987.** ABSTRACT: Eighteen midwater fish aggregating devices (FADs) were deployed alternately off the ends of two piers (one acting as a control) in Wrightsville Beach, NC, to evaluate their ability to attract coastal fishes. Creel censuses of pier fishermen and diver surveys of FADs were conducted to determine: 1) The aggregation capabilities of FADs, by number, size, and fish species; 2) the effect of FADs on catch per unit of effort by species; and 3) the durability of the FADs in this environment. Results of the study were mixed. The FADs proved to be successful in aggregating baitfish in the nearshore environment. An average of 3.67 plus or minus 8.91 fish, representing 35 different species,
appeared on each FAD. The control site had no fish. The FAD units were not successful in improving fishing success at the fishing piers most likely due to the distance of placement from the end of the pier (229 m). The FAD units were durable enough to hold up under normal conditions, but slightly more than half of the FADs were lost and most were damaged during a Category 2 hurricane.

100. Murray, J.D., D.G. Lindquist, D.C. Griffith, and J.C. Howe. 1985. ABSTRACT: In recent years, due in part to rising energy costs, there has been increased effort toward the development of midwater fish aggregating devices (FADs). The purpose has been to aggregate fish in order to reduce the search time for commercial and recreational fishermen. In the fall of 1983, a small grant was obtained from the UNC Sea Grant College Program to investigate the potential of FADs to aggregate fish in the nearshore ocean environment and to determine if catch per unit of effort could be improved on fishing piers. (Prepared in cooperation with North Carolina Univ. at Wilmington, and East Carolina Univ., Greenville, NC. Inst. for Coastal and Marine Resources. Sponsored by NOAA, Rockville, MD. Office of Sea Grant, and North Carolina State Dept. Admin., Raleigh, NC.).

33. Naamin, N., C.P. Mathews, and D. Monintja. 1996. ABSTRACT: Since 1990, an important offshore industrial tuna fishery has been established in northern Indonesian waters. This fishery is theoretically confined to the EEZ, but in practice it occupies large areas of territorial and archipelagic waters. Fishing is carried out by “sets” or groups of boats based on a single purse seiner, supported by carrier and smaller patrol boats. These groups fish around “rumpon” (FADS) deployed in waters from 200-4,000 m deep, and take substantial catches, most of which are landed directly into General Santos City and other southern Philippine ports. The offshore fishery lands more than 50,000 mt per year from waters around North Sulawesi and northern Irian Jaya. Coastal fishing is carried out for skipjack by two kinds of small pole-and-line vessels (“funai”: 5-15 GT; “huhaté”: 20-30 GT) in North Sulawesi. The coastal fishery landed less than 9,000 mt of skipjack in 1989, the last year before large scale offshore fishing commenced. Data for Manado and Bitung (North Sulawesi) were analysed to determine the effects of the offshore fishery on the skipjack (Katsuwonus pelamis) and yellowfin (Thunnus albacares) fisheries based in these cities. Skipjack CPUE fell in Manado (from 50-70 mt/boat/year in 1980 to less than 20 mt/boat/year in 1992) and Bitung (from more than 100 mt/boat/year in 1980 to about 60 mt/boat/year in 1990). Effort on skipjack in Bitung rose slowly from approximately 40 boats in 1986 to more than 100 boats in 1991, and then fell to under 35 boats in 1995, the decline was probably due to competition with the industrial fishery. Industrial CPUE fell from 0.69 mt of tuna/GT of effort/year in 1993 to 0.37 mt/GT In 1995. Available data are insufficient for a complete analysis of offshore-onshore tuna fishery interactions. Nevertheless it is likely that industrial, offshore tuna fishing impacted the
coastal fisheries in Manado and Bitung by reducing the amount of skipjack and yellowfin available to the coastal fishery.

68. **Naeem, A. 1988.** ABSTRACT: Experience gained over the past seven years shows that large quantities of fish become attracted to artificial floating objects tethered to the ocean floor, in the same way as fish are seen to aggregate around some surface-floating debris found in the open seas. The advantages of utilizing FADs for fishing are prominent. The one and only problem is the unpredictable durability and premature loss of these devices which often cause the loss of not only the FAD itself but also large quantities of fish attracted to them. Considerable effort has been made to improve the reliability of FADs and to develop FAD fishing in the Maldives.

45. **Naeem, A., and A. Latheefa. 1994.** ABSTRACT: Fish aggregating devices (FADs) have proved very successful in the Maldives, where there is a countrywide FAD installation programme by the Ministry of Fisheries and Agriculture (MOFA) underway. The main reason for the success of FADs in the Maldives is their applicability to the existing fisheries. With the motorization of the fishing fleet, the efficiency and range of operation of the fleet has increased. FADs help not only to reduce searching time and fuel costs, but they also considerably increase production. Although the aggregation of fish around FADs has been demonstrated successfully, and the merits of FAD-fishing proven, data on the cost-effectiveness of FADs are still lacking. MOFA, with the assistance of the Bay of Bengal Programme's (BOBP) regional "Bioeconomics" project (RAS/91/006), therefore, undertook to assess and quantify the impact of FADs in tuna fishing. The project installed two FADs in two separate areas in the Maldives and closely studied the biological, economic and sociological effects of them on the fisheries and on the island communities in the two areas. The effectiveness of the two FADs was measured by comparing data collected one year before and one year their installation. The results of the study are presented in this paper.

460. **Nemerson, D., S. Berkeley, and C. Safina. 2000.** ABSTRACT: The Gulf of Mexico is the only known spawning area for bluefin tuna (*Thunnus thynnus thynnus*) in the western Atlantic. Although it is known from tag recaptures that eastern Atlantic bluefin tuna travel to the western Atlantic, whether or not these fish spawn in the western Atlantic is of critical importance in interpreting the significance of this movement. East Atlantic bluefin tuna mature at a younger age (4-5 yr) and smaller size (45 kg) than western bluefin tuna (8 yr and 135 kg), and tag recaptures indicate that some young fish make the trans-Atlantic swim. Thus, the presence of small (<135 kg) bluefin tuna in the Gulf of Mexico during spawning season would constitute evidence that bluefin tuna of East Atlantic origin spawn in the west. We used size-frequency analysis to test the hypothesis that Atlantic bluefin tuna of eastern and western origins mingle on the Gulf of Mexico spawning grounds. We created a simple model to estimate the proportion of small eastern spawning fish that should be
found in the Gulf of Mexico catch, assuming a 2% east-to-west transfer rate and complete mixing of eastern and western fish. Using conservative assumptions, the model predicts that between 5% and 10% of the bluefin tuna catch in the Gulf should consist of fish that are less than 135 kilograms in weight, and thus are presumably eastern migrants. We analyzed Gulf of Mexico catch records from 1980 to 1992 for the presence of bluefin tuna less than 135 kg. These small fish represented from 0% to 0.9% of the catch annually, and only 0.3% for the entire period. We conclude that eastern migrant tuna do not mix completely, if at all, with western bluefin tuna on the Gulf of Mexico spawning grounds.


443. **Parin, N.V., and B.I. Fedoryako. 1999.** ABSTRACT: Fish communities of the biotope of floating objects are divided into intranatant (small fishes of demersal origin), extranatant (fishes that swim at a close distance to the floating object during the day), and circumnatant (comprised mainly of large active predatory fishes like dolphinfish, rainbow runner, skipjack and juvenile yellowfin tuna).

55. **Pianet, R. 1994.** ABSTRACT: A second phase of the Regional Tuna Programme (PTR2) of the Association Thonière (AT) was funded for three years by the EDF for ORSTOM execution in collaboration with national support centres in Comoros, Madagascar, Mauritius, Seychelles and La Reunion. Eight scientific projects cover, for the western Indian Ocean tropical tunas, the collection and analysis of statistics, population dynamics, behaviour and migrations, biology, oceanographic and biological environment and fish aggregation around logs, FADs and sea mounts. The feasibility of starting an albacore fishery is also being evaluated from historical and environmental data.

456. **Pipitone, C., F. Andaloro, S. Campagnuolo, M. Romanelli, and A. Potoschi. 2000.** ABSTRACT: Ten fish species have been recorded under the FADs used in the dolphinfish fishery off the Sicilian coasts: dolphinfish (*Coryphaena hippurus*), pilot fish (*Naucrates ductor*), greater amberjack (*Seriola dumerili*), triggerfish (*Balistes carolinensis*), wreckfish (*Polyprion americanus*), bluefin tuna (*Thunnus thynnus*), blue runner (*Caranx crysos*), lesser amberjack (*Seriola fasciata*), horse mackerel (*Trachurus trachurus*) and imperial blackfish (*Schedophilus ovalis*). The most abundant species were dolphinfish, pilot fish and greater amberjack. The diet of the first two species, which are caught at a subadult or adult stage, has been studied in order to shed light on the relationships existing between them. Also the diet of very small greater amberjacks associated with FADs has been taken into account. The study showed that the diet of the three studied species collected
under FADs off the Sicilian coasts are based on different items, or on different proportions of similar items, so that the dietary overlap is reduced to a minimum. Dolphinfish feed essentially on fishes and, to a lesser extent, on pelagic invertebrates (mostly decapod larvae and hyperiid amphipods). The diet of pilot fish is based on the same pelagic invertebrates as dolphinfish and also on small amounts of fish larvae. Juvenile greater amberjacks feed almost exclusively on pelagic amphipods and on larvae of several invertebrates. None of the FAD-related fish species have been recorded in the stomach contents analysed, with the exception of a few small-sized triggerfishes found in dolphinfish stomachs.

32. Plante, R. 1997. ABSTRACT: The discovery of a coelacanth at Anakao (Madagascar) has given a new glimmer of hope to biologists. The minds and eyes of the scientific community are now on the alert to track down these fish in other waters. Three coelacanths have been caught off the coast of South Africa. With the one caught at Anakao, that makes four. In 1995, our scientific campaign had confirmed the worst fears for one thing, the coelacanth population at Grand Comore was even smaller than had previously been thought: fewer than two hundred individuals at the time of our investigation; at the same time, coelacanth catches were on the increase. Towards the 1970s, the Fonds Europeen de Developpement (FED) and the French Scientific Cooperation organisation ORSTOM had developed a programme in the Comores aimed at offering local fishermen the means to fish in the open sea by trolling, by means of Fish Aggregation Devices (FADs), in waters 1000 to 2000 m deep. To make this possible, a parallel programme enabled fishermen to acquire seagoing canoes with outboard engines. The operation was a success. Deep sea fishes – tuna, bonito, sailfish, big shark – gathered under the FADs, providing the fishermen with an abundant and valuable resource, that was held in high esteem on the local market. This meant that the fishermen could give up one of their traditional fishing techniques: bottom fishing for the oilfish, Ruvettus pretiosus. It was while fishing for this species that they had accidentally caught coelacanth. All went well, and the catch rate of coelacanth had begun to drop encouragingly. But unfortunately, the FED programme was halted. The fishermen went back to fishing for oilfish, and the catch rate for coelacanth reached new heights: a dozen specimens a year caught at Grand Comore. from a total population of a few adults. This is a danger that could prove fatal, and in the short term. So what is to be done? Ban bottom fishing altogether? Obviously, that would be out of the question. Our feeling is that the battle must be waged on two fronts: by providing the fishermen with an alternative resource, by implanting FADs at intermediate depths closer to the coast than were the FED programme structures. The fishermen could come and fish there in simple paddle-powered canoes; by running educational campaigns which could dovetail with intelligent forms of tourism. The coelacanth has become a real symbol for the archipelago. Our aim is to set up a Coelacanth Park offering a range of facilities: information for tourists, educational facilities for local
fishermen and villagers and research facilities for scientists from all over the world.

5. **Polovina, J.J. 1991.** ABSTRACT: Biological impacts of artificial reefs and fish aggregating devices are discussed. Three types of impacts on the exploitable biomass and total stock due to the artificial habitat are considered: 1) impacts due to a redistribution of exploitable biomass; 2) impacts due to increased exploitable biomass but not stock size; and, 3) impacts when total stock size increases. In all functions, artificial habitat has the potential to alter fishing effort, gear, size at entry to the fishery, species targeted and hence fishing mortality. It is concluded that more rigorous experimental designs are needed to document the biological impacts of artificial habitat. These designs need to use large numbers of artificial habitat to ensure sufficient statistical power exists to detect impacts in the presence of considerable natural variation which occurs in many marine systems.

10. **Polovina, J.J. 1991.** ABSTRACT: A review is made of four applications and worldwide impacts of artificial reefs (ARs) and fish aggregating devices (FADs): 1) enhancement of artisanal fishing; 2) small-scale commercial fishing; 3) recreational fishing and diving; and, 4) mitigation of habitat loss due to shoreside development. Experience in many countries has shown that properly constructed and sited ARs and FADs can create convenient fishing sites, and also prove to be particularly effective for artisanal applications in which fishing effort is relatively low. However, since these structures serve to change the distribution of fishing effort and fish, they must be viewed within an overall fishery management plan. Their impacts need to be considered in a broad socio-economic context, rather than just in terms of changes in CPUE.

9. **Prado, J. 1991.** ABSTRACT: An examination is made of various types of surface/midwater fish aggregating devices (FADs) currently in use. The two main types are: 1) traditional FADs, made on the spot with local materials and used in shallow coastal waters by small-scale fishermen to catch small pelagic fish and bait, e.g., payaos, unjang, rumpon; and, 2) modern FADs, a result of imported technology and materials which are either anchored or left drifting offshore in deep waters to help the offshore, artisanal and industrial fleets to catch big pelagic fish. Some ongoing activities with surface/midwater FADs are outlined and some observations and recommendations are given regarding construction, position and setting, duration and maintenance, efficiency, utilization, impact, legal aspects and regulations and cost and revenue. In addition to existing international conventions concerning the safety of navigation and dumping at sea, it is concluded that some specific internationally agreed standards and guidelines are needed to assist administrations of coastal states to legislate on and manage the installation and utilization of FADs.
157. **Prado, J., and S. Drew. 1999.** ABSTRACT: A significant amount of research and development is being conducted in fishing technology in Latin America. The Fishing Technology Service of the FAO Fisheries Department sent inquiries to contacts in Latin American countries to gather information on current activities and on the potential for increased international cooperation. The document includes responses from Argentina, Brazil, Chile, Colombia, Cuba, Peru and Venezuela. Some common research areas of interest include fishing gear efficiency and selectivity, bycatch reduction, improvement of artisanal fishing technology, the introduction of more advanced electronics, remote sensing, exploration of deepwater resources, and exploration of non-traditional species and fishing. All respondents indicated interest in expanding international cooperation. Considering the similarities in biological, technical, social and economic challenges that fisheries organizations now face, and the wealth and variety of expertise within the region, the potential benefits from increased cooperation appear very great.

8. **Preston, G.L. 1991.** ABSTRACT: A summary is given of the historical development of Fish Aggregation Device (FAD) programmes and the major issues that concern FAD utilisation in the South Pacific Commission (SPC) region at present. The paper is intended to refer only to anchored FADs; there is no reference to artificial reefs, which are essentially unused in the region. Because of its currency, as well as the paucity of documentation on Pacific Island FAD programmes, much of the information contained is necessarily anecdotal and/or speculative. References are provided where written sources have been used. SPC’s historical and possible future involvement in FAD-related issues is also discussed.

297. **Ravier, C., F. Marsac, A. Fonteneau, and P. Pallares. 2000.** ABSTRACT: Spatial and temporal distribution of tropical tunas (yellowfin, *Thunnus albacares*, skipjack, *Katsuwonus pelamis*, bigeye, *Thunnus obesus*) is characterized by fishes congregating in schools and schools gathering into concentrations. These concentrations are essential for the purse seine fisheries of the eastern tropical Atlantic. Because of this periodic and important biomass, purse seiners can make considerable catches with a limited searching effort. Taking advantage of these aggregations, a fishery on floating artificial logs has been successfully developed since 1991. In the present paper, we present an automatic computerized method to identify the concentrations from fine catch and effort data (daily logbooks). The results contribute to defining the major characteristics of the concentrations during historical (1980-1990) and recent periods (1991-1997). Since 1991, two fishing modes, free swimming schools and floating objects (FADs), were distinguished. It appears that the change in fishing mode and exploitation rate has affected both the number and the species composition of the concentrations. FADs allow the exploitation of new concentrations, particularly of skipjack tunas. The decreasing abundance of tropical tunas leads to a decreasing number of concentrations as well as a lower biomass.
111. Relini, G., M. Relini, and Torchia G. 1997. ABSTRACT: Recruitment of fishes in the artificial reefs of Loano (western Liguria, Italy) and Lavagna (eastern Liguria) is described. The fish assemblages were studied by means of visual census at five different sites differing in terms of length of exposure, depth, presence of FADs, and design. Thus it was possible to highlight seasonal variations, the presence of new species (colonization) and the arrival of new specimens of species previously recorded (recruitment). In total, the young of the year of 18 fish species were recorded, which are divided into three different groups: 1) four taxa (*Symphodus* spp, *Chromis chromis*, *Apogon imberbis*, *Coris julis*) which reside on the artificial reef from early larval stages; 2) nine species (*Mullus barbatus*, *M. surmuletus*, *Oblada melanura*, *Phycis phycis*, *Scorpaena notata*, *S. porcus*, *S. scrofa*, *Serranus cabrilla*) recorded on the artificial reef some months after hatching; and 3) six species (*Diplodus annularis*, *D. sargus*, *D. vulgaris*, *Pagellus acarne*, *Spondyliosoma cantharus*, *Seriola dumerili*) which come to the artificial reef from shallow water when they are 4-12 months old.

26. Renones, O., E. Massuti, S. Deudero, and B. Morales-Nin. 1998. ABSTRACT: The pilotfish (*Naucrates ductor* Linnaeus, 1758) (Pisces: Carangidae) is an epipelagic oceanic species almost cosmopolitan in tropical and subtropical seas. However, despite its world-wide distribution, very little biological information is available. Only Maksimov (1968) studied the trophic and reproductive biology of *N. ductor* in the Galapagos Islands and more recently, Relini et al. (1994) reported some data on its length-frequency distribution and feeding behavior from specimens associated with an offshore buoy in the Ligurian Sea. In the Mediterranean Sea, *N. ductor* is caught as a by-catch of the seasonal dolphin-fish (*Coryphaena hippurus*) fisheries carried out in Malta, Sicily and Mallorca, using special surrounding nets and fish aggregation devices (FADs). These are traditional commercial fisheries undertaken from late August to early December by the small-scale fleets. In Mallorca (Balearic Islands, western Mediterranean) annual catches of *N. ductor* from 1981 to 1995, have showed large variations. The maximum catches were obtained in 1989 (30.5 mt) and the minima were registered in 1984 and 1993, with 0.92 and 1.1 mt respectively. Although the dolphin-fish fishery was not carried out from January to August, occasional catches of *N. ductor* were still recorded, but they never represented more than 1% of the total annual catch for this species. The object of the present note is to contribute to the knowledge of the biology of this little studied species, although the seasonality of the fishery does not give a complete view of its life cycle. Consequently, the population structure, reproduction, feeding habits, age and growth are reported, based on specimens caught in the Mallorcan dolphin-fish fishery.

248. Rey, H. 1998. ABSTRACT: This paper attempts to assess the experimentations of Fish Aggregating Devices (FAD) in the countries of the Tuna-Fish
Association, considering that these devices may constitute a major innovation, able to modify noticeably the dynamics of the fish-systems in which they are placed. After a review of the main realisations, our analysis was centered on the evolution and transformation processes that FAD imply in the fish systems. These processes are examined as depending of the fish resources and of the fishing tactics, as well as of the regulation modes that they may imply to solve appropriation conflicts. Attention will be put here not only on the results, in terms of efficiency, but also on the determining factors of the evolution process.

284. **Reyal, N., G. van Burrt, and M. Taq. 2000.** ABSTRACT: This summary tackles the development of fisheries in the Caribbean using FADs. It highlights the principal causes which explain why, in spite of more than thirty years of experimenting, fishing on FADs has not developed as much as had been hoped. Whereas the deep-sea production of pelagic fish by the continental countries of the region has considerably increased since the early eighties, that of the Lesser Antilles has grown more slowly. Anchored FADs have given the boats of the small-scale fisheries from three islands (Guadeloupe, Martinique and Curacao) access to these pelagic resources. The various modes of development and management of the FADs observed in each island are described. The first available data are used to provide some indications of the effects of the various strategies implemented and the changes induced by this new fishing technique.

242. **Rey-Valette, H., E. Cillaurren, and D. Gilbert. 2000.** ABSTRACT: Since fifteen years the introduction of anchored Fish Aggregating Devices (FADs) has been an important component in the development of the small-scale fishery of many tropical island countries. Results however, have not always been as good as expected. In this paper we propose the use of a method to assess the diversity and complexity of changes caused by the FADs on one side, and the sustainability of this innovation process on the other side. The concept of sustainability includes both ecological and socio-economical purposes. The first aims to preserve the resource, the second to secure the innovation process. The assessment framework is based on a grid of twenty-one key parameters of biological, technical, economical and sociological nature. A value ranging from zero to three is given to each parameter according to its effect (no effect, doubtful effect, sustainable effect). An example of this grid is presented by combining experts' viewpoints in three cases (Comoros, Reunion Island, Vanuatu), which are representative for the diversity of FAD projects. A graphic representation is given for an easier reading of the grid and to improve its use for decision making.

320. **Rey-Valette, H., and P. Martins. 2000.** ABSTRACT: A new programme concerning the experimentation of about thirty Fish Aggregating Devices (FADs) is to start in the Cape Verde Islands at the end of 1999. In this context, this communication is intended: - to evaluate the aleutic, economic
and social conditions of the artisanal fishery in this archipelago, notably in terms of assets and constraints. Although these conditions are very heterogeneous depending on islands, the FADs seem to be able to help the stabilization and the development of the fishing activities, disadvantaged by a low productivity, limited operating ranges of boats, and very irregular outings at sea. But the narrowness of the domestic market is likely to cause drops in the fish prices if the production increases, while the level of absence of institutional framework may be a handicap at the level of the management (of the programme itself, and/or of some possible conflicts of uses); - to carry out an assessment of the former experiments. It emphasized the insufficiency of the follow-up and the maintenance of the structures, of which the lifespan varied at the most between four and six months, as well as the positive effects of the concentration, and the interest of the fishermen already sensitized with these structures.

318. Romagny, B., F. Menard, P. Dewals, D. Gaertner, and N. N'Goran. 2000. ABSTRACT: Abidjan is the biggest fishing harbour of tropical tunas in the Gulf of Guinea (around 100,000 mt per year). Three canneries work on four species (yellowfin, skipjack, bigeye and albacore). Small size tuna, minor tuna and by-catches are refused by the canneries and are sold on the local market fish. It is the only part of the industrial purse seine catches directly sold in Abidjan. Since 1990, fishing operations on schools of tuna associated with artificial drifting FADs has become widespread. Log fishery allows catches in which the majority is small tunas, and generates by-catches of various other pelagic species associated to the logs. The landed amounts of local market fish have increased: from 8,500 mt per year estimated between 1987 and 1990, 21,000 mt is reached between 1991 and 1993. Since 1994, controls have been carried out by French fishing companies. A sampling scheme allows us to analyse precisely the landings since 1998. From an interdisciplinary approach, we study the socio-economic role of this local fish market, especially the links between the different actors on this market, and we analyse his impact on fishing strategies by identifying the distribution networks (actors, prices, profit) and estimating the turnovers connected to this sector.

99. Roullot, J., and A. Venkatasami. 1987. ABSTRACT: An examination is made of findings of a pilot study in Mauritania regarding the use of fishery aggregating devices as a means of controlling the fish catches.

91. Roullot, J., A. Venkatasami, and S. Soondron. 1988. ABSTRACT: FADs have been set around Mauritius since 1985 in the coastal waters at depths from 900 to 3,000 mt and between 2.5 to 12 nm. from the coast. Meant to be used by the artisanal fishery, FADs were also visited by the sports vessels and amateur fishermen. Catch data were collected from these fisheries and supplemented by the more complete data recorded by the project vessels. Over 330 tons of pelagic fish was caught around the FADs last year and the
catch per boat of the artisanal fishery manned by two or three fishermen was between 40 and 56 kg daily. The main fishing methods were trolling, hand lining and longlining, and the predominant species in the catch of the project boats were the dolphin-fish while it was the yellowfin tuna which had the main share in the catch of the artisanal fishermen.

61. **Roullot, J., A. Venkatasami, and S. Soondron. 1990.** ABSTRACT: Fish Aggregating Devices (FADs) have been set around Mauritius since 1985 and the observations, catch data and fishing techniques used since then have been analysed. Following the development of a design suited to the Mauritian context, 23 FADs were set, 15 of which are still in place. Fishing in the vicinity of FADs by artisanal, sports and part time fishermen is successful and is increasing progressively. By conservative estimate, over 330 t of pelagic fish are caught annually around the FADs. The average daily catch per boat of the artisanal fishery is 50 kg, compared to a catch rate of less than 5 kg per fisherman in the lagoon and outer reef area. The catch per FAD per year was estimated at around 47.5 t of fish. The main species caught are given.

72. **Rountree, R.A. 1989.** ABSTRACT: The hypothesis that the abundance of fishes associated with fish aggregation devices (FADs) is a function of the degree of shelter provided by the structure was tested by comparing recruitment to three sizes of mid-water FADs. Each treatment was replicated six times and the eighteen FADs were deployed in a randomized block array in 14 m of water in the Atlantic Ocean off South Carolina. A total of thirteen species of fishes was observed to associate with the FADs. Eighty-nine FADs were censused in eight surveys from May through November 1985. The fauna associated with the FADs was very similar to published reports of fauna associated with *Sargassum* spp. and jellyfish, suggesting similar origins and causes of these associations.

77. **Rountree, R.A. 1990.** ABSTRACT: Twenty-two fish aggregation devices were deployed in 14 m of water off South Carolina (USA). Species composition and abundance were determined by diver visual census on eight occasions from May through November, 1985. A total of 21 families and 36 species of fishes was observed at 121 stations. Pelagic fishes dominated the fauna with a 99.3% relative abundance, and *Decapterus punctatus* accounted for 97.6% of the individuals. *Caranx crysos*, *Diplectrum formosum*, *Decapterus punctatus*, *Centropristis striata* and *Monacanthus hispidus* were the most frequent species. Total fish abundance, number of species and abundance of four of the six most common species were significantly affected by season. Hurricane activity may have caused a significant drop in pelagic fish abundance at the FADs in July. No significant correlations among species abundances were found after removal of season and FAD type effects. Spatial zonation and seasonal occurrence patterns suggest some competition among pelagic fishes.
132. Sacchi, J., and E. Tessier. 1999. ABSTRACT: The development of the FAD gave rise to technical problems owing to their conception, their setting spot and of their utilisation. Failings generated by the unreliability of components or the uncertain repair precariousness, those can prove to be here more and more expensive with the progression of the ageing of devices and reasons of their loss. For as various domains that aerospace or the fishing deck layout, the engineering has functional analysis tools that permit to reduce conception uncertainties of systems by the mean of a hierarchical classification of function values of components. The application of one of these techniques, the FMEA, Failure Mode and Effects Analysis, to the study of reasons of FAD loss in La Reunion describes perfectly everything that this type of method can bring to the appraisal in fishing technology. This preventive analysis method assess the potential risks integrates perfectly in the mind of a precaution approach as it would agree to see to apply to the FADs and to their exploitation.

294. Sacchi, J., and Tessier, E. 2000. ABSTRACT: Since 1983, the research on the optimal conception of FADs in Martinique was particularly focused on the improvement of their resistance to different maritime or human aggressions. Following several experimentations made with different types of FADs, the choice was brought on light devices anchored in 1,500 to 2,000 m depths and an experimental approach was conducted to identify the causes of loss of FADs and to attempt to modelize their hydrodynamic behaviour with relation to the sea conditions. Three mathematical models are used to simulate the FAD behaviour under current action and swell, and to estimate the forces exerted on each part of the device. The results of this study are presented. The FAD design used nowadays for the development of pelagic fishing in Martinique, recommendations for maintenance and preservation of the FADs are also proposed.

459. Safina, C. 1993. ABSTRACT: The bluefin tuna (Thunnus thynnus) is a creature of superlatives. Growing to 1500 pounds (700 kilos), traveling on transoceanic migrations, and reputedly capable of swimming 50 miles (90 km) per hour, it is one of the largest, most wide-ranging, and fastest of animals. To anyone who has seen this saberfinned giant explode through the surface of the sea, it is among the most magnificent. The bluefin is also one of the most valuable and most over-exploited of creatures. Its west Atlantic breeding population has plummeted 90% since 1975, from an estimated quarter million to 22,000 animals (ICCAT 1991). The east Atlantic adult population is currently estimated to be half what it was in 1970 (ICCAT 1992). A highly prized delicacy in Japan's most exclusive sushi restaurants, a single bluefin can bring fishermen up to US$30,000, sell at auction in Tokyo for more than US$60,000, then cost diners US$350 per pound. Most fishing for bluefin tuna is driven by the Japanese market and this international trade.
302. **Sakagawa, G.T. 2000.** ABSTRACT: It is generally accepted that innovations in tuna purse seine technology have affected fishing operations and the traditional measurement of fishing effort, days fished including searching time. Not much is known, however, about the actual effects of the innovations on fishing performance. Data from the US tuna purse seine fishery in the western Pacific Ocean were used to determine the impact of drifting Fish Aggregating Devices (FADs) on the performance of the US fleet. The results indicate, *inter alia*, a high rate of success (96%) in catching tuna and high yield rate (37 t/successful set) for FAD sets. Log sets were comparable in success rate (94%) and catch rate (36 t/successful set). Unassociated sets, on the other hand, had a higher catch rate (42 t/successful set) than FAD sets, but a low success rate, 53 per cent. FAD sets significantly improved the fleet's performance.

98. **Samples, K.C. 1986.** ABSTRACT: This report describes the socioeconomic characteristics, attitudes, and motives of (fish aggregation devices) FAD users based on a 1984 survey. It also describes the costs of Hawaii's FAD program and the monetary benefits that accrue to users. The 622 surveyed fishermen made 13,819 visits to FADs, or 26.4 visits each during a 12-month period in 1983-84. An average of 4.4 fish, consisting primarily of various tuna species, were caught per FAD visit. Fishermen generally claimed that fish catch and overall fishing fun were improved around FADs, but they also frequently identified crowding as a detracting factor. A benefit-cost analysis of Hawaii's FAD program shows that, on an annual basis, users' willingness to pay for FADs ($184,906) slightly exceeds estimated average annual program costs ($182,000).

73. **Samples, K.C., and J.R. Hollyer. 1989.** ABSTRACT: This paper addresses the problem of configuring fish aggregation device (FAD) networks to achieve maximum social value in commercial fisheries. A simplified network planning situation is analyzed from an economic perspective to optimize the number and location of FAD stations. Prioritization of potential deployment sites is conditional upon fleet dispersion and composition. Site ranking also depends on whether or not catch rates are sensitive to aggregate fishing pressure exerted at FAD locations. Clustering of aggregation devices in close proximity to one another is a viable alternative only when fishing effort and catch rates are inversely related. Economic efficiency criteria are used to determine the optimal number of FAD stations given programmatic budget constraints. Optimal system size is conditional on placement decisions.

74. **Sanjeeva Raj, P.J. 1989.** ABSTRACT: Bergstrom (1983) reviewed traditional fish aggregating devices used in the Bay of Bengal. Some fishing villages on the Bay of Bengal coast, 20 to 30 km south of Madras, have traditionally used column fish aggregating devices (FADS) called "kambi." Column FADs are composed of a long rope with coconut fronds fastened at 0.3 m (1 ft) intervals and attached to a float at one end and anchored at the other end. A lift-net,
called "mada valai," is used to fish these FADs (Hornell, 1924). Some fishermen make benthic artificial reefs, called "mullom," from tree branches weighted with a rock. These are fished by hook and line. Some fishermen combine the two structures and fish with both gears. In recent years, most local artisanal fishermen were disinclined to fish with artificial structures in part because of conflicts with trawl fishermen whose nets often got damaged by these traditional artificial fish habitats. Over the years extensive trawling has damaged the inshore habitat and fisheries. Here we attempted to revive artificial habitat use and evaluate their efficacy for enhancing catches of the artisanal fishery.

409. Scott, M.D. 1999. ABSTRACT: This is a summary and overview of the 1992 workshop.

153. Shinn, E.A., and R.I. Wicklund. 1989. ABSTRACT: Examination of 16 artificial reef structures with a two-person submersible in depths ranging from 30 to 120 m (100-400 ft) indicated that the highest numbers of fish are found around reefs in water shallower than 46 m (150 ft). Structures that penetrated above the thermocline, such as two upright oil "rigs" and a hopper barge, were also effective reefs. The open structure and high profile of the rigs enhance their use as artificial reefs by providing a range of well-aerated habitats. Any effect of substrate or post-deployment age on fish abundance could not be documented. Wood appeared to be a more effective fish-concentrating material but has a shorter useful life than does steel.

238. Sibert, J., K. Holland, and D. Itano. 2000. ABSTRACT: Yellowfin and bigeye tunas (Thunnus albacares and Thunnus obesus) were tagged and released between August 1995 and December 1997 at Cross Seamount and NOAA weather buoys about 200 nmi south of Honolulu. The release and recapture data were stratified into five sites, and a bulk transfer model was used to estimate natural mortality, fishing mortality and transfer rates between the five sites. Bigeye are much more persistent at Cross seamount and less vulnerable to the fishery than yellowfin. Fishing accounts for about 5% of the total mortality of both bigeye and yellowfin at Cross Seamount. Yellowfin are a major component of catches at inshore FADs in Hawaii. The rate of immigration from Cross Seamount to the inshore FADs is very low for both species. The fishing mortality at Cross Seamount is substantial but is not adversely impacting the populations either at Cross or the inshore FADs.

319. Sabisopere, M.B. 2000. ABSTRACT: From 1972, when Solomon Taiyo Limited (STL) started a pole-and-line fishing operation, to 1980, STL vessels had been catching tuna almost exclusively from surface free-swimming schools. In 1981, a FAD programme group purse-seining fishing operation, using the Filipino "payao" model, was put in place. Results were excellent and STL vessels quickly adapted their fishing methods to make the best use of FADs. STL slightly modified the original payao design to better suit its own needs.
and nowadays, about 90% of the group purse seine catch, i.e., 5,800 t annually, and around 60-70% of the pole-and-line catch, i.e., about 15,000 t annually, come from FAD fishing. FADs bring benefits not only to STL but also to the rural communities of the region. For STL, it allows savings on the operational costs, especially those of pole-and-line fishing operations, reduction of searching time and a better regularity of fish landings. For the rural communities, it gives better returns to bait-ground owners through royalties paid by STL for their baitfishing boats and it allows local fishing communities (known as canoe-fishermen) to increase their catches using fishing methods (artisanal) such as trolling and midwater handlines set around FADs. This provides fish for family consumption and a source of income from fish sold. Overall, the importance of FADs to STL's fishing operation, and therefore to the local economy as a whole, is high, although no precise value can be attached to it.

207. **Sloan, R. 2001.** ABSTRACT: The article discusses sportfishing for yellowfin tuna in the Gulf of Mexico off of Texas. Yellowfins are caught by sport-fishermen by trolling near deepwater petroleum structures including Hoover Rig, located 123 miles off Freeport and sitting in 4,800 ft of water. Other rigs lying 100 to 130 miles offshore are also are places where large yellowfin tuna are caught. Sportfishing boats also target and catch blue marlin around these structures. Yellowfin tuna are also caught in shallower water, and a primary tactic of sportfishermen is to fish near deepwater shrimp boats that are discarding bycatch that attracts tuna. Some of the best catches are made in water as shallow as 300 ft.

464. **Snyder, D.B., L. Lagera, P. Arnold, L. de Wit, G.H. Burgess, and C. Friel. 2001.** ABSTRACT: The fishing and offshore energy industries have coexisted and developed amicably for many years in shelf waters of the northern Gulf of Mexico. Recently, the offshore energy industry in the Gulf has shifted its interest beyond the shelf and into deep waters (>200 m). Currently there are over 3,500 active leases and 48 development/production facilities in water depths greater than 200 m. Deepwater oil and gas structures include fixed platforms, sub-sea completions, moored floating structures, and dynamically positioned ships. These surface-piercing structures represent obstacles to passively drifting longlines. The longline fishery targets yellowfin tuna and swordfish. From 1994 to 1998 permitted longline vessels made over 4,000 sets per year with an average length 37 miles of main line per set. Spatial distribution of longline sets and catches of major species for 1994 to 1998 period were plotted. These plots were compared with the location of current and future oil and gas structures structures to identify potential problem areas. Field observations around deepwater structures indicate that tuna, dolphin, and wahoo are attracted to deepwater structures.

327. **Solana-Sansores, R., G. Compean-Jimenez, and G. Aldana-Flores. 2000.** ABSTRACT: We compared the length structure of yellowfin tuna, *(Thunnus*
albacares) caught in three different sets, dolphin sets (ds), tuna sets (ts), and log sets (ls), of the Mexican tuna fleet that operated in the Eastern Pacific Ocean, between 1995 and 1998. The data sampled of fork length (FL) were obtained aboard the ships through three-stage strata probabilistic sampling design. The strata corresponded to those defined for the management of this resource by the Inter-American Tropical Tuna Commission (IATTC). The stages of sampling were as follows: random fish sample (stage 3), from sets that were selected by systematic sample (stage 2), of fishing trips that were selected through random sampling (stage 1), in a period of one year. We have defined equations for average weight, total number of fish in the commercial catch and the number of fish by length class. The results showed that the average weights and average lengths at the ds and ts are more important than those for ls. Besides, we found that the total fish number catch by ton at the ls was highest and their length structure tended to values lower than 60 centimetres. We observed that the ds and ts are more productive than ls to the Mexican fisheries. This sampling design allowed comparing the characteristic of the length structure by zone and type of sets.

75. **Stephan, C.D., and D.G. Lindquist. 1989.** ABSTRACT: As an aid to determining the best artificial habitat for use by North Carolina's pelagic sport fishermen, we examined the fish assemblages associated with three structurally different artificial reefs: an old dredge wreck (ca 1940s); a new tugboat wreck (placed February 1985); and four arrays of FADS (deployed May 1985). The fish populations were estimated by use of the stationary diver survey technique. Surveys were performed on 19 days (weather permitting) during the period of June to December 1985. A total of 48 species was recorded in association with the structures during the survey period. Species richness was highest at the dredge (40 species), high on the recently sunken tugboat (37 species), and, low on the FADs (16 species). Species diversity for each site followed the same pattern, and species evenness did not differ significantly between the dredge and tugboat.

148. **Stobberup, K.A., F. Marsac, and A.A. Anganuzzi. 1998.** ABSTRACT: Biogeography, movements, reproduction, feeding habits, growth, weight-length relationship, natural mortality, stock structure, fisheries, and stock assessment are reviewed. As tuna fisheries management is implemented in the Indian Ocean with the recent establishment of the Indian Ocean Tuna Commission, bigeye will become one of the main focuses of interest. The status of the stock is currently unknown, although concerns have been raised regarding the potential impact of recent catches of bigeye by the surface fisheries on the long-term productivity of the stock and on the catches of the traditional longline fisheries operating in the region. Age-structured stock assessment should be undertaken to assess the recent trends in the age composition of the population and the possible trade-offs in productivity resulting from the changes in age-specific fishing mortality. Further research, especially tagging experiments, would contribute to better understanding of
stock structure (including migration and ranges of exchange among various areas) and natural mortality. These population parameters are crucial to assess the extent of interactions among fisheries and future effects of changes in exploitation patterns.

216. Taquet, M. 1998. ABSTRACT: There are two types of tuna fisheries in the Caribbean region. The Venezuelan and American fleets are the most important high seas fleets; these are purse-seine, longline and pole and line fleets. There are also artisanal fishing fleets of insular states that regularly fish on the tuna resources crossing through their waters. Since there is intensive exploitation of reef resources, these artisanal fleets increase their fishing efforts for tunas and tuna-like fishes. In the Caribbean region, as in some other regions of the intertropical area, the use of moored Fish Aggregating Devices (FADs) has been one of the main methods of developing these fisheries during the last decades. More than twenty years after the first tests in the French West Indies, a first evaluation must be carried out by analyzing the results obtained in different spots and understanding the conditions that led to good results. The future prospects of this fishing activity will be discussed in reference to the development of FADs. Research around FADs, aggregating determinism, and impacts on the fishery (including the resources and the fishers). These research priorities could be established on the basis of recent work with results obtained on a large geographic scale. International scientific and technological collaborations might allow a greater efficiency which would benefit both fishermen and scientists. It is in this context, and to reach the latter goal, that an international symposium “Tuna fishing and FADs” will be held this October in Martinique.

311. Taquet, M., L. Reynal, and M. Laurans M. 2000. ABSTRACT: For most fisheries, increasing the local production of pelagic fish is the main objective of Fish Aggregating Devices (FADs). This does not rule out the existence of a larger-scale impact, especially on the migratory behaviour of fish. The analysis of data collected during 25 experimental fishing surveys around Martinique between 1995 and 1997 has led to the hypothesis that FADs influence the migratory behaviour of young dolphinfish. Unlike recent studies of dolphinfish migration in the Caribbean, which tend to show an annual migration pattern with a seasonal passage through the French West Indies, the experimental fishing surveys done over more than a year on a monthly basis on a single cohort, show that the migratory pattern of part of the regional stock could be disrupted. This analysis has made it possible to estimate an average growth rate for this species during the first year of life.

243. Taquet, M., L. Reynal, M. Laurans, and A. Lagin. 2000. ABSTRACT: This paper examines the fishing of blackfin tuna (Thunnus atlanticus) around Fish Aggregating Devices (FADs) in Martinique (French West Indies). It is based on the compared analysis of catches from monthly experimental fishing
surveys and sampling of commercial landings. The data collected in these two different ways allowed comparison of blackfin tuna length frequencies. A large part of the commercial landings were made up of young immature tuna with a fork length of less than 40 cm, whereas the experimental longline catches were mainly made up of fish with a fork length ranging between 55 and 75 cm. We give evidence that these discrepancies were mostly due to the fishing technique used. Indeed, contrarily to the experimental surveys, Martinican fishermen only fish during daytime and usually on the surface by trolling. This way, fishermen do not have access to the largest fish, which are found deeper. Our results suggested that a new fishing technique such as vertical longlining, could improve commercial catches of big blackfin tuna under FADs.

323. Taquet, M., L. Reynal, M. Laurans, and A. Lagin. 2000. ABSTRACT: Data on the biology and behaviour of blackfin tuna (Thunnus atlanticus) have been collected during 24 experimental fishing surveys, seven days each, carried out from October 1995 to October 1997 around Martinican FADs. FAD have been used as scientific tool, to concentrate biological observations on fish present in the area. Following these surveys, landings of fishermen who work around FAD and offshore have been observed two times a week. Sampling occurs on some main landing sites of the Caribbean and Atlantic coasts. These observations feed the data base on the large pelagic fishes occurring in Martinican waters. This poster shows a synthesis of the main biological and fishing results obtained on this species by using this data base. Original Abstract: Une serie de 24 campagnes de pêche experimentale de sept jours chacune, realisee entre octobre 1995 et octobre 1997 au voisinage des dcp implantes autour de la Martinique, a permis de collecter des donnees sur la biologie et le comportement du thon noir (Thunnus atlanticus). Le dcp a ete utilise comme un outil scientifique permettant de concentrer des observations biologiques sur les poissons presents dans la zone. DT la suite de ces campagnes, un suivi des captures des professionnels operant sous et hors dcp a ete initie sur une base bihebdomadaire et se poursuit actuellement. Les echantillonnages realise sur plusieurs sites principaux de deburquement, sur les cotes caraibe et atlantique, permettent de completer la base de donnees sur les grands poissons pelagiques frequentant les eaux martiniquaises. Ce poster presente une synthese des principaux resultats biologiques et halieutiques obtenus sur l'espece a partir des observations effectuees.

324. Taquet, M., L. Reynal, M. Laurans, and A. Lagin. 2000. ABSTRACT: Data on the biology and behaviour of yellowfin tuna (Thunnus albacares) have been collected during 24 experimental fishing surveys, seven days each, carried out from October 1995 to October 1997 around Martinican FADs. FADs have been used as scientific tool, to concentrate biological observations on fish present in the area. Following these surveys, landings of fishermen who work around FAD and offshore have been observed two times a week. Sampling occurs on some main landing sites of the Caribbean and Atlantic
coasts. These observations feed the data base on the large pelagic fishes occurring in Martinican waters. This poster shows a synthesis of the main biological and fishing results obtain on this species by using this data base. 

*Original Abstract:* Une série de 24 campagnes de pêche experimentale de sept jours chacune, realisée entre octobre 1995 et octobre 1997 au voisinage des DCP implantes autour de la Martinique, a permis de collecter des données sur la biologie et le comportement de l'albacore (*Thunnus albacares*). Le DCP a été utilisé comme un outil scientifique permettant de concentrer des observations biologiques sur les poissons présents dans la zone. A la suite de ces campagnes, un suivi des captures des professionnels operant sous et hors DCP a été initié sur une base bi-hebdomadaire et se poursuit actuellement. Les échantillonnages réalisés sur plusieurs sites principaux de débarquement sur les côtes Caraïbe et Atlantique permettent de compléter la base de données sur les grands poissons pelagiques fréquentant les eaux martiniquaises. Ce poster presente une synthese des principaux resultats biologiques et halieutiques obtenus sur l'espece a partir des observations effectuees.

325. **Taquet, M., L. Reynal, M. Laurans, and A. Lagin. 2000.** ABSTRACT: Data on the biology and behaviour of dolphinfish (*Coryphaena hippurus*) have been collected during 24 experimental fishing surveys, seven days each, carried out from October 1995 to October 1997 around Martinican FADs. FADs have been used as scientific tool, to concentrate biological observations on fish present in the area. Following these surveys, landings of fishermen who work around FAD and offshore have been observed two times a week. Sampling occurs on some main landing sites of the Caribbean and Atlantic coasts. These observations feed the data base on the large pelagic fishes occurring in Martinican waters. This poster shows a synthesis of the main biologic and fishing results obtain on this species by using this data base. 

*Original Abstract:* Une série de 24 campagnes de pêche experimentale de sept jours chacune, realisée entre octobre 1995 et octobre 1997 au voisinage des DCP implantes autour de la Martinique, a permis de collecter des données sur la biologie et le comportement de la dorade coryphene (*Coryphaena hippurus*). Le DCP a été utilisé comme un outil scientifique permettant de concentrer des observations biologiques sur les poissons présents dans la zone. A la suite de ces campagnes, un suivi des captures des professionnels operant sous et hors DCP a été initié sur une base bi-hebdomadaire et se poursuit actuellement. Les échantillonnages réalisés sur plusieurs sites principaux de débarquement sur les côtes Caraïbe et Atlantique permettent de compléter la base de données sur les grands poissons pelagiques fréquentant les eaux martiniquaises. Ce poster presente une synthese des principaux resultats biologiques et halieutiques obtenus sur l'espece a partir des observations effectuees.

121. **Taquet, M., G. Van Burrt, and L. Reynal. 1999.** ABSTRACT: This conference will develop a comparative overview of the development of FADs by the
tropical purse seine fisheries in the various oceans (Atlantic, Indian, Western and Eastern Pacific oceans). First a comparative review of fishery statistics will be developed. This comparison will cover geographical patterns, trends over time, seasonality, species composition, size taken, sizes of schools in the various FAD fisheries. Then a comparative review of observer data will be done. Rate of unsuccessful sets on FADs, times of setting, variance of species composition between FAD schools, the observed by-catches by species observed in the various oceans will be compared. The FAD technology used in the various oceans (radio location, underwater nets, numbers, turn over, use of sounders, satellite positioning, use of underwater light, tracking of FAD with satellite and PCs, use of bait, auxiliary boats, etc.) will then be reviewed and compared. The environment and water masses (currents, thermocline, wind, etc.) in which FADs are used more efficiently by purse seiners will be analyzed and discussed. Potential problems introduced by FADs in the tuna stock assessment, primarily because FADs are heavily changing the nature of fishing effort and then most stock assessment, will be discussed. As a last point, the management of FADs presently done or in view by the various tuna bodies will be introduced. It appears that the present massive use of FADs world wide is probably an unsafe fishing mode which need to be limited to reasonable biological levels.

410. **Telleria, J.A., A. Delgado de Molina, A. Fonteneau, F.G. Costas, and P. Pillares.** 1999. **ABSTRACT:** The goal of this study is to review the tuna fisheries associated with floating logs in the eastern tropical Atlantic. In the Atlantic, the log fishery contributes a relatively minor proportion of the purse-seine catches (approximately 15% during the time period 1988-1990). The dominant species in log sets is skipjack (76% for the same period), followed by yellowfin (17%) and bigeye (7%). Skipjack taken with logs have a weight distribution identical to those in free schools (average weight of 5.3 kg for yellowfin and 4.5 kg for bigeye). The fishing seasons and locations on logs are geographically restricted and stable from year to year during the period under study. As in other oceans, the catch per set under logs is on the average greater than on free schools (34 t versus 19 t), and the rate of unsuccessful sets is low compared to free-swimming schools (6% versus 28%). Many logs in the Atlantic seem to be from natural origin and are drifting in the surface currents of the area. The exact origin of the logs is still questionable, especially the proportions from the Amazon and from African rivers (especially Zaire), both located at similar distances from the fishing zone. The accumulation of logs in the north equatorial convergence zone has been noticed and contributes to important tuna catches. Since the end of 1990, artificial logs have been deployed in large numbers in the offshore area by purse seiners and have enabled catches of skipjack and larger yellowfin in new fishing zones. Yield per recruit analysis has been conducted and concludes that a further development of the artificial log fishery should increase yield per recruit of the total fishery, the potential benefit being mainly for skipjack. Research recommendations are
developed in order to improve knowledge about tuna and log dynamics, and also to estimate the tuna abundance in a purse-seine fishery developing a log fishing strategy.

316. **Tessier, E., and F. Poisson. 2000.** ABSTRACT: More than ten years after its launching, an evaluation of the results of the FADs programme carried on in Reunion Island has been made. Its implementation and its impact on artisanal fishery in Reunion Island have been analysed. This analysis demonstrates that, following a continuously ascending phase, the production of fish caught on FADs has reached a plateau. Parallel to the FAD-associated fishery, the longline fishery has developed since 1991. This type of fishery includes production units whose operating zone is bordering the FAD installation area. Analysing the evolution of the small longliner sector is based on general activity indicators (number of ships, production, fish selling prices). Besides, a synthesis of the interactions between those two types of fisheries, whether in terms of exploited resources, space conflicts, fishing population or market, has been effected. Judging from the complementary and antagonistic natures of the two fisheries identified above and given their evolution, the future of the FADs programme is pending. Have the FADs just been a step in the evolution of the Reunion fishing system or have they modified it on a long-term basis?

290. **Tessier, E., H. Rey-Valette, D. Ah-Nieme, R.-M. Bargain, A. Vnkatsamy, and B. Wendling. 2000.** ABSTRACT: The first FADs in the islands of the South West Indian Ocean were moored in the fifties. The area under study forms part of the Indian Ocean Commission which include Comoros, Madagascar, Mauritius, Seychelles, Reunion and the island of Mayotte. After a few isolated trials that turned to be inconclusive, especially for lack of reliability of the devices moored, trials were pursued under the auspices of international organizations. A new type of FAD was successfully designed and implemented in Mauritius. This model was then applied in the Comoros in 1987, in La Reunion and Madagascar in 1988 and in Mayotte in 1989. The various programmes have had various results. In some cases such as La Reunion and Mauritius, they have played a key role in the development of the inshore fishery. In other cases they have been less significant. Finally in other cases although a significant impact on artisanal fishery, the experience was halted due to financial constraints. Beyond the history of the various programmes and the results obtained, thus have attempted to underline the social and economic factors that have characterized the various trials in the different regional countries.

127. **Tessier, E., H. Rey-Valette, J.N. de Lestang, A. Venkatasamy, and B. Wendling. 1999.** ABSTRACT: The first FADs in the islands of the South West Indian Ocean were moored in the 50's. These islands are memberships of the Indian Ocean Commission which include Comoros, Madagascar, Mauritius, Seychelles, France (Reunion) and the island of Mayotte. After a few isolated
trials that proved to be inconclusive, especially for lack of reliability of the devices moored, trials were pursued under the auspices of international organisations. A new model was successfully tried and implemented in Mauritius. This model was then transferred to the Seychelles in 1983, in the Comoros in 1987, in La Reunion and Madagascar in 1988 and in Mayotte in 1989. The various programmes have had various results. In certain cases, such as La Reunion and Mauritius, they have played a key role in the development of the inshore fishery. In other cases, they have been less significant. Finally, in certain cases, although the impact on artisanal fishery was significant the experience was not pursued due of financial constraints. Beyond the history of the various programmes and the results obtained, the authors have attempted to underscore the various ecological, social and economic factors that have characterised the various trials in the different regional countries.

27. Tomlinson, P.K. 1998. ABSTRACT: During the mid-1950s, Japanese longline vessels began to fish in the eastern Pacific Ocean east of 150 degree W (EPO) and their catches of bigeye increased over time, reaching a peak of 97 thousand metric tons in 1986. In the 1965-1993 period, 24 to 43 percent of the world catches of bigeye came from the EPO and were caught mostly by longlines. During late 1993 purse seine vessels operating in the EPO discovered that bigeye associated with floating objects, but well beneath the surface of the water, can be detected with sonar, and they developed methods for catching them. Many of these floating objects were fish-aggregating devices (FADs) placed in the water by the fishermen. Most of these purse-seine catches of bigeye were taken between 5 degree N and 10 degree S. Accordingly, beginning in 1995, the IATTC staff further increased its studies on bigeye, principally to estimate the effects of increased catches by the surface fishery on the longline fishery and on the sustainable yield.

136. Torres, A. 1999. ABSTRACT: Guam is a territory of the United States with a population of approximately 133,000 people. It is the largest and southernmost island of the Mariana Archipelago in the western Pacific Ocean. Installation and maintenance of FADs by the Government of Guam began in 1979, initially with funding from the Salstonstall-Kennedy Act through the Pacific Tuna Development Foundation. Current funding for the Guam FAD project is provided through the Dingell-Johnson/Wallop-Breaux Sport Fish Restoration program, a Federal Aid Project funded by taxes collected on the purchase of fishing equipment and motorboat fuels nationwide. There are now sixteen operational FAD sites in Guam's waters. At a cost of approximately $US10,000 per system, concern for the rising costs of replacing and maintaining FAD systems has prompted the Department of Agriculture's Division of Aquatic and Wildlife Resources (DAWR) to investigate alternative FAD maintenance strategies and system design. Several cost-cutting measures being considered include the use of reliable solar-powered navigation lights to reduce the number of maintenance
trips required, and switching to a newer generation of lighter, more durable buoys and mooring systems. Average time on station for a DAWR FAD system is nearing two years. Interestingly, in most cases where an errant system is recovered, the failure in the mooring system was observed to occur at a depth of between 35-500 m. These observations have lead to speculation that additional protection of the mooring line down to 500 m may result in doubling the average time on station of most FAD systems.

329. Torres, A. 2000. ABSTRACT: Installation and maintenance of FADs by the Government of Guam began in 1979, initially with funding from the Salstonstall-Kennedy Act through the Pacific Tuna Development Foundation. Current funding for the Guam FAD project is provided through the Dingell-Johnson/Wallop-Breaux Sport Fish Restoration Programme, a Federal Aid Project funded by taxes collected on the purchase of fishing equipment and motorboat fuels nationwide. There are now sixteen operational FAD sites in Guam's waters. At a cost of approximately US$10,000 per system, concern for the rising costs of replacing and maintaining FAD systems has prompted the Department of Agriculture's Division of Aquatic and Wildlife Resources (DAWR) to investigate alternative FAD maintenance strategies and system design. Several cost-cutting measures being considered include the use of reliable solar-powered navigation lights to reduce the number of maintenance trips required, and switching to a newer generation of lighter, more durable buoys and mooring systems. Average time on station for a DAWR FAD system is nearing two years. Interestingly, in most cases where an errant system is recovered, the failure in the mooring system was observed to occur at a depth from 35 to 500 m. These observations have led to speculation that additional protection of the mooring line down to 500 m may result in doubling the average time on station of most FAD systems.

51. Vande Vusse, F.J., and E. Pileo. 1994. ABSTRACT: The "payao" an indigenous deep water FAD, attracts juvenile tuna and small pelagics for commercial harvest by pursuing seines of varying sizes. Unrestricted use of the payao/purse seine combination contributes to overfishing. Artisanal fishermen compete for the same fish using multiple hook (200-250) hand lines trolled from outrigger canoes. Harvests vary, averaging 2 kg/day. Net income is $1.53/day from a $2.00 gross. Fishing at commercial payaos is good in the brief interval between attraction and a school's harvest by purse seine. Payaos were established in municipal waters (to 5.6 km) exclusively for hand line fishermen to try to provide more regular harvests while reducing direct competition with purse seines. They also served as a community organization focal point. As fish were not routinely caught or scattered by purse seines, hand line harvests became more regular. Average catch doubled and costs decreased 50% as fewer hooks (25-40) were needed. Average net income increased 140% to $3.78/day. Organized artisanal fishermen have forced purse seines offshore resulting in a redistribution of the harvest,
increased fishery profit with a more equitable distribution and reduced fishing pressure in municipal waters.

67. **Venkatasami, A. 1990.** ABSTRACT: Details are given of experience with FADs in the Southwest Indian Ocean, discussing their use in the following countries: Comores, Madagascar, Mauritius, Mozambique, Reunion, Seychelles, and Tanzania. The design, construction and longevity of the FADs are described and fishing techniques outlined, indicating species caught and giving an analysis of catch data. Socioeconomic and other aspects of FADs are also considered.

7. **Venkatasami, A. 1991.** ABSTRACT: An account is given of experience with FADs in the Southwest Indian Ocean, considering the following countries individually: Comores, Madagascar, Mauritius, Mozambique, Reunion, Seychelles, Tanzania. The design of long-lived FADs developed in the region is described, outlining design consideration, construction details, longevity and reasons for loss and location. FADs and fishing production is also considered, indicating fishing techniques, species caught, and catch data analysis. Socio-economic and other aspects of FAD fisheries are examined briefly. It is concluded that the introduction of FADs in certain countries of the region is positively perceived by the fishermen communities. The investment required for the programme is relatively low compared to the benefits derived by the fishermen and the country. Landings from FADs are expected to increase gradually, as more and more fishermen, motivated by higher catch rates, join the fishery.

22. **Venkatasami, A., and A. Sheik Mamode. 1996.** ABSTRACT: Mauritius is one of the first countries in the South West Indian Ocean to have started a fishery associated with Fish-Aggregating Devices (FADs). The productivity of fishermen engaged in this fishery is quite low compared to neighboring Reunion and Comoros Islands. An FAD efficiency assessment survey revealed that production of fish could easily increase. This paper analyses the fishermen's catches, the problems they encounter, and the high performance some of them achieve.

317. **de Verdihac, P., J.-M. Maggiorani, and P. Debouvry. 2000.** ABSTRACT: A development programme for the promotion of FADs in Sao Tome and Principe has implemented an original interactive approach by granting a predominant place to the initiative of the target group and its participation in decision making. The appropriation process of the innovative FADs by the beneficiaries takes place in three stages described herewith.

- the technical research phase. This consists of formally describing an idea in reply to an expressed or potential need. The envisaged FAD type is developed and tested by the project's agents in order to obtain a technically appropriate prototype.
- the research and adjustment phase. The FAD is given to a small number of people to be used in real-life conditions. Reaction surveys will enable its pertinence to be tested and its adaptation to normal conditions of use. This second phase results in the production of a technically and socio-economically appropriated FAD.

- the diffusion-perpetuation phase. This entails i) identification of the sequences of the various stages, ii) definition and grouping of contributions by the various parties, iii) production of educational auxiliaries, iv) initiating actions for user awareness and demonstration, v) staff training, vi) monitoring of the FAD "socialisation", vii) solving funding problems.

Original Abstract: Un projet visant, entre autres, la promotion de DCP pour la pêche artisanale fonctionne à Sao Tome et Principe depuis 1993. Le processus d' appropriation da une telle innovation par les bénéficiaires comprend trois étapes ici décrites. La phase de recherche technique. Il s'agit d' instrumentaliser une idée en réponse à un besoin exprimé ou potentiel. L'innovation envisagée est mise au point et testée par les agents du projet en milieu contrôlé de façon à obtenir un prototype techniquement approprié. La phase de recherche-développement: l'outil est confié à un petit nombre de personnes pour une utilisation en conditions réelles. C'est une phase de mise au point interactive, seule susceptible de provoquer une réelle appropriation par les recipiendaires. Des enquêtes de réaction permettront de tester sa pertinence et de l'adapter aux conditions normales d'utilisation. Cette seconde phase débouche sur la production d'un outil de référence techniquement et socio-économiquement approprié. La phase de diffusion-perpétuation: il s'agira là : i) d'identifier les séquences d'intervention, ii) d'identifier et de regrouper les apports des différentes parties, iii) de définir et de produire les auxiliaires pédagogiques (manuels, affiches, radio), iv) d'entreprendre des actions de sensibilisation et de démonstration, v) de former les personnels, vi) de veiller à la socialisation de l'innovation, pour les outils collectifs, vii) de résoudre le problème du financement.

79. Wahlert, G. von, and H. von Wahlert. 1990. ABSTRACT: Oil rigs are known to offer homesteads to territorial fish, and to attract also more vagrant feeders. In recent years open sea mariculture with floating Fish Aggregating Devices (FADs) and "artificial reefs" on the sea bottom has become state of the art in fisheries development in rural areas and industrialized countries. In rural fisheries traditional methods of building FADs from bamboo (or, if available, old car tires) are revived; Japan erects underwater structures with an outlay of about $1 billion in ten years. This development deserves the attention of students of ecology, faunistics, biogeography and evolution. Even if mariculture will remain restricted to coastal and shelf areas, it might amount here in due time to changes comparable to the far-reaching effects of forestry and agriculture on land. Whether or not this new partnership between man and animals will induce evolutionary changes in the latter comparable to those studied by and since Darwin in domesticated animals, the future will
show. We will review recent developments in this field and the authors' own experiences in rural mariculture development in the Pacific area since 1972.


97. **Weerasooriya, K.T. 1987.** ABSTRACT: This paper discusses the experiences of the small-scale fisheries project of the Bay of Bengal Programme (BOBP) with fish aggregating devices (FADs) in Sri Lanka from 1982 to 1986.

133. **Wendling, B. 1999.** ABSTRACT: The volcanic island of Mayotte (374 km²) is part of the Comoros Archipelago, which is situated on the North of Mozambique’s Canal (Indian Ocean). Mayotte is composed of two islands and some thirty small islands distributed in a lagoon of more than 1,000 km². Being one of the French Republic's Territorial Collectivity, this island is characterized by a very fast demographic evolution (growth rate : 5.8%), which constitutes the foundation of the development problematic. Most of local halieutic production comes from the reef (nearly 2,000 t in 1999), the technique of "palangrotte" (deep line) is still dominating. The fishing fleet is composed of monoxyl pirogues and polyester fishing boats for the 1,200 fishermen. The first FADs (Fish Aggregating Devices) were installed in 1989. Now, five FADs are situated in the lagoon whereas ten others have been installed out of it. If it is very hard to evaluate economic impact of FAD in Mayotte, their success seems to be limited because of several local constraints fear to fish out of the lagoon, little interest in tuna, lack of formation. Nevertheless, faced with the demographic evolution and the decrease of the reef resources, a program of fishing development on FAD has been initiated in 1998, with those following themes realization of a new prototype of FAD, experimental fishing program with vertical drift "long line", teaching programs for the local fishermen. Today, it is too early to analyze the information already collected, but the results are very promising, and validate the technical improvement of the new prototype.

295. **Wendling, B., and S. Le Calve. 2000.** ABSTRACT: The volcanic island of Mayotte (374 km²) is part of the Comoros Archipelago, which is situated on the North of Mozambique's Canal (Indian Ocean). Mayotte is composed of two islands and some thirty small islands distributed in a lagoon of more than 1,000 km². Being one of the French Republic's Territorial Collectivity, this island is characterized by a very fast demographic evolution (growth rate : 5.8%), which constitutes the foundation of the development problem. Most of local halieutic production comes from the reef (nearly 2,000 t in 1999), the technique of "palangrotte" (deep line) is still dominating. The fishing fleet is
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**Abstract:** L'île volcanique de Mayotte (374 km$^2$) fait partie de l'archipel des Comores située au Nord du canal du Mozambique (océan Indien). Mayotte comprend deux îles et une trentaine d'îlots répartis dans un lagon de plus de 1 000 km$^2$. Collectivité territoriale de la République française, l'île se caractérise par une évolution démographique très rapide (taux de croissance: 5,8%), qui constitue le socle de toutes les problématiques de développement. L'essentiel de la production halieutique provient du milieu récifal (environ 2 000 t en 1999), la pêche à la ligne de fond reste la technique dominante. La flottille de pêche est constituée de pirogues monoxyles et de barques polyester pour une population de 1 200 pêcheurs. Les premiers DCP mahorais furent installés en 1989. À ce jour, on dénombre cinq DCP dans le lagon et dix hors lagon. Il semble que leur succès soit resté limité en raison de plusieurs contraintes locales : peur de la pêche hors lagon, peu d'intérêt pour les poissons pelagiques, manque de formation. Neanmoins, face à l'explosion démographique et à l'appauvrissement des ressources lagonaires, un nouveau programme de développement de la pêche sur DCP a été initié en 1998. Ce programme comporte trois axes : réalisation d'un nouveau prototype de DCP, lancement d'un programme de pêches experimentales à la palangre verticale dérivante et formation des pêcheurs. À ce jour, les informations obtenues sont trop parcellaires pour être analysées mais les données et observations réalisées sur les nouveaux dispositifs permettent de valider leur conception technique.

144. **Wickham, D.A., and W.R. Seidel. 1973.** ABSTRACT: The report discusses studies with mid-water artificial structures which showed that certain species of both pelagic baitfish and sport fish can be concentrated with artificial structures, thereby increasing their availability to both commercial and sport fishermen. Multiple structures appear to be significantly more effective than single structures. The range of a structure's attraction seems to be limited by factors, such as water clarity, which affect the visibility of the structure or associated baitfish schools.
80. Wilkins, R.M., and M.H. Goodwin. 1989. ABSTRACT: Many eastern Caribbean countries are net importers of seafood. While the current harvest of traditional shallow-water marine resources is close to sustainable levels, pelagic fishes found in deeper waters appear to have significant potential for increased landings to the small island nations of the eastern Caribbean. Fish aggregating devices (or FADs) have been used in many parts of the world as an aid to the harvest of pelagic fishes. A grant was secured from the United States Agency for International Development to support a pilot scale FAD project which was launched in St. Kitts. The objectives of this project were to evaluate the usefulness of fish aggregating for improvement of artisanal fisheries in the eastern Caribbean, and to adapt and develop appropriate mooring, deployment, and monitoring techniques to assist local use of FADs in the region.

6. Willmann, R. 1991. ABSTRACT: A framework is provided for social and economic analyses which are needed in the planning, monitoring and evaluation of artificial reef (AR) and fish aggregating device (FAD) development programmes. Following an examination of the various objectives which are pursued with such structures, a discussion is presented on the costs and benefits from FADs and ARs and derives social and economic information needs which are of relevance in planning and monitoring and evaluation. It is concluded that the efficiency of FADs and ARs is closely related to their proper management.

64. Wood, J. 1989. ABSTRACT: The report describes the findings of a consultancy conducted in Cape Verde regarding the construction of FADs made from locally available materials and their deployment in suitable localities around the islands. In all, 12 FADs were positioned; the following types of fishing gear are recommended for working in the area of FADs: handlines, trolling lines, long lines, pole-and-line, purse seine, drifting gillnet, and light attraction.

54. Yahaya, J. 1994. ABSTRACT: In Malaysia, Fish Aggregating Devices (FADs) have been widely deployed to increase the productivities of fish biomass in the surrounding waters, thereby enhancing fishermen's catch and income. The FADs are usually constructed by LKIM, a government agency entrusted with the socio-economic development of the fishing communities. In some instances, however, FADs are privately constructed and owned by individual boat owners or groups of boat owners who have exclusive use right over the FADs. Under their own management regime including a rental scheme to other fishermen who wish to fish in their FADs areas. Understanding and documenting the management systems currently practised by fishermen in the FADs areas are therefore of crucial importance. This paper examines the different types of institutional arrangements and management practices established over the artificial structures and the surrounding fisheries resources. Issues and problems related to the management of FADs are also
discussed. Some general suggestions on the possibility of using FADs as a community-level mechanism in the implementation of a community-based management system in the artisanal fisheries are included.
## Key Word Indexes

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AUSTRALIA
CARIBBEAN
GOM (Gulf of Mexico)
GULF OF GUINEA
INDIAN OCEAN
MEDITERRANEAN SEA
PACIFIC OCEAN
TAXONOMIC

ALBACORE (*Thunnus alalunga*)
AMBERJACK (*Seriola* sp.)
BARRACUDA (*Sphyraena* sp.)
BIEYE TUNA (*Thunnus obesus*)
BLACKFIN TUNA (*Thunnus atlanticus*)
BLUE MARLIN (*Makaira nigricans*)
BLUEFIN TUNA (*Thunnus thynnus*)
CARANGIDAE
CLUPEID
DOLPHIN (*Coryphaena hippurus*)
DOLPHINS (Mammal)
FILEFISH (*Monacanthus* sp.)
FLYING FISH (*Cypselurus* sp.)
MARLINS
PILOTFISH (*Naucrates ductor*)
RAINBOW RUNNER (*Elagatis bipinnulata*)
SCAD (*Decapterus* sp.)
SCOMBRIDAE
SEA TURTLES
SHARKS
SKIPJACK (*Katsuwonus pelamis*)
SWORDFISH (*Xiphias gladius*)
TUNAS
WAHO (Acanthocybium solandri)
WHALES
WHALE SHARKS (*Rhincodon typus*)
WRECKFISH (*Polyprion americanus*)
YELLOWFIN TUNA (*Thunnus albacares*)

FADS, OPERATIONAL/GENERAL

ANCHORED FADS
ATTRACTING TECHNIQUES
BEACONS
BOAT (AGGREGATION TO)
DESIGN (FADs)
DEVELOPMENT PROGRAM
DRIFTING/FLOATING STRUCTURES
FADS (General)
FADS LOSS
FLOATING OBJECTS/LOGS
LEGAL ASPECTS
MANUALS
MIDWATER

AGGREGATION AND ATTRACTION (TO FADS AND OBJECTS) RELATED PHENOMENA/PROCESSES

ABUNDANCE
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AGGREGATION
ASSOCIATION
ATTRACTION
BEHAVIOUR
COLOR
COMPARATIVE STUDIES
DEPTH/VERTICAL DISTRIBUTION/MOVEMENT
DIETS/FOOD/FEEDING
DIURNAL VARIATIONS
HOMING
HORIZONTAL DISTRIBUTION
HYPOTHESES
LIGHT
LUNAR PHASES
MIGRATIONS
MODELS
MORTALITY
MOVEMENTS = MOVEMENTS/DISTRIBUTION
NETWORK
OBJECT CHARACTERISTICS
OBJECT SIZE
PHYSIOLOGY
POPULATION DYNAMICS
POPULATION STRUCTURE
PREY
PROBLEMS (NEGATIVE IMPACTS)
RECRUITMENT
RESEARCH
RESIDENCE TIME
SAMPLING
SCHOOLING BEHAVIOR
SP. DIVERSITY = SPECIES DIVERSITY/COMMUNITY COMPOSITION/ASSEMBLAGES/ECOLOGICAL AGGREGATIONS SIZE DISTRIBUTION
SPAWNING
TEMPORAL
VISION

FAIDS RESEARCH/STUDY TECHNIQUES

ACOUSTIC TELEMETRY
FISHERY-DEPENDENT
HYDROACoustics
LIDAR
MODELS
SAMPLING
TAGGING (mark/recapture)
UNDERWATER OBSERVATION

FISHERIES RELATED

ARTISANAL
BAIT FISHING
BYCATCH
CATCHABILITY
CATCH COMPOSITION
CATCH/EFFORT
CATCH STATISTICS
DEVELOPMENT PROGRAM
ECONOMICS, FISHERY
FISHERIES
FISHERIES, TUNA
FISHERY, COASTAL
FISHERY-DEPENDENT
FISHERY DEVELOPMENT
FISHERY MANAGEMENT
FISHERY OCEANOGRAPHY
FISHERY, PELAGIC
FISHERY RESOURCES
FISHERY SURVEYS
FISHERY TECHNOLOGY
FISHING
FISHING BUOYS
FISHING, COMMERCIAL
FISHING EFFORT
FISHING, EXPERIMENTAL
FISHING GEAR
FISHING GROUNDS
FISHING OPERATIONS
FISHING, POLE-LINE
FISHING POWER
FISHING, PURSE SEINING
FISHING, SPORT
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FISHING VESSELS
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COMPARATIVE STUDIES
CONFERENCES = CONFERENCES/WORKSHOPS/SYMPOSIA/MEETINGS
REVIEW/SUMMARY

MISCELLANEOUS

ARTIFICIAL REEFS
COASTAL PELAGICS
COASTAL WATERS
DEEPWATER
HABITAT IMPROVEMENT (PHYSICAL)
JUVENILE FISH
LARVAL FISH
PETROLEUM STRUCTURES
PLANKTON
REEF FISH
SEAMOUNTS
APPENDIX A

FADs Technical Session Proposal to American Fisheries Society.
PROPOSAL FOR SPECIAL SESSION FOR
2001 SOUTHERN DIVISION MIDYEAR MEETING

FISH ATTRACTING DEVICES (FADs): SCIENCE AND MANAGEMENT ISSUES,
WITH SPECIAL EMPHASIS ON GULF OF MEXICO PELAGIC FISHES AND
OFFSHORE OIL AND GAS STRUCTURES

Objectives: The objective of the session is to assemble a wide range of scientists and
resource managers to consider the phenomenon of fish attraction to objects in the pelagic
environment. Fish attracting devices (FADs) have been found to be very effective and
recently have been widely employed around the world in pelagic fisheries, particularly
tuna fisheries. Technical developments in the offshore oil and gas production industry
have made it likely that large numbers of deepwater (>300 m) drilling and production
platforms will soon be deployed on the Gulf of Mexico (GOM) outer continental shelf.
The potential FADs effects and fisheries impacts of a network of large structures needs to
be considered early in the design and permitting process. Additional science may be
required. Additionally, commercial fisheries in the Gulf may some day adopt FADs
fishing techniques now used to a high degree (over half of catch now taken from FADs)
in Pacific tuna fisheries. Therefore, the general objective of the session is to determine
what is known and what needs to be known about FADs and related processes in order to
assess potential impacts of deepwater structures and other FADs in the GOM and similar
marine environments.

Interest: Because FADs issues are of global importance, the session will not just be of
interest to and attract participation from the southern US, but is expected to have national
and international appeal and involvement. Its focus on Gulf of Mexico makes it highly
appropriate for inclusion in the Southern Division AFS meeting.

Schedule: A full-day session will be broken roughly into a morning session in which
individual papers on the full range of FADs science and management issues will be
presented, and an afternoon panel discussion session. Science issues in the morning
session will include basic processes and phenomena pertinent to fish attraction and
aggregation, as well as recent empirical studies of FADs. Management issues will
include the effects and potential impacts of FADs on recreational and commercial
fisheries, with special emphasis on the Gulf of Mexico or comparable environments. If
more papers than can be presented in the morning are submitted, we will have the
flexibility to schedule the afternoon such that contributed papers are continued in the
early afternoon, with the remaining portion of the day allocated to the panel discussion.

The afternoon session will consist of a facilitated panel discussion in a format
encouraging a high level of input from audience participants. The panel will be
comprised of scientists and resource managers with knowledge and/or involvement in
FADs or Gulf of Mexico pelagic fisheries. The goal of the afternoon panel session will be
to examine the current state of knowledge about FADs scientific understanding and
management issues. The panel will be directed to identify critical scientific information
needs or gaps, and to make prioritized suggestions for research needs. The panel will
similarly analyze existing and needed resource management understanding of FADs, and it will be directed to identify potential problems, solutions, and opportunities with regard to GOM deepwater structures and other FADs. Prior to the meeting, the panel members will receive background information on FADs issues and phenomena, goals and structure of the panel discussion, and instructions for preparing statements on topics pertinent to their expertise and experience. In short, we will make every effort to make this be a well organized, focused and productive panel discussion.

**Participants:** Although individual participants cannot be definitively identified until the session has been formally approved for inclusion in the meeting, numerous potential participants have been contacted and already have indicated likelihood of participation. Interest has been indicated from individuals from a wide range of institutions including: Inter-American Tropical Tuna Commission (IATTC), Institut Francais de Recherche pour l'Exploitation de la Mer (IFREMER); Gulf Coast Research Laboratory; Louisiana State University; University of California, Santa Cruz; MacIntosh Marine Inc.; and others. Immediately upon receipt of official approval of inclusion of this symposium in the midyear meeting, an intensive advertising and networking effort will be started. All major marine laboratories (academic, federal, state), all major universities with marine research programs, all marine resource management agencies (state, federal and regional), and all known FADs-related researchers in the US will be contacted (individuals by email, institutions will receive hard-copy fliers) to publicize the meeting and to solicit contributions and attendance. Additionally, the session will be widely publicized through posters, fliers and a paper presented at a major regional fishery meeting this fall.

**Organizers:** This session is an essential and important component of an ongoing and funded research project being conducted by USGS-BRD on behalf of MMS. Because of this, the project PI’s (Ken Sulak, Randy Edwards and Doug Weaver) will act as session organizers. We have been actively working to develop this session and will work diligently toward making it the kind of session that will be a credit to the AFS Florida Chapter and Southern Division. We will be available to directly assist the Program Committee Co-Chairs in all aspects of the session. Randy Edwards is the primary contact person for any such participation and assistance.

**Visual aids/resources:** Normal visual aids (carousel projector, overhead projector, and, if possible, LCD projector and PC with MS PowerPoint) will be needed for the technical session. The same equipment will be needed for the panel discussion, plus at least one or two table-top microphones and PA system. Arrangements will have to be made for

---


2 Organizers: Dr. Kenneth J. Sulak and Mr. Doug Weaver, USGS-BRD, Florida Caribbean Science Center, 7920 NW 71 Street, Gainesville, Florida 32653-3071, Telephone: 352-378-8181, FAX: 352-378-4956, Email: ken_sulak@usgs.gov, doug_weaver@usgs.gov; Dr. Randy E. Edwards, USGS-BRD/CFCG, 600 Fourth St. S., St. Petersburg, FL 33701, Telephone: 727-803-8747, FAX 727-803-2030, Email: rewards@usgs.gov.
proper tables and chairs for the panel. Session organizers will be available and pleased to assist the Program Committee in any way requested.
APPENDIX B

FADs Technical Session (“Rigs and FADs”) Announcement Flier.
Call for Papers and Participants
DEEP RIGS as FADS
Technical Session and Panel
AFS Southern Division Midyear Meeting
Jacksonville, FL, Feb. 22-25, 2001

http://www.sdafs.org/meetings
Abstracts by Nov. 15, 2000
to: redwards@usgs.gov
or to: Randy E. Edwards
USGS-BRD-FCSC-CCG
600 Fourth Street South
St. Petersburg, FL 33701
(727) 803-8747/803-2030 (FAX)

The goal of this technical session and panel is to facilitate interaction of a broad range of scientists and managers having expertise or interest in fish attraction, fish aggregation, FADs, and related biological, ecological, behavioral, and environmental processes. Focus will be given to (but not restricted to) potential impacts of deepwater petroleum and gas structures in the Gulf of Mexico and similar environments.
APPENDIX C

FADS Technical Session Program Announcement
Reminder and Invitation

Special Session – Southern Division AFS Midyear Meeting, Jacksonville, FL
February 24, 2001 (All Day)
Detailed information on the meeting (including registration and accommodations) is available at: http://www.sdafs.org/meetings/01sdafs/2001home.htm.

RIGS AND FADS -- FISH AGGREGATING DEVICES (FADs): SCIENCE AND MANAGEMENT ISSUES, WITH SPECIAL EMPHASIS ON GULF OF MEXICO PELAGIC FISHES AND OIL AND GAS STRUCTURES

You are reminded of and urged to attend this important session that is now only one month away (Feb. 24, 2001). National and international experts on FADs and related issues will provide technical and background information on this issue of potentially great importance.

CONTENT: This session will assemble a wide range of FADs experts, scientists and resource managers to consider the phenomenon of fish attraction to objects in the pelagic environment – with particular focus on potential developments in the northern Gulf of Mexico. Fish aggregating devices (FADs) have been found to be very effective and recently have been widely employed around the world in pelagic fisheries, particularly tuna fisheries. Recent technical developments in the offshore oil and gas production industry have made it likely that large numbers of deepwater (>300 m) drilling and production platforms will soon be deployed on the Gulf of Mexico (GOM) outer continental shelf. The potential FADs effects and fisheries impacts of a network of large structures needs to be considered early in the design and permitting process. Additional science may be required. Additionally, commercial fisheries in the Gulf may some day adopt FADs fishing techniques now used to a high degree (over half of catch now taken from FADs) in Pacific tuna fisheries. Therefore, the general objective of the session is to determine what is known and what needs to be known about FADs and related processes in order to assess potential impacts of deepwater structures and other FADs in the GOM and similar marine environments.

PROGRAM: An inclusive spectrum of national and international experts on FADs and related fishery issues will provide analysis and overview of current understanding of FADs science and management issues in the context of predicting fish aggregating effects of deepwater GOM petroleum structures.

Session Schedule

• Deepwater petroleum structures in the Gulf of Mexico – Assessment of their potential to function as fish aggregating devices (FADs). R.E. Edwards, K.J. Sulak, and D. Weaver (USGS-BRD, Florida Caribbean Research Center, Gainesville, FL).

• The fishery for tunas associated with flotsam and FADs in the eastern Pacific Ocean. M.A. Hall (Inter-American Tropical Tuna Commission).

• Questions about the association of tunas and other species with floating objects. M.A. Hall (Inter-American Tropical Tuna Commission).

• Fish and FADs: A review of the influence of FADs on the movement and distribution of Pelagic Fishes. K.N Holland (Hawaii Institute of Marine Biology, University of Hawaii).

• Tuna fishing and fish aggregating devices. M. Taquet (Ifremer, Laboratoire Ressources Halieutiques, Réunion) and J.-Y. LeGall (Département Halieutique, Rennes, France).

• Integrated statistical models of tuna movement in relation to fish attractors. J. Sibert (Pelagic Fisheries Research Program, Joint Institute for Marine and Atmospheric Research, University of Hawaii at Manoa).

• Tuna in the Gulf of Mexico. C. Brown (NMFS/SEFSC Sustainable Fisheries Division) and G. Scott (NMFS/South East Regional Office).

• Petroleum platforms in the northern Gulf of Mexico: Deepwater structures as fish attracting devices for pelagic fishes. J.S. Franks (Center for Fisheries Research and Development, Institute of Marine Sciences, University of Southern Mississippi, Ocean Springs).

• Cold-core eddies, the Loop Current and larval tuna; a preferred spawning and nursery habitat? J.T. Lamkin (NMFS/SEFC, Miami), J.J. Gavoni (NOAA National Ocean Service Beaufort Marine Laboratory, Center for Coastal Fisheries and Habitat Research), and T.D. Leming (NOAA NMFS, Stennis Space Center, MS).

• Gulf of Mexico petroleum and gas rigs as FADs for sharks and rays. R. Hueter (Mote Marine Laboratory, Sarasota, FL) and J. Childs (Center for Coastal Studies, Texas A&M University, Corpus Christi TX).

• Now it can be told: 5 long years of deepwater surveys around the oil platforms of southern California. M. Love (Marine Science Institute, University of California, Santa Barbara).

• The role of petroleum platforms as artificial reefs in the northern Gulf of Mexico. C.A. Wilson. (Coastal Fisheries Institute, Department of
• Potential interactions between pelagic longline fishing and deepwater oil and gas structures in the Gulf of Mexico. David B. Snyder¹, Luis Lagera¹, Peter Arnold², LeRay de Wit³, George H. Burgess⁴ and Chris Friel⁵. (¹-Continental Shelf Associates, Inc. 759 Parkway Street, Jupiter, FL 33477, ²-914 Beau Chene Drive, Mandeville, LA 70471, ³-2054 Bluerock Circle, Concord, CA 94521, ⁴-Florida Museum of Natural History, University of Florida, Gainesville, FL 32611, ⁵-Florida Marine Research Institute, St. Petersburg, FL).

• Panel Discussion.
APPENDIX D

FADs Technical Session ("Rigs and FADs") Abstracts.
Deepwater Development Structures

G. Ed Richardson

U.S. Department of the Interior
Minerals Management Service
Gulf of Mexico OCS Regional Office
1201 Elmwood Park Boulevard
New Orleans, Louisiana 70123-2394
Email: Ed.Richardson@mms.gov

Deepwater leasing activities in the Gulf of Mexico have expanded rapidly in the last few years. Currently, the Gulf of Mexico has approximately 7,600 active leases – about 48 percent of these (about 3,650 leases) are in deepwater (1,000 ft or more of water depth). Only a portion of these deepwater leases will be drilled and explored. If commercial quantities of recoverable hydrocarbons are discovered through drilling activities, deepwater structures may be emplaced. These deepwater structures will reside on the OCS for the “production life” of the field – maybe 5 to 20 or more years. The deepwater structures may also serve as fish aggregating devices in the Gulf.

This paper will explain the current types and characteristic of the Gulf of Mexico’s deepwater development structures including

• Bottom Supported and Vertically Moored Structures
  • Fixed Platforms
  • Compliant Towers
  • Tension Leg Platforms
  • Mini Tension Leg Platforms

• Floating Production and Subsea Systems
  • Spar Platforms
  • Floating Production Systems
  • Floating Production, Storage, and Offloading Systems

• Subsea Systems

Pipelines, both in-field and export/right-of-way, will be briefly discussed. The concept of “host facilities” will be introduced. Graphics will depict the location of existing deepwater structures, proposed or projected deepwater structures, and subsea developments.
Deepwater petroleum structures in the Gulf of Mexico – Assessment of their potential to function as fish aggregating devices (FADs)

Randy E. Edwards¹, Kenneth J. Sulak², and Doug Weaver²

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Gainesville, FL 32653
ken_sulak@usgs.gov, doug_weaver@usgs.gov

In view of recently accelerating deployment of petroleum structures in deep waters (>1,000 ft) in the northern Gulf of Mexico (GOM), the Minerals Management Service (MMS) recognized the potential for such structures to act as FADs. In order to allow assessment of this potential, we have researched and organized existing information and literature on FADs and on GOM highly migratory species (HMS) into an annotated, key worded, bibliographic database. This very large body of diffuse information has been reviewed and analyzed. It is being synthesized to provide MMS with a scientific basis for predicting and understanding potential impacts of deepwater structures on HMS. The existing body of information and literature clearly documents the importance and large impacts of FADs on fish and fisheries around the world. Extrapolation to the GOM from literature on FADs elsewhere indicates that yellowfin tuna (Thunnus albacares), bigeye tuna (Thunnus obesus) and skipjack (Euthynnus pelamis) have high potential to be impacted. However, detailed predictions of FADs effects of GOM deepwater structures cannot be made from existing literature. It is likely that direct studies of fish aggregations around various types of deepwater petroleum structures will be needed.
The fishery for tunas associated with flotsam and FADs in the eastern Pacific Ocean

Martin A. Hall

*Inter-American Tropical Tuna Commission, 8604 La Jolla Shores Dr, La Jolla, CA 92037, e-mail: mhall@iattc.org*

Since its inception, the purse-seine fishery for tropical tunas in the eastern Pacific Ocean has obtained substantial portions of its catches from sets on flotsam and on fish-aggregating devices (FADs) placed by the fishers. Many other fisheries, both commercial and recreational, also utilize a variety of floating objects to find their target species. This paper describes the tuna fishery with respect to its evolution, the location, the techniques employed, and the catches and by-catches, and also the characteristics of the flotsam and FADs. This mode of fishing has increased considerably in recent years, and it is currently being regulated with temporal closures. Fishing on anchored FADs is not currently practiced in the EPO, but some coastal nations have plans to develop this type of fishery.
Questions about the association of tunas and other species with floating objects

Martin A. Hall

Inter-American Tropical Tuna Commission, 8604 La Jolla Shores Dr, La Jolla, CA 92037, e-mail: mhall@iattc.org

Several hypotheses have been offered to explain the association of tunas and other species with floating objects in the world oceans. These are reviewed, in an attempt to assess which ones best explain the association of tunas with floating objects. The emphasis is on experimental approaches that could shed light on the remaining alternatives. Besides the adaptive value of the association, it is also important to address other issues that should help in understanding the ecological and behavioral responses to the floating objects: How are the objects detected/found? Are all objects attractive? What is the residence time under an object? Are there diel changes in the association? Is there fidelity to individual objects? Why do some species or sizes associate with floating objects, while others do not?
Fish and FADs: A Review of the Influence of FADs on the Movement and Distribution of Pelagic Fishes.

Kim N. Holland  
Hawaii Institute of Marine Biology  
University of Hawaii  
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The state of knowledge of the influence of anchored FADs on the behavior and distribution of pelagic fishes (predominantly tuna) will be reviewed. Various techniques have been employed to investigate the influence of FADs on fish behavior. These methods include gut analyses, tag-and-recapture experiments and sonic tracking. Tag-and-recapture experiments are demonstrating that FADs can have a very strong influence on the movements of tuna (and on fishing effort) on a regional level. Sonic tracking has taken two forms; active tracking of animals equipped with transmitters and passive monitoring of fish movements by data loggers placed on the FADs. In the former case, tracking vessels are used to follow individual fish and continuously monitor their horizontal and vertical movements - both when they are near a FAD and when they move away. Passive monitoring can elucidate the long-term revisititation patterns of tuna and also possibly give indication of school cohesion and longevity. Current data will be discussed in terms of possible pertinence to Gulf of Mexico fisheries.
Tuna Fishing and Fish Aggregating Devices

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The international symposium "Tuna Fishing and Fish Aggregating Devices", October 1999, in Martinique, takes stock of the exploitation of large pelagic fish around FADs, based on regional synthesis for the three oceans and the Mediterranean Sea. Main themes included technology, fishing methods, impact on resources, biology of fish aggregation, anthropology and economic aspects of FAD exploitation. This meeting gathered results from recent and ongoing studies on FADs in different oceans of the world, enhanced collaboration between scientists and managers involved in the development of FADs, promoted the emergence of scientific and technical research and formed a first network for cooperation on this topic. This communication resumes the main discussions and results of this worldwide consultation on FADs purposes.
Integrated Statistical Models of Tuna Movement in Relation to Fish Attractors.

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Integrated statistical models combine theoretical models of biological processes with statistical models of the observational errors in measuring the dependent variables in the process model. Three classes of integrated statistical models will be presented — compartment models, advection-diffusion-reaction models, and state space Kalman filter models. The data requirements, expected output and possible interpretations of each class of model will be presented with examples of application for the analysis of tuna tagging data. The applicability of these models to the study of the movement of pelagic fish in relation to deep water rigs.
Title: Tuna in the Gulf of Mexico

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A general overview of tuna biology, ecology and fisheries in the Gulf of Mexico will be presented, with emphasis on yellowfin (Thunnus albacares) and skipjack (Katsuwonus pelamis) tuna, species known to associate with fish aggregating devices (FADs). In the context of considering potential impacts on fish populations and fisheries by the presence of FADs, the current state of knowledge regarding various aspects of tuna biology and fisheries will be discussed, as well as some potentially important areas where more information is needed. Recent results from studies regarding yellowfin abundance trends and spawning in the Gulf of Mexico will be presented. The potential impact of FADs on stock assessments will also be discussed, with reference to recent Atlantic tuna assessments.
Petroleum Platforms in the Northern Gulf of Mexico: Deepwater Structures as Fish Attracting Devices (FAD) for Pelagic Fishes

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Petroleum platforms in the northern Gulf of Mexico (NGOM) comprise one of the largest FAD (fish aggregating device) arrays in the world, attracting surface and midwater pelagic fishes. Petroleum platforms influence pelagic fishery resources and are an important component of the northern Gulf’s commercial and recreational fishing industries. Among the numerous pelagic fishes attracted to offshore NGOM platforms are *Rachycentron canadum*, *Seriola dumerili*, *Scomberomorus cavalla*, *Decapterus punctatus*, *Coryphaena hippurus*, *Acanthocybium solandri*, *Thunnus albacares*, and *Thunnus atlanticus*. The role of offshore NGOM platforms as FADs for pelagic fishes is examined, and possible mechanisms for the attraction of pelagic species to platforms are explored. Potential interactions/interrelationships between “deepwater” (300 - 1,550 m) platforms and pelagic fishes (predators and forage species) are discussed. Deepwater platforms provide new opportunities for the study of pelagic species to better understand their life history, ecology, behavior, and habitat requirements in the Gulf of Mexico.
Cold-core eddies, the Loop Current and larval tuna; a preferred spawning and nursery habitat?

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Bluefin tuna, Thunnus thynnus and other scombrids spawn in the Gulf of Mexico in late April, May, and into early June. The relationship between larval bluefin tuna and thermal fronts has been established through previous studies, while an assessment of eddies and their associated fronts as spawning and nursery habitat has not been undertaken. In 1995 we began a three year effort in the eastern Gulf of Mexico to examine the influence of these eddies and the Loop Current on the distribution of scombrid larvae. Preliminary results indicate that scombrid larvae were located in the upper 25 meters, and were most abundant near the cold-core ring - Loop Current interface. Understanding the dynamics of scombrid spawning habitat is difficult in view of the scale and variance in inter-annual and decadal circulation patterns in the Gulf of Mexico, and our efforts are far from complete. However, we are concerned that offshore oil structures acting as FADS could disrupt this spawning behavior by concentrating bluefin in non traditional spawning sites. This would not only increase their vulnerability to longline and recreational fishing gear, but could lead to greatly increased larval mortality as well.
Gulf of Mexico petroleum and gas rigs as FADs for sharks and rays

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Offshore petroleum and gas structures can function as attracting devices for a variety of marine species, including elasmobranchs (sharks, skates and rays). Sharks and rays may use these structures as refuges, as core areas for daily activities, and as sources of food, both natural and anthropogenic (bait, offal). In the shallow depths surrounding these structures in the Gulf of Mexico, sharks such as the silky shark (\textit{Carcharhinus falciformis}), scalloped hammerhead (\textit{Sphyrna lewini}) and whale shark (\textit{Rhincodon typus}) and rays such as the spotted eagle ray (\textit{Aetobatus narinari}) and the Atlantic manta (\textit{Manta birostris}) are often observed. Some pelagic elasmobranch species, such as the silky shark, appear to use these structures as core areas for juvenile stages. In the deep waters surrounding the structures (>1000 ft), species of deepwater sharks such as sixgill sharks (\textit{Hexanchus} spp.) and large deepwater dogfishes (\textit{Centrophorus} spp.) have been observed by ROV-mounted video cameras deployed from the rigs. The implications of these various observations will be discussed in reference to the emerging trend of deeper petroleum and gas rigs in the Gulf of Mexico.
Now It Can Be Told: 5 Long Years of Deepwater Surveys Around the Oil Platforms of Southern California

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Beginning in 1995, we have been conducting surveys, using an untethered research submersible, of the fish assemblages of seven oil and gas production platforms and numerous natural reefs in southern California. Thirty-five species of rockfishes (Sebastes spp.) form the dominant taxa over both artificial and natural structures; they comprise over 90% of all fishes by both number and biomass. There are three distinct fish assemblages around platforms: 1) midwater, 2) near-platform benthic and 3) the shell mound surrounding the platform. Young-of-the-year (YOY) rockfishes predominate in the midwater, subadult and adult rockfishes are found near the bottom and a separate suite of YOY rockfishes live on the shell mound. Because the midwater assemblage depends on YOY rockfish recruitment strength, it exhibits strong annual variability, depending on ocean conditions. The near-platform benthic assemblage appears to be more stable. There is some evidence that platforms both produce and aggregate fishes, depending on species.
Potential interactions between pelagic longline fishing and deepwater oil gas structures in the Gulf of Mexico.

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The fishing and offshore energy industries have coexisted and developed amicably for many years in shelf waters of the northern Gulf of Mexico. Recently, the offshore energy industry in the Gulf has shifted its interest beyond the shelf and into deep waters (>200 m). Currently there are over 3,500 active leases and 48 development/production facilities in water depths greater than 200 m. Deepwater oil and gas structures include fixed platforms, sub-sea completions, moored floating structures, and dynamically positioned ships. These surface-piercing structures represent obstacles to passively drifting longlines. The longline fishery targets yellowfin tuna and swordfish. From 1994 to 1998 permitted longline vessels made over 4,000 sets per year with an average length 37 miles of main line per set. Spatial distribution of longline sets and catches of major species for 1994 to 1998 period were plotted. These plots were compared with the location of current and future oil and gas structures to identify potential problem areas. Field observations around deepwater structures indicate that tuna, dolphin, and wahoo are attracted to deepwater structures.